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Abstract

The fast growing demand for fresh water-coupled with the need to protect the environment has made many areas of India and the rest of the World vulnerable to water shortages for various uses of the economy. As they interact with Electricity Industry, water availability is critical to power generation. With out access to adequate amounts of water for steam generation and cooling, power plants that rely on heat energy to generate electricity cannot operate. Seasonal anomalies in water systems and electricity production are inextricably linked. A change in one of these systems induces a change in the other. Therefore, there is an imperative need to better understand the interrelationship of Electric Energy- water for effective management of serious water related power generation issues. This paper gauges the effects of the some of overlaps and gaps between seasonal anomalies in water availability and growth of power generation in rainy, summer, winter and post monsoon season for power plants of different energy types (Both non-renewable and renewable sources)

Keywords:

Andhra Pradesh (AP), Electric –Energy Water Nexus, Water Withdrawals (WD), Loss of generation (LG), Water Shortage, Seasonal Variation Index, cooling effectiveness

JEL Code:

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"Why does water scarcity arise" When there is decline in Sathya (Truth) and Dharma (righteousness), the level of water in the earth also declines. As compassion and love have diminished in human heart, water has become scarce. This problem is not due to divine fury as some people may imagine. It is because of the rise in evil qualities in man. If people strictly adhere to the path of truth and righteousness there will never be water scarcity". - Bhagwan Sathya Saibaba, Sanathana Sarathi.

1. Introduction:

Electric Energy production is a vital prerequisite for our economic and social development. As acknowledged in a recent report of World Water Development Report (2009) and technical reports of Electric power Research Institute of US (2007), water and electric energy are both indispensable inputs to modern economies but currently water resources are under intimidation owing to the impact of changing climate. The World's entire Electric Energy production is heavily dependent on water. For Example, consider the production of electricity at hydro power sites in which kinetic energy of falling water is converted to electricity. In case of thermal and combined cycle gas based power plants, huge quantities of water is used in boiler for its processing and to drive turbine generators. Apart from this, these power plants require water for thermoelectric cooling process that is imperative to maintain high energy efficiencies. Recognizing the significance of vital resource" water" in energy production , this paper highlights the issue that much of electric energy production is very much at the mercy of water availability, which is expected to be drastically affected not only by increasing demands but more of by climate changes.

Seasonal variations in the water availability induced by climate change are more of associated today with scanty rainfall, changes in precipitation patterns, droughts, floods, disappearance of glaciers, high temperatures. The recent Intergovernmental panel on climate change reports of 2007 reiterated the fact that climate change will hit through water and many world regions will experience increased water shortages. This situation becomes of greater concern when the growing demands for water from other sectors such as for human consumption. agriculture, energy production is brought in to play and could further lead to water scarcity. In consideration of the fact in terms of our long term needs and effects of electric energy production, the Electric Energy-Water- Climate seasonal link makes it essential for adaptation to climate change and its effective management in a sustainable manner for future.

Scope of the Study

The scope of the study deals with context and background of present work, the problem definition, hypothesis, research objectives, literature review backed up with national and international issues, approach and methodology with data analysis and research outcome.

- The first section begins with a brief review of literature related to this field to understand issues that have been of concern both in the International and Indian context. The section attempts to review the different approaches that have been followed by researchers to measure water scarcity for various uses of the economy. It also examines the extent of fresh water shortages in Electricity Generation Industry both at global and Indian scenario quoting the instances of ground realities.
- The second section is a description of overview of selected power plants namely Narla Tata Rao Thermal Power Station (NTTPS), Kothagudem Thermal Power Station (KTPS O &M), KTPS V, Rayalaseema Thermal Power Plant (RTPP), Srisailam Left and Right hydel power plant, Nagarjuna Sagar Main power House , Nagarjuna Sagar left canal power house, Nagarjuna Sagar Right Canal Power House, Lower and Upper Sileru hydro power plants, My Home Power Limited, Sri Satyakala, and Rayalaseema Green Energy Power Limited biomass power plants and wind power plants in three regions of Andhra Pradesh i.e. Coastal, Rayalaseema and Telangana regions.
- The third section highlights the estimation of water to electric energy generation ratio using Water Foot printing Method. This is followed by an effort to calculate fresh water footprints for various types of feedstock (thermal, natural gas, hydel and biomass) used in Electricity Production.

- The fourth section deals with potential consequences of climate variability on fresh water supplies in study regions of selected power stations. This section also deals with analysis of month wise data on various parameters such as water consumption for boiler feed and DM water, condense cooling, ash slurry and DM water make up, for domestic purpose (in case of thermal, hydel and biomass), generation particulars, Plant load factor, outages, auxiliary consumption and other miscellaneous items.. As far as hydel power stations are concerned this paper collected information pertaining to reservoir levels, storage capacity, evaporation losses, tail water level, water withdrawals of electricity production, auxiliary consumption, power generation particulars etc.

The study monitors and evaluates the seasonal patterns for monthly data of fresh water withdrawals in four seasons namely rainy, winter, summer and post monsoon season and tracks its impact on current production of electricity and correspondingly on Plant Load Factor using Seasonal Variation Index. This paper also estimates forecasts of loss of generation and fresh water withdrawals associated with non-renewable sources of electric energy.

- The fifth section disseminates information about cooling water system mechanism and evaluates the performance of cooling towers by the technology adopted (Natural Draft or Induced Draft Technology)

- The Sixth section is a continuation of themes in the context of how to surmount these problems. It examines how documentation of case studies relating to water efficiency management strategies in electric energy sector for sustainable future can be more useful, useable and can be replica for other states to implement to reduce the negative impacts of climate variability on water supply reliability. This section also focuses on the policy recommendations for sustainable future of water availability in electric energy sector.

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2. Recent Trends in Fresh water Resource Scarcity

Two well known facts that are quite obviously aware even for a layman are: i) water is a common chemical substance that is prerequisite for survival of all known forms of life. The other important fact is that from the very existence of civilization on this globe, the major portion of earth is covered with water to the total volume of 1386 million Km^3. According to scientific estimations out of total available water 98 percent is salt water and 2 percent is only fresh water that supports 86 percent of the population. For a long time researchers have looked for an easy way of defining whether a region presents water scarcity problems or not. Different authors have identified different parameters for doing so.

The studies of Falkenmark and widstrand (1992); Earth Trends (2001); Lazarova et al (2001); lehner et.al (2001); and Bixio et.al (2006) based on per capita water availability of renewable fresh water, m^3 per capita and water Intensity Use Index clearly pointed out various thresholds by representing its characteristic, with given situation. For example (Table 1), A region with > 10,000 m^3 /year is characterized as water surplus. It represents a situation of availability of water for future need also, by satisfying the present needs of all aspects of the economy. Similar is the case for other thresholds. In 2001 India was designated as water stress region with current utilizable fresh water standing at 1122 m^3.

Table 1: ***Threshold Values: Water stress within a region (Cubic meters per year)***

Characteristic	**Threshold**	**Situation**
Water Surplus	> 10000	Sustainability of water after fulfilling the needs of all aspects of the economy
Water Abundant	>4000-10000	Able to cater to the needs of all sectors of the economy and also for the future
Adequate	>1700-4000	Water sufficient to meet the present needs of the economy
Water Stress	<1700	The economy or human health may be harmed due to lack of proper drinking water, health and sanitation
Chronic Water Scarcity	<1000	Frequent Water shortages both short term and long term
Absolute water stress	<500	The region completes its water supply by desalting seawater and over exploiting aquifers
Minimum Survival level	<100	Water supply for industry and commercial purpose is compromised so as to fulfill demand for all other uses
Water stress	>20%	Severe water supply problems – Reusing waste water, overexploiting aquifers(by 2-30 times), desalinating seawater

The water intensity use index (Table 2) expresses in percentage terms, the relationship between the quantity of water used (extracted from environment) and the total renewable water available for a region.

Table 2: Water Availability and water Intensity Use Index

Region	Water Availability Index(2006) m³/Capita-year	Water Intensity Use Index (2000) %
Middle East & North Africa	1383	62.8
Asia	3990	19.3
Mexico, central America &Caribbean	6740	8.5
United States &Canada	19649	9.3
Europe	10680	6.4
Sub-Saharan Africa	7209	3.1
Oceania	53290	1.6
South America	45400	1.3
Developed Countries	11392	
Developing Countries	7693	
High Income Countries	10554	10.1
Middle Income Countries	10171	6.9
Low Income Countries	5894	12.1
World	8462	8.9

The table 2 depicts the world situation of water availability index and WIUI. The region wise picture for 2006 clearly indicates that the water availability for Oceania region was more that is 53290 m^3/year but for Middle East and North Africa it was as little as 1383 m^3 /year. As per WIUI, the percentage of water use in Middle East and North Africa is more i.e. 62.8 percent in comparison with South America that is 1.3 percent. The percapita water availability in developed countries is 58 percent higher than that of developing countries. The water availability index at global level is 8462m^3/year and as per WIUI it is 8.9 percent. As far as Indian scenario is concerned, during the period 1955-1990, the percapita availability of fresh water has fallen from 5277 m^3 to 2464 m^3. (Tata Energy Research Institute, 1998). A study conducted by World Bank (1999) indicated that in 1997, India further exhibited a declined trend of 2266m^3 and it continued a similar trend as reiterated by Rakesh Sharma et.al (2005) that stood at 1902 m^3 in 2001. It can be expected that the paradigm of water resources shortage will be increasingly followed around India for future years with a percapita availability of less than 1000 m^3. For Andhra Pradesh, in particular currently the percapita availability of water resources was more than 1400 m^3. In years ahead it may move from water stress to water scarcity.

Woefully under appreciated, however is the fact that as a result of water scarcity problems, many countries are reusing waste water. For the World as a whole, the reuse of waste water in agriculture is more that is 70 percent in comparison with domestic and industrial sector. When it comes to the bifurcation of developed and developing countries, its reuse is more developing countries for agriculture that is 80 percent where as in developed countries stood at only 42 percent for agriculture. (Rather there was a balance between agriculture and industry, as industry also stood at 40%) The underlying reason for such demarcation is to ensure reliable source of water generation of waste water near agricultural fields demanding more water. Henceforth, it is clearly evident that World wide Water Sustainability in 21st century is at stake. Therefore it becomes increasingly crucial to focus on existing and futuristic challenges of water scarcity levels for the World as a whole. For instance,

- For the year 1995 in 31 countries, half a billion people faced either water stress or water scarcity.
- At present it is estimated that around 700 million people (i.e. almost 11 percent of the total world population in 43 countries live with less than 1000m^3/capita-year.
- For 2025, in 48 countries, 3 billion people will face water shortages.
- For 2050, in 149 countries, 4 billion people will live in water scarcity conditions.

The most common underlying reasons for this kind of situation was a) Ballooning Population and Urbanization b) More Water Demand in Core Sectors (Agriculture, Domestic, Industry (in particular Electricity Generation Industry) c) Environmental pollution through Warm water discharge d) Uneconomic Pricing of water. These kind of real life evidences motivate to further examine the extent of water scarcity that India is facing in various sectors of the economy.

The other literature examines the authenticity of fresh water shortages in reality and there was much debate on the extent to which low, middle and high income countries will have exhausted available water supplies in a period of 50 years i.e. from 2000-2050. Currently World Population is 6.6 billion. Yearly the figure is likely to grow @ the rate of 80 million people. In 2008 the population was estimated to be equally distributed between urban and rural areas. It is predicted that by 2030, number of dwellers in urban and coastal areas is 1.8 billion migrants. This constitutes 60% of World Population. This trend increases fresh water demand to about 64 million cubic meters a year. But *Amara* Singhe, Tshah et.al, 2007 points out that in India population increases from 1.13 billion in 2005 to 1.66 billion by 2050. Urban population is expected to grow from 29 percent in 2007 to 55.2 percent by

2050.This will increase fresh water demand by 22 percent and 32 percent by 2025 and 2050 from present level of 680 billion m^3 .

Keeping in view of the focus of existing literature on water demand and consumption pattern in core sectors it can be rightly remarked that World wide the production of water intensive agricultural crops is expected to grow by 90 percent between 2000-2050, where as in India it will be 80%. (Economic Survey: 2007-08).

- In Low and Middle income countries the over all water consumption for 2050 in agriculture, domestic and industry is 82 percent, 10 percent and 8 percent. The reasons are increase in population and urbanization, change in consumption patterns towards water intensive products and rapid industrial growth.
- High income countries: Over all water consumption for 2050 in agriculture, industry and domestic is 30 percent, 59 percent and 11 percent. The reasons are better water management measures and reduction in percapita water consumption. (WWDR,2003, UN Economic &Social Commission for Asia and Pacific, 2007)

To quote an example, the requirements of water in low and high income countries for a period of 50 years (2000-2050) can be represented as follows

- Low Income India : Domestic- 184 billion liters/day and high income USA only 21 billion liters/day
- Low Income India: Agriculture- 114 billion liters/day and high income USA only 60 billion liters/day
- Low Income India: Industry- 87 billion liters/day and high income USA 227 billion liters/day

The reason for less water need for industry in India is due to water stress as much of water is consumed by domestic and agriculture on priority basis. But for high income countries like USA water availability will be more for industry (227 billion litres /day) due to adaptation of good water management practices. According to World Water Development Report, 3, 2009, the volume of water per industry was 752 km^3/year and expected to rise to 1170 km^3/year by 2025.

As environmental pollution is another factor for fresh water scarcity, the study made United Nation Educational Scientific and Cultural Organization (UNESCO Report) 2003 indicated some startling results. World Wide polluted water is estimated to be 1200 km^3. This with projected increase of population @80 million along with pollution will lose 18,000 km^3 of fresh water by 2050. One liter of waste water pollutes 8 liters of fresh water. It is estimated that each year roughly 450 km^3 of waste water are discharged in to rivers, lakes and streams. To dilute and transport this dirty water, another 6000 km^3 of clean water are needed. This equals to an amount of about 2/3rds of World's total annual useable fresh water run off. A recent study conducted by European Environment Agency ,2009 revealed that further the imposition of more stringent waste water regulations, increases the costs of waste water treatment The uneconomic pricing of water is another important factor for aggravating the problem of water scarcity by its uneconomic use. It should be realized that though water from times immemorial is considered as Nature's gift, nowadays due to crisis of nature's resources, water is no longer a free good but considered as an economic good. But water pricing in energy sector is often under priced by charging only average costs. (Covers only the present costs averaged over volumes of water consume by existing customers.) Only a nominal cess is paid by power plants for the water usage.

From the above analysis it is clear that the critical driver of success for any economy i.e. economic growth has also been affected due to one among several contributory factors i.e. water shortages. The World economy has recorded a growth rate of 5.2 percent in 2007 but in 2008-09 it is only 3.6 percent. The Indian scenario also have exhibited similar trend. According to Economy Survey Report, 2007-08, during 2004-05 to 2007-08, India showed a growth rate of 9% but rate came down to 6.7% due to water shortages.

2.1 Incidences of Fresh water Shortages in Electricity Generation Industry: International Context

This paper highlights the ground realities of Fresh water shortages in Electricity Generation Industry at Global, Indian and specific state level by quoting real life illustrations. The impact assessment of different research studies relating to fresh water shortages in power sector ushers gainful insights that are imperative for this particular study.

According to Government Accounting Office (2003), climate variability on water availability can have a dramatic impact on water supplies i.e. severe water shortages, with the most obvious impact being drought[1] during next 10 years, in 46 states of United States. In USA the main source of water for power generation are ground and surface water. The 2001 drought in the Northwest significantly reduced hydroelectric power production as quoted by Washington State Hazard Mitigation Plan, 2004. A study conducted by Bartolino and Cunningham, 2003, revealed that considerable effort has been made to address the problem of loss in hydel power generation due to drought. For example in some regions like West-central, (Florida); Long Island, (NY), Baton Rouge,(LA); Houston (Texas); Arkansas, High Plains; Chicago-Milwaukee area; Pacific Northwest; Tucson/Phoenix,AZ; Las Vegas, NV; Antelope Valley, CA are facing decline in surface and groundwater levels. As a result there was huge thermo electric power generation loss and power reliability (as these power plants use surface and ground water for steam generation, cooling and scrubbing of machinery).

Similar situation has been felt in drought of 2002. This drought has made lawmakers in Idaho to rule out, five large coal based and gas-fired power

[1] Drought is a situation where there is sustained and extensive occurrence of below average water availability.

plants. They are denied of water rights for cooling because they would deplete much needed freshwater for drinking and irrigation. In Nevada, the 1,580 megawatt (MW) coal-fired Mohave Generation Station was forced to close in 2005 due to lack of groundwater. Another study made by Dr. Benjamin K. Sovacool, 2008 in United States examines the status of upcoming projects due to water scarcity. For example, the American National Power had to withdraw its application to build a 1,100 MW natural gas plant near Hillburn, New York, because it created a controversy concerning water rights. The water issues have complicated power plant construction or operation in Arizona,4 Georgia,5 California,6 Colorado,7 Massachusetts,8 Missouri,9 New Mexico,10 North P Carolina,11 Pennsylvania,12 Rhode Island,13 South Dakota,14 Tennessee,15 Texas,16 and Wisconsin.17 . In 2007, prolonged drought conditions forced the Tennessee Valley authority to partially shut down its Brown Ferry Nuclear plant in Alabama due to high temperature of the cooling water drawn from Tennessee River. In 2007, prolonged drought conditions forced the Tennessee Valley authority to partially shut down its Brown Ferry Nuclear plant in Alabama due to high temperature of the cooling water drawn from Tennessee River. This clearly indicates that the fresh water consumption for energy production in USA will be 165 percent for 2000-2030. However in other countries like France for 2003, Electricite de France had shut down quarter of its 58 nuclear plants due to water shortages caused by record setting heat wave. According to Florke and Alcamo , J (2004) and Lloyd G, Larsen H (2007), for Europe union in 30 countries (from 2000-2030) , the thermal energy production will be 54 percent and fresh water consumption for energy production requirement will be 130 percent but the fresh water withdrawals are down by 65 percent due to water shortages. It is observed in Spain that, dams for hydro electric production and irrigation were at about 40 percent of their capacity due to lack of proper inflow of water. Hydroelectric power generation fell to its lowest in 48 years during the drought of 2005.

Canada has diverted more water by damming rivers for hydro than any other country. An estimated 85% of the drainage basins contained in whole or in part in the Boreal Shield have been altered by hydroelectric development in one way or another. One estimate about the impacts of climate change on hydroelectricity suggested that generation would be reduced by as much as 15% by 2050. Apart from this, the rise in temperature is another factor responsible for water scarcity. It has been predicted that temperature will increase all over Europe ranging between 1ºC to 3.5ºC by 2100. Estrela et al, 2001, Lehner *et al.*, 2005, noted that about 30% reduction in run-off is forecasted in drier regions of southern and eastern Europe . The country china is also affected by water scarcity problems due to increasing maximum summer temperatures. In a research carried out by Global Equity Research, 2008 over 60% of its power plants are located in provinces where per capita water resources are less than 700 cubic meters per year. The provinces are Beijing, Hebei, Jiangsu, Henan and Liaoning. Various other parts of the

World are suffering with this climatic affect on water availability especially in Electricity Supply Industry.

2.2 Live examples of Water Stress in Electricity Generation Industry in Indian Context

Now let us examine the extent of water irregularities in Electricity Generation Industry for the Indian Scenario with live examples. Through out much of the developing world the fresh water Supply comes in the form of Seasonal rains. Such rains runoff too quickly for efficient use during the time of monsoons in Asia. For example in India 90 percent of annual rainfall is due to influence of south west monsoon between June to September (only 4 months), But in case of Tamil Nadu due to influence of North East monsoon, the rainfall lasts from October to November. For the remaining 8 months, the country barely gets a drop.

A major feature of the Indian climate, which has a direct bearing on water dynamics, is the alternation of wind direction twice a year, resulting in four distinct seasons. Consequently the distribution of rainfall in the country is erratic and varies both in space and time. Some areas in Rajasthan and Gujarat receive annual rainfall ranging between 100-150mm. The south western parts of Punjab, Haryana, Rajasthan are little better off as they receive around 500 mm of rain. The plains of Punjab and Western parts of Deccan, extending further South and East to Karnataka and Andhra Pradesh are blessed with 500-1000 mm of rain respectively. Moderately high rainfall areas from 1000-2000mm form a broad belt in the Eastern parts of the country. Rainfall is highly erratic, with huge intensive storms falling in a very unreliable pattern over time and space. Coefficients of variation vary in the range of 20 to 40 percent even higher with lower annual rainfall. The atmospheric thirst is huge, generally exceeding rainfall depths even during rainy seasons. (potential evapo-transpiration ranging from 5 to 10 mm per day. High rainfall intensity and large rainfall depths over short periods of time lead to high surface run-off and significant drainage (even in dry lands). The problem, then is not only necessarily a lack of water, but that when water is there, it is in abundance and often at a wrong time. And if it is left to form open water surface, it evaporates quickly.

The country gets about 420 million hectare meters of precipitation annually, of which 200 m ham is contributed by rivers flowing in from neighboring countries. Net evapo transpiration losses are nearly 200mham. About 135 mham is available on the surface and the remaining ground water Therefore the challenge is how to deal with large spatial and temporal variability and how to reduce water losses.

For better transparency of facts relating to this particular paper, there is a need to introspect the history of water resources in India. As far as Water Resource potential in India is concerned, the national percapita annual availability of water is 2208m³. The biggest percapita water availability in Bramhaputra and Barak is 16589m³ and in rest of the basins it is 1583 m³. The Sabarmati basin ranks lowest to the level of 360 m³. In the report National Commission for Integrated Water Resources Development, 1999 , it is estimated that the Basin wise average annual flow is 1953 km³ and utilizable water flow is 690 km³ There were nearly 81 reservoirs in India including, Northern, Eastern, Western, Central and Southern Region. The total live storage in all these reservoirs has reached a level of 14.18 billion m³ by end of June 2009. This figure is 56 percent below than last year's level of June 2008. The situation further exhibited down ward trend by first week of July 2009 over previous due to prolonged dry spell since December and poor pre-monsoon showers. This has resulted in water supply shortage for farming as well as power generation activities. (The Central Water Commission). But the average annual rainfall in India is 4,000 billion cubic metres, the estimated utilizable surface water resources is 690bcm. It has been forecasted by hydrologists that by the year 2025, India will face severe water crisis to the level of 1700 to 2000 meters per person, against the world average of 5000 to 9000 cubic meters per person. This indicates the warning signal of water stress for India according to international threshold hold values. The Central Electricity Authority 2009 also stated that all new power generation projects will face water constraints for thermal, hydro and natural gas based projects, if the water issue is not tackled effectively.

According to Centre for Science and Environment Estimate, 2001 there is a fundamental notion that 4 liters of water are required to produce 1 Megawatt[2] hour of electricity produced. On average Indian Thermal Power Plants for every 1000KWH consume 80 cubic meters of water and developed countries consume10 cubic meters. This indicates alarming situation of water Scarcity.

Table 3: All India[3] and Andhra Pradesh[4] Generating Installed Capacity (MW)

Fuel	Installed Capacity(All India Level)	Percentage Shares	Installed Capacity (At Andhra Pradesh Level)	Actual Generation	Percentage shares
Total Non-Renewable	103981.48	66.6	3382.5		
Total renewable	52110.75	33.4	3666.4		
Coal	81605.88	52.3	3382.5	2393.37	79.24
Natural Gas	17055.85	10.9	272.0	113.96	3.77
Diesel	1199.75	0.77			

[2] 1000 Kilowatt hour = 1MW
[3] As on 31-12-09 Installed Generation Particulars
[4] As on March, 2009 Generation Particulars

Nuclear	4120.00	2.6			
Hydro	36885.40	23.6		626.96	20.76
RES	15225.35	9.7			
Total	156092.23		7048.9	3020.33	

The installed capacity of Electricity Generation Industry by the end of December, 2009 at All India Level and end of March 2009 for Andhra Pradesh are indicated in the table 3. The total installed capacity at the All India level constitutes 156092.23. At All India level the percentage share of non-renewable energy is high to the percentage of 66.6 and renewable energy is 33.4 percent. In that the coal share constitutes 52.3 percent, natural gas 10.9 percent, diesel 0.77 percent, nuclear 2.6 percent. Among renewable energy sources, the hydro constitutes 23.6 percent and RES share is 9.7 percent. As far as Andhra Pradesh scenario is concerned, similar trend has been exhibited. The percentage share of thermal records highest to the percent of 79.24 where as hydro constitutes 20.76 percent. The percentage contribution of natural gas was very minimal to the level of 3.77 percent.

India by 2011-2012-hopes to add 78000MW, where as for 2007-2012, it hopes to add 78000 MW. The energy requirements are expected to grow at 6.4 percent per annum for (2007-2012). However the annual growth in power generation during 10th Plan period during the period 2002-03 to 2006-07 showed a remarkable increase from 3.1 to 7.3 percent and for the first two years of 11th Plan during the period 2007-08 to 2008-09 it has declined from 6.3 to 2.7 percent. The reason for this kind of dismal performance in 11th plan is due to Huge Water Shortages in Electricity Generation Industry. To substantiate these points, this paper focuses on live examples of water stress in various parts of the country.

- In Orissa state, for the year 2008, 7496 cusec water was discharged from the reservoir for irrigation and power generation purpose. Now, in 2009 the inflow was only 671 cusec. As a consequence of these low levels of water inflow, the Burla power plant is producing only 17 MW capacity as against 307 MW capacity.
- The Himachal Pradesh State Electricity Board is having 13 hydro projects. In June 2008, it generated 9.6244 MU, but in June 2009, the generation was scanty.i.e.7.588MU. As a consequence of this, 3 MW Guma hydro project was able to produce only 2000 units against the capacity of 36000 units. Two units of 60 MW Basi project was shut down .There was a huge monetary loss to the level of 35 lakhs.
    - In Andhra Pradesh, the Rayalaseema Thermal Power Plant during the period 1995-2005 was on brink of closure due to scarcity of water to the level of only 4.50 TMC in Mylavaram reservoir.
    - In Karnataka state, for the year 2008 from the Almatti reservoir there was 519.6 meters of inflow of water. The customary inflow

of water was 4900 cusec and live storage was 19.8 TMC. But in 2009, there were only 507.75 meters of water and the inflow was only 1300 cusec and where as the live storage capacity was only 2.8 TMC. The shortage was to the level of 17 TMC. The reason was lack of rains in Krishna river. As a consequence of this, 6 power generation units were not functional.

- In Delhi, during 2004, 3 Thermal power plants namely Badarpur and Indraprastha (7 lakh kilo liters /day) and Rajghat (8 KL/Day) that is almost 50 percent is used for Fly Ash Disposal. The ash is disposed in the form of slurry by mixing water in the ratio of 1: 15(Delhi Pollution Control Board). The other half was used for cooling boilers. Due to use of huge amount of water requirement, the generation of electricity was hampered greatly.

Therefore most of the studies and evaluations point out that water shortages are the main reasons for this kind of worrying figures, especially given that water resources are known to be shrinking.

2.3 Methodological Approaches with Theoretical Underpinnings: To measure water scarcities for various uses of the economy: (river basins, domestic, agriculture, industry including energy

Various approaches have been followed by different researchers to measure water scarcity for various uses of the economy. These researchers have varied in their approach and methods to measure water scarcity. But every method is subject to certain limitations. The most widely used measure is water stress index. This index is proposed by Swedish Hydrologist Falkenmark, Lundquist and Widstrand, 1989. This index represents scarcity as a relationship between water availability and human population. It establishes three thresholds that is water available per capita per year related to the needs of domestic, agriculture and industry including energy to describe water stress situations. It proposes that the present critical values of 1700 m^3 as Water stress, <1000 m^3 as Water Scarcity and <500 m^3 is considered as Chronic water scarcity. The empirical methods include calculations and appropriation that are based on human and economic needs through food intake calculation and industrial use estimates. Leif Ohlsson (1999), Buchs, 2007, and Rijsberman, 2006 criticized this method of measuring water scarcity on the ground that, annual averages hide important disparities related to variations with demand for water linked to life styles, climate etc. and debatable issues of population. Ohlsson (2000) modified Falkenmark indicator by taking in to account adaptive capacity- meaning capacity to adapt to stress through economic, technological and other means. Ohlsson used Water Stress Index with UNDP Human Development Index (HDI) and termed it as Social Water Stress Index. This index includes three important factors like life expectancy (proxy for general level of development), educational attainment (as a proxy for institutional capacity) and real GDP percapita. He used HDI along with standard indicators for water scarcity and social water stress index was constructed. Based on adaptive capacity, he applied it for Nile Basin states Egypt, Sudan, Ethopia, Kenya, Uganda, Tanzania, Rwanda and Burundi. It is found that Burundi (68) and Egypt (17) are more socially water stressed with low social adaptive capacity in comparison with other states of Nile. A major effort has been made by team of researchers in State Hydrological Institute St.peterburg Russia led by Prof. Igor Shiklomanov (1991). He compared national annual water availability with assessment of national annual water demand in agriculture, domestic and industry including energy. In a Global water Assessment, the UNC on sustainable development stated the fact that Raskin et.al (1997) used Shiklomanov national annual water availability data, but replaced water demand with water withdrawals. Raskin presents scarcity as total annual withdrawals as percent of available water resources referred as Water Resource Vulnerability Index. They suggested that if annual water withdrawals are between 20 -40 percent of annual water supply it is water scarce and if it is greater than 40 percent it is severe water scarcity. The major pitfall of this Index is it does not take in to account variations of demand related to climate etc. Another study made by Alcamo, J.Henrichs, T Rosch.T (2000) using their Water Gap global model and Feitelson & Chenoweth, 2002 have proposed Criticality Ratio (ratio of average annual withdrawals for human use to total renewable water availability resources. The CR between 0.4 to 0.8 is termed as high water stress and 0.8 is termed as very high water stress. This index has not taken in to account in its water withdrawal data, how much of it is consumptively used that is evapotranspired and adaptive capacity. Molle & Mollinga (2003) have commented on this study on the plea that, large differences between countries' water use for irrigation and other sectors make comparisons dubious. A study by Merrett (1997) and Smakthin et.al have proposed hydro social cycle index. This index describes the relation ship between total water use (sum of water withdrawals for all sectors, water availability, mean annual runoff and environmental requirements.

Merrett (1997) and Smakthin et.al have proposed hydrosocial cycle index. This index describes the relation ship between total water use (sum of water withdrawals for all sectors, water availability, mean annual runoff and environmental requirements. Rijsberman (2006) criticized this index on the ground that it does not describe how much water withdrawn is actually consumed in yearly data and amount of return flows and evapotranspiration[5]. For example for a typical vegetarian diet of a person, the water requirement per day is 2600 litres, but along with evapotranspiration the water requirement is 5400 litres. In another study made by Feitelson & Chenoweth 2002, Sullivan (2002) and Lawrence *et al*., an index namely water poverty index has been proposed. This index takes in to account resources (total amount of water physical water availability as well as variability and quality, access

[5] Transport of water in to atmosphere from surfaces including soil, vegetation and reservoirs.

(access to water for human use taking in to account distance, time needed for collection as well as for productive uses), capacity (people's ability to manage water, use (the amount of water used per capita for domestic, agriculture, industrial in order to express water use efficiency) and environment (environment water management and degree to which water environment are taken in to account). The result is index will be ranging from 0 to 100. The Asian Development Bank (2007) used this index to develop its index of Drinking Water Adequacy Index. This index has been applied for pilot sites like Srilanka, South Africa and Tanzania. Savenije (2000), has contradicted this point on the ground that, water scarcity indicator has to comprise different colors of water (green water, recyclable grey water, virtual water etc.) to highlight water's natural temporal variability, to be adaptable and to identify climatic conditions, to pay attention to shared water and finally, to be based on a comprehensive and situational understanding of water needs. A recent study carried out by European Environment Agency, 2009 have employed Water Exploitation Index (Annually as the ratio of total fresh water abstraction to the total renewable source.) to calculate water scarcity. It has been estimated that WEI for 35 selected river basins of Europe and Southern Europe are extremely facing high stress- Andalusis (164 percent) and Segura (127 percent). Decreased precipitation and high temperatures are expected to have adverse impact on generation sector. As pointed out early, this index is based on annual data and cannot account for seasonal variations in water availability and abstraction. The study made by Shadananan Nair (2007) and Jyothi Prakash regarding decadal changes in run-off and percapita water availability in altered climate changes for the period 1901-10 to 1991-00 and Water Balance Model for Hydro power stations revealed interesting facts. There was considerable reduction in run off in some rivers due to construct of dams and diversion of water. Run off is high in Central Kerala (8956) because of large water shed, but very low in south Kerala (392) due to low rainfall. The study reveals that the present percapita availability of surplus water from precipitation for the state as a whole is 2503 $m^{3.}$ But by the year 2025, the rise in population and predicted increase in global temperature to the level of 3.5^{o} C, the availability will be drastically reduced to 1470 m^3. The State has been trying to exploit huge hydro potential to the capacity of 4333 MU, but only 1834 MW has been reined in. Failure of monsoons created further shortage of hydel power production, leading to increased import of thermal power and increased electricity cost. Though kerala state is considered to be water rich state due to good rainfall, seasonal anomalies in summer made Kerala to depend upon water scarce Tamilnadu for import of thermal power.

The recent study by Pacific Institute (Jason Morrison, Mari Morikawa, 2009) has used water foot printing method. (It indicates calculation of both direct (eg. Water withdrawals) and indirect water use (eg. Water used to produce inputs). This method was employed based on location of water withdrawal/discharge and socio-economic environment of that region, quality of water required, timing and reliability of water supply and climate change impact on electrical energy of water use. The water foot prints were calculated for 8 industries in Europe namely Apparel, High Tech/Electronics, Beverage, Food, and Biotech/Pharma, Forest Products / Metals / Mining and Electric power/Energy.

Though many indexes to water scarcity are employed by various researchers, each index is having pitfalls of its own kind. None of the index was able to capture the seasonal variability of water availability. Taking cue of this, the present study tries to explore the variability in water withdrawals due to seasonal fluctuations in Electricity Supply Industry in particular.

From the existed literature, my study tries to highlight two major problems faced by Electric-Energy Sector .One is physical and the other one is economic.

- Whether or not the possible seasonal variations in a 12 month period of a year adversely affect the amount of fresh water available for power generation.
- To determine the most cost effective way to find out fresh water for power generation, regardless of what the physical effects turn out to be.

It is a well known fact that water is only one of the basic factors of production and accurate modeling of the derived demand relationships for water requires due consideration of full range of relevant factor substitutions in production activities. For electricity generation, it is probably sufficient to consider three factors namely capital, water and fuel. Generally shortage of capital and primary energy inputs are considered responsible for amount of electricity generated. But keeping in view of resource crunch, particularly 'Water- as a factor for Electric-Energy crisis' the hypothesis established from existed literature in the area of research is

Hypothesis

- The amount of electricity generated by fuel type thermal (non-renewable) and renewable energy (Hydro and biomass) depends on availability of fresh water in a 12 month period.
- The water availability due to varied climate change (seasonal fluctuations) affects electric energy production and its effectiveness in terms of Plant Load Factor.

Research Objectives

- To identify major water consuming power plants (Thermal, Combined Gas cycle, Hydro and other renewable sources)

- To determine typical water consumption per unit of generation for each power plant by fuel type.
- To estimate present and future aggregate water availability and loss of generation requirements associated with power plant type.
- To highlight and document water sustainable management techniques in Electricity Industry for meeting present and future Electricity Generation needs.

Hypothesis to Be Tested

The seasonal impact of fresh water availability on Electric Energy production and its Plant load factor

Reference Period: 2000-2001 to 2008- 2009.

Sampling Design: Three regions of Andhra Pradesh viz; Coastal Andhra Pradesh, Rayalaseema and Telangana are selected. In each of these regions one power plant by fuel type (both non-renewable and renewable energy source will be selected. They can be listed as follows:

Table: 1 Selected power plant in three regions of Andhra Pradesh

Power Plant by Fuel Type	Coastal Region	Rayalaseema Region	Telangana Region
Thermal	Narla Tata Rao Thermal Power Station	Rayalaseema Thermal Power Plant	Kothagudaem Thermal Power Station
Hydel	Lower and Upper Sileru Hydel Power stations	Nagarjuna Sagar Hydel Power station	Srisailam Hydel Power Station
Natural Gas	Vijjeswaram Combined Cycle Gas power plant	Nil	Nil
Biomass	Satyakala Private Power Projects Limited	Shri Rayalaseema Green Energy Limited	My Home Power Limited

II

3.0 Over view of Sample Thermal Power Stations in Andhra Pradesh

NARLA TATA RAO THERMAL POWER STATION (NTTPs) IN COASTAL REGION, APGENCO

The Vijayawada Thermal Power Station (earlier name) is situated in a vast area of about 2,370 acres in between Ibrahimpatnam and Kondapalli about 16 km to the north of busy Vijayawada station. The project was completed in three stages, each stage consisting of two units of 210 MW each, thus the total capacity being 1260 MW.

Installed Capacity: 1260 MW
No. of Unit, Unit wise installed capacity & Commissioning of dates

Unit No.	Stage –I		Stage-II		Stage-III	
	I	II	III	IV	V	VI
Capacity (MW)	210	210	210	210	210	210
Date of Commissioning	0/11/1979	10/10/1980	05/10/1989	23/08/1990	31/03/1994	21/02/1995

The first stage was approved by planning commission in July 1973 at a cost of Rs.76.86 Crores. (Rs.0.183 Crores per MW). The project work was inaugurated by the then Hon'ble Prime Minister Mrs.Indira Gandhi on 7th April 1974. The first and second units were commissioned on 1st November 1979 and 10th October 1980 respectively. However the final completed cost of project was Rs.193.6 Crores (Rs.0.46 Crores per MW) due to increase in cost of land acquisition, main plant equipment, design improvements to have enhanced performance, reliability and general global price escalation etc. The main source of coal linkage then was from Singareni Collieries which were located about 250 Km away from the power station. The main source of water for power plant was from River Krishna and while the unique direct circulating canal water system, with out cooling towers, was by drawal of water from Prakasam Barrage through a 11.5 km long cooling water canal with a capacity of 2000 cusecs and feeding the water back in to barrage through Budameru after utilizing the water for plant cooling purposes.

Due to ever growing power demand of Andhra Pradesh, the second stage with two units of 210 MW each was put in operation during 1986. The units were commissioned on 5th October 1989 and 23rd August 1990. The second stage costed Rs.511 Crores. (Rs.1.22 Crores per MW). The third stage with another two machines of 210 MW each has taken up during 1991 by the Andhra State Electricity Board (APSEB) to meet the power requirements of the State and completed by February 1995 at a cost of Rs.840 Crores (Rs.2 Crores per MW). All the six units now are linked to Talcher coal mines in Orissa for their seven million tones coal every year. Narla Tata Rao Thermal Power Station has acquired ISO 9001: 2000 Certification from M/s Lloyds Register Quality Assurance in May 2004. NTTPS continues to sustain its prominence among best performing power stations in the country.

The performance of NTTPS can be assessed based on various parameters such as generation, running hours, Plant load factor, Auxiliary power consumption, specific coal consumption, specific oil consumption. The two important parameters related for this particular study are generation of electricity, running hours and plant load factor.

Table 4: Details of Maximum Generation

Unit No.	Day	Month
	MU/Day	MU/Month
I	5.17	155.45
	16-11-1985	1/1989
II	5.21	156.4
	22-12-1982	01/1989
III	5.20	157.83
	28-12-1991	12/1993
IV	5.15	158.11
	12-09-2003	03/1996
V	5.24	160.81
	30-03-2004	03/2004
VI	5.23	159.95
	28-11-2003	10/1997
Station	30.67	933.58
	02-03-2002	03/2001

The installed generation capacity of NTTPS is 210 MW. The per day installed capacity generation for one unit is calculated as follows:

Per day unit generation of electricity = 210 x 24 hours = 5040/1000 = 5.04 MU. This means that power plant is designed to produce electricity of 5.04 MU per day. As far as month is concerned it is supposed to generate electricity of 151.2 MU. Per month unit generation of electricity = 5.04 x 30 = 151.2 MU. The table 4 depicts the NTTPS remarkable achievement of production of electricity which is more in comparison with designed value, for selected years of 1985 (Unit 1), 1982 (Unit 2), 1991 (Unit 3), 2003 (Unit 4), 2004 (Unit 5) and 2003(Unit 6). To quote an illustration, for Unit V, the actual generation of electricity was 5.24 MU that is much greater than the designed value i.e. which stood at 5.04 MU. Similar trend is exhibited by remaining units of NTTPS. With respect to monthly scenario, for instance unit V has generated electricity to the level of 160.81 MU, that is more in contrast with designed value i.e. 151.2 MU. At the end, it is quite evident from the table 4 that for the NTTPS as a whole, for all the six Units similar calculations can be made.

Table 5: Details of Maximum Continuous Running of Units

Unit No.	From	To	No. Of Days
	Date/Time	Date/Time	
I	03- 09-1994	14-02-1995	164
	09-15 Hrs	09-33 Hrs	
II	18-02-1987	26-07-1987	157
	13-44 Hrs	01-52 Hrs	
III	07-11-1997	04-07-1998	239
	18-03 Hrs	23-03 Hrs	
IV	23-01-2002	27-07-2002	184

	18-01 Hrs	09-54 Hrs	
V	29-09-2003	22-02-2004	145
	04-49 Hrs	09-52 Hrs	
VI	10-01-1997	06-08-1997	208
	10-18 Hrs	20-38 Hrs	

As a customary in NTTPS, out of 365 days (working hours) in a year, nearly 45 days are given for overhauling of power plant. In other words, nearly 320 days are available for a power plant to function. But due systemic shortfalls such as planned and forced outages, loss of generation due to water shortage (in lean seasons), fuel related problems such as coal shortage etc the power plant is not gearing up and running to the standard level of 320 days. The table 5 depicts the maximum number of days a power plant has been put in to service for all the six units. Out of all the six units of NTTPS, the third unit has the maximum number of running hours i.e. from 07-11-1997 (18.03 hrs) to 04-07-1998 (23.03 hrs). In other words the power plant has run for 239 days. As far as sixth unit is concerned, the running hours were in the range of 10- 18 hrs and 20-38 hrs for the period from 10-01-1997 to 06-08-1997 that numbered to 208 days. The NTTPS have done a commendable job and has won meticulous awards for its remarkable achievements from Ministry of Energy.

KOTHAGUDAEM THERMAL POWER STATION (KTPS O&M, KTPSV) IN TELANGANA REGION

Kothagudem Thermal power station Operation and Maintenance (O & M) and Stage V are located at paloncha, near Kothagudem, Khammam District, and Andhra Pradesh and at a distance of 36 Km from the temple town of Bhadrachalam and 300 Km from Hyderabad by road. The site lies at an elevation of about 90 to 95 meters above the mean sea level. For KTPS O & M, the project consists of A, B, C stations comprising 1, 2, 3 and 4 units of 240 MW for Station A, 5 and 6 units of 240 MW for Station B and 7 and 8 units of 240 MW for Station C. Stage V of KTPS comprises 9 and 10 units of 250 MW each at a cost of about Rs.1424 Crores i.e. Rs.2.85 crores/ MW. The first unit of KTPS V that is KTPS Unit No.9 was successfully completed in 31 months after commencement of work and was commissioned on 27-03-1997. The Second that is Unit no.10 of KTPS V was successfully completed in 28 months after commencement of work and was commissioned on 28-02-1998. The largest reservoir created by the kinnerasani project near 10 KM from the plant provides water requirement for the plant in addition to the requirement of 8 units of old plant that is KTPS O & M.

The KTPS Stage V has coal linkage with M/s Singareni Collieries Limited and Coal requirement of 7500 MT per day (28 lakh Tonnes per Year) is met from collieries. The average distance of S.C.C.L coal fields by train is about 35 KM. The performance of KTPS Stage V can be evaluated based on various parameters such as maximum generation, plant load factor, availability factor, loading factor, minimum specific oil consumption, minimum specific coal consumption, minimum auxillary power consumption, minimum DM water consumption, maximum demand and maximum running days.

Table 6: Performance Review of Stage V of KTPS

Sl.No	Parameter	Unit 9	Unit 10	Station
1.	Maximum generation per Day (MU/Day)	6.32 /31.03.03	6.30/31.3.03	12.62/31.3.03
2.	Maximum Generation per month (MU/Month)	191.74 (03/05)	187.86 (12/04)	377.12 (03/05)
3	Maximum Generation per financial Year (MU)	2100.25 (04/05)	2045.84 (02/03)	4140.20 (04/05)
4	Maximum Plant Load Factor per month (% /month)	102.18 (02/04)	101 (12/04)	100.70 (9/2000)
5	Maximum PLF per Financial Year	95.90 (04/05)	93.42 (02/03)	94.53 (04/05)
6	Maximum Availability Factor per month	100 (4,8,11/03), (4,6,11/04), (2,3,4,6,8,9/05), (1,4, 7/06),(01,02,03,05,06,10,12/ 07), (01,02,03,10,12/8), (01,03/09)	100 (4,8,11/03), (4,6/04), (01,4,8,12 /05), (4,9/06), (02,03,05,06,07,09,1 1/07), (01,06,11/08)	100, (4,8,11/03), (4,6/04),(4,8/05) ,(4,7/06), (02,03,05,06/07) , (01/08)
7	Maximum	102.18(02/04)	101.25 (12/04)	101.17 (12/04)

	Loading Factor per month			
8	Minimum Specific Oil Consumption (ml/kwh/month)	Nil (12/07) (01,03/08)	Nil (06/06), (05,11/07), (11,12/08)	0.034(07/06)
9	Minimum Specific Oil Consumption (for Fin.Year)	0.344(02-03)	0.325 (07-08)	0.360 (06-07)
10	Minimum Specific Coal Consumption (kg/kwh/month)	0.527(10/2000)	0.531(10/2000)	0.529 (10/2000)
11	Minimum Auxillary Power Consumption per month	8.587 (10/06)	8.16(11/04)	8.66 (12/04)
12	Minimum DM water Consumption per month (%)	1.21 (11/02)	1.37 (02,06/04)	1.35 (02/04)
13	Maximum Demand /Time and date	264 /0.8:00 on 31-3-03	264 / 8:00 on 31.3.03	528 / 8:00 on 31.3.03
14	Maximum Running Days	143 days 19 hours 35 minutes 11.11.07/ 23:05 hrs 03-04-08 /18:040 hrs	28.02.06/16:25 hrs-08.10.06 /19.43 hrs	

The installed generation capacity of KTPS is 250 MW. The per day installed capacity generation for one unit is calculated as follows:

Per day unit generation of electricity = 250 x 24 hours = 6000/1000 = 6 MU. This means that power plant is designed to mandatorily generate electricity of 6 MU per day. As far as month is concerned it is supposed to generate electricity of 180 MU. Per month unit generation of electricity = 6 x 30 = 180 MU. The table 6 depicts the KTPS V remarkable achievement of production of electricity which is more in comparison with designed value, for selected years of 2003 and 2005 for units 9 and 10. To quote an illustration, for unit 9 and 10, the actual generation of electricity per day was 6.32 MU and 6.30 that is much greater than the designed value i.e. which at stood at 6 MU. Similar trend is exhibited with respect to monthly scenario, for instance unit 9 and 10 has generated electricity to the level of 191.74 MU and 187.6, that is more in contrast with designed value i.e. 180 MU. At the end, it is quite evident from the table 6 that for the KTPS Stage V as a whole, for the two units of Stage V. With respect to Plant Load Factor, for two units it will be in the range between 80- 95 percent PLF. But for units 9 and 10, the PLF was more than 100 percent to the level of 102.2 and 101 percent in the month of February and December in the years 2005 and 2003. The minimum specific oil consumption was nil for the years 2005, 2006, 2007 and 2008. The coal consumption was very low i.e. 0.527 and 0.531 kg/kwh for the month of October for the year 2000

RAYALASEEMA THERMAL POWER PLANT (RTPP) IN RAYALASEEMA REGION

The Rayalaseema Thermal Power Project Stage I consists of 2 units of 210 MW thermal units in the drought prone region of Andhra Pradesh. Stage II also envisages 2 numbers of 210 MW thermal units. The power station is located near Mekalabalayapalle village about 50 kms from Kadapa town and 8 Kms from Muddanur Railway station in Kadapa District. The power station helps to improve the voltage profile in Rayalaseema region. The water requirement of the power station is met from Mylavaram reservoir across river pennar through a 22 km long steel pipe line laid underground. The annual coal requirement of 2.06 million tones has been linked to Singareni collieries. The coal is transported by rail via Vijayawada –Gudur –Renigunta-Muddanur. The electricity generated from the project is evacuated through 220 KV transmission systems. The installed generation capacity of RTPP is 210 MW. The per day installed capacity generation for one unit is calculated as follows. The per day unit generation of electricity = 210x24hrs = 5040/1000 = 5.04 MU. The per month unit generation of electricity can be estimated as 5.04x30 = 151.2 MU.

Table 7: Performance Review of RTPP Stage I

Parameter Name		Target	Best Month /year
Generation	Unit-I		160.09 (12/2000)
	Unit-II		158.97 (01/2003)
	Stage –I	296	317.78 (01/2003)
Plant Load Factor %	Unit-I		102.42 (02/2002)
	Unit-II		102.48 (11/2001)
	Stage -I	94.73	
Availability Factor %	Unit -I		100

	Unit-II		100
	Stage- I	100	100
Specific Coal Consumption Kg/Kwh	Unit-I		0.553 (01/2002)
	Unit-II		0.553 (01/2002)
	Stage-I		0.553 (01/2002)
Specific Oil Consumption (ml/kwh)	Unit-I		0 (07/2004)
	Unit-II		0 (07/2004)
	Stage-I	2.0	0 (07/2004)
Make Up Water Consumption			
	Unit-I		1.09 (11/2004)
	Unit-II		1.22 (02/2009)
	Stage-I	3.00	1.36(02/2009)
Auxillary Consumption	Unit-I		9
	Unit-II		
	Stage-I	9.50	
Heat Rate Kcal/Kwh	Unit -I		2176.68 (11/2000)
	Unit- II		2175.45 (06/1997)
	Stage- I	2500	2176.93 (11/2000)

The table 7 above illustrates the commendable performance of RTPP Stage I with respect to parameters namely Generation, PLF, Availability factor, Specific Coal Consumption, Specific Oil Consumption, make up water Consumption, Auxillary consumption and Heat rate. It is quite evident from the table that there has been meticulous performance of Stage I RTPP with respect to Generation. For instance for units I and II, the actual generation was 160.09 MU for the year 2000 in the month of December and 158.92 for the year 2003 in the month of January. These generation values are much higher than the designed values i.e. 151.2 and also combined the actual generation for both Unit I and Unit II stood at 317.78 MW that is much greater than the target value 296 MW. The actual plant load factor for both units for the year 2001 and 2002 years in the months of February and November stood at (102.42 % and 102.42 %) that are more than the target value that stood at 94.73 %.

The targeted specific oil consumption for stage I should be maintained at 2 ml/KWh, but it was absolutely nil for stage I in the month of July for the year

2004. The make up water consumption in the boiler should be statutorily be at 3 %, but in the months of November, January for the years 2004 and 2009, there were recorded to be meager consumption of make up water to the level of 1.09 % and 1.22 %. For start up running of power plant, minimum consumption of electricity is needed that can be termed as auxillary consumption. The targeted auxillary consumption stood at 9.50 %, but the actual auxillary consumption was low to the level of 9% and 9.04 % in the month of December for the years 2006 for both the units. The heat rate for stage I was targeted at 2500 Kcal/KWh but in actual terms there was reduction in heat rate in the month of November and June at the value of 2176.68 Kcal/Kwhr and 2175.45 Kcal/Kwhr for the years 2000 and 1997.

The units 3 and 4 of Stage II were first synchronized with Grid on 25/01/2007 and 20/11/2007. However the units were able to generate electricity from April 2008-March 2009. The installed generation capacity was 210 MW. The per day generation of electricity was 210x24 = 5.04 MU. The per month installed electricity generation was 5.04 x 30 = 151.02

Table 8: RTPP Stage II Performance Review: Generation and PLF

Month	Unit -3		Unit -4	
	Generation	Plant Load Factor %	Generation	Plant Load Factor %
April-2008	133.15	88.06	117.47	77.70
May- 2008	146.23	93.59	127.27	81.46
June- 2008	142.18	94.04	139.50	92.26
July- 2008	137.29	87.87	145.70	93.25
August- 2008	122.58	78.46	81.72	52.31
September-2008	148.52	98.23	144.07	95.29
October-2008	152.91	97.87	152.43	97.56
November-2008	131.69	87.10	150.79	99.73
December-2008	156.06	99.89	154.92	99.16
January-2008	147.53	94.43	154.92	98.92
Febrauary-2008	142.74	101.15	141.61	100.35
March-2009	158.50	101.45	154.83	99.10

The table 8 clearly provides the real picture about installed generation Vs actual generation. From April 2008 onwards to remaining months, except October, December and March 2009, the actual generation was much less than the installed one's. For the mentioned months the actual generation recorded 152.92, 156.06 and 158.50 MU that is much above the installed generation 151.02 MU. In a similar manner for Unit II of Stage II the actual generation is more than the installed for the months of October 2008 (152.43), December, 2008 (154.56), January 2009 (154.56) and March 2009 (154.84). The PLF recorded was notified to be highest in the months of February and March 2009 for both units of Stage I at 101.15 % and 101.45 %.

However the best performing years can be mentioned in the table as below:

Table 9: Best Performance Parameters: RTPP Stage II

SL.No.	Description	Previous Best	Units	Month/Year
1	Generation	313.34	MU	March- 2009
2	PLF	100.75	%	February – 2009
3	Auxillary Power Consumption	8.14	%	December- 2008
4	Sp.Oil Consumption	0.032	(ml/Kwh)	February- 2009
5	Specific Coal Consumption	0.634	(Kg/Kwh)	November-2008
6	Heat Rate	2121.09	Kcal /Kwh)	July-2008
7	DM make Up	1.56	%	March-2009

The table 9 clearly shows that there was highest actual generation of electricity i.e. 313.34 that is much above the installed generation i.e. 151.02 MU in the month of March, 2009 Similarly highest PLF was maintained at 100.75 % in February month for the year 2009. The parameters relating to auxillary power consumption (8.14 %) , specific oil consumption (0.032 ml/Kwh), specific coal consumption (Kg/Kwh) , Heat rate (2121.09 Kcal/Kwh), DM make UP (1.56 %) are all maintained at low level in comparison with the target values for the months of February (2009), December (2008), February (2009), November (2008), July (2008) and March (2009).

Over View of sample Hydel Power Stations in Andhra Pradesh

APGENCO has total installed capacity of 65609 MW and it stands third in terms of largest utility in the country. It has the highest hydro capacity of 3588.4 MW. It is currently operating 16 hydro power stations including one wind power station. The selected hydel power projects for the study includes Srisailam, Nagarjuna Sagar and Lower and Upper Sileru power Stations. The river Krishna is one of the main river systems in peninsular India and its basin continues to be cradle of civilization. Srisailam and Nagarjuna Sagar dams are constructed on this river and they form largest manmade lakes with a combined storage capacity of 672 TMCft. This contributes to the development of hydel power both in the conventional as well as pumped storage mode. The Srisailam dam forms the upper reservoir with a gross storage of 263.64 TMCft where as Nagarjuna Sagar dam is concerned it is 100 kms down stream of the river and from Srisailam forms the lower reservoir with a gross storage of 408 TMC ft. The storage capacities of reservoir are as follows:

Reservoir	Gross Storage in TMCft	Live Storage in TMCft	Dead Storage in TMCft
Srisailam	263.64	213.58	49.42
Nagarjuna Sagar	408.15	244.37	163.78

SRISAILAM LEFT CANAL POWER HOUSE (SLCPH) IN RAYALASEEMA REGION

Srisailam Dam Particulars

The dam is of straight gravity type with a maximum height of 470 '(143.2 m) above the deepest foundation level with an over all length of 1680' (512.06 m) at the top. The spill way is 874' (266.395) long and has 12 no's radial crest gates of 60 X 55' (18.288 m X 16.764 m). This has been structured in such a way to discharge a maximum flood of 13 lakh cusecs. The sill level of the dam is 830' (252.984 m). The construction of the dam and section of crest gates were completed during 1984. The selected hydel power projects Srisailam Right Bank has an installed capacity of 7 x 110 = 770 MW with a conventional mode of operation, whereas left bank comprises an installed capacity of 6 x 150 = 900 MW with a pumped storage as the mode of operation.

Srisailam Right Canal Power House (SRCPH)

This power station on the Right Bank consists of seven generating units of 110 MW capacity each. This station is operated at its full capacity as a base load station during prospective periods of rainy season as the river Krishna receives its flows and abundant surpluses are experienced during this period. During post monsoon season the storage in the reservoir is optimally utilized to meet the peaking requirement of the system. The commissioned details of Srisailam Right Bank Power House with 7 x 110 MW= 770 MW can be enumerated as follows

Stage- I and Stage –II

Unit 1	**30.08.1982**	**Unit 5**	**31.3.1986**
Unit 2	**14.12.1982**	**Unit 6**	**30.10.1986**
Unit 3	**19.11.1983**	**Unit 7**	**15.03.1987**
Unit 4	**27.08.1984**		

Table: 10 Srisailam Right Bank Power House: Performance Details

Full Reservoir Level: 265.75 Mts/885 Fts

MDDL: 245.37 Mts/805 Fts

Description	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08
Target in MU	3155	1950	680	1031	975	1220	1452
Units Generation in MU	1942	538.650	307.672	941.043	1489.429	1750.187	1451.667
Running Hours as Generation	17878:48	6592:31	3341:41	8418:38	15584:55	18515:55	6510:28
Max. Load in MW with date	784 14/10/01	660 05/11/02	689 11/11/03	788 07/10/04	784 14/10/01	784 14/10/01	681 07/07/07
Available Hours of the Station	34458:23	7575:55	49287:18	51891:01	38297:51	53655:36	27114:01
Water Drawn for Generation in Million Cubic Meters	9551.656	2982.059	3459.587	4194.884	7363.046	8748.439	7178.02
Maximum Date	885 15.10.01	847.93 27.08.02	852.20 03.11.03	883.70 28.08.04	885.00 16.08.05	885 22.09.06	885 29.08.07
Minimum Date	796.20 28.07.01	752.40 02.08.02	753.28 26.04.03	739 15.04.04	760 19.06.05	794.10 08.05.06	806 29.08.07
Total Auxiliaries Consumption in MU	6.03	3.05	2.17	3.74	6.07	6.6	4.5
Highest Generation in a month	363.775	137.443	141.857	268.458	435.728	439.1090	432.575
Highest Generation in a Day				17.832	16.094	16.545	16.332

The installed capacity of Srisailam Right Bank Power House was 770 MW. The per day installed capacity generation for one unit is calculated as follows: The per day unit generation of electricity = 770 x 24 hrs = 18480/1000 = 18.48. As far as month is concerned it is supposed to generate electricity of 554.4 MU. The table 10 portrays the undermining performance of production of electricity, which is less in comparison with the designed value for the years 2001-02 (363.775 MU), 2002-03 (137.443 MU), and 2003-04 (141.857 MU), so on and so forth up to 2007-08 (432.575 MU). However the water drawn for generation in thousand million cubic feet was highest for the year 2001-02. The maximum reservoir level was maintained for the following dates 15/10/01, 27/08/02 so on and so forth in the range of 885 feet where as minimum reservoir level was maintained in the range of 739.99 feet to 806 feet for the following dates 28/07/01 etc as shown in the table. The running hours as far as generation is concerned recorded highest for 2001-02 (17878:48 hrs), 2005-06 (15584:55) and 2006-07 (18515:55). The highest maximum load in the range of above 700 MW was notified for the years 2001-02, 2004-05, 2005-06, 2006-07. Therefore it can be concluded that for all the 7 units, the actual generation is much below the target achievement of generation for the year 2001-02 to 2004-05. For the remaining years 2005-06 to 2007-08 the actual generations was much higher than the target one's, despite the hard core fact that its actual generation was much lower than the designed values (year wise) that stood at 6745.2 MU. The underlying reason for this plight of situation was shortage of water especially during summer months through out all the years.

Srisailam Left Bank Power House

Keeping in view of the determination of allocation of water by the tribunal and taking in to account the huge surpluses that are overflowing the dam, it was considered that the additional generating capacity could be installed to tap the monsoonal electric energy as well as to offer peaking capacity to the system. Taking in to account, the limitation of right bank power house, the left bank was conceived. An intake was provided for the proposed power house on the left bank (1000 MW) capacity before water is impounded in the reservoir. The reservoir comprises of trash racks, entry tunnel 50'diameter with invert + 720 feet gate shaft with 3 no.s gates and a short exit tunnel. This facilitates the construction of head race tunnel and other related works of left bank, with out affecting the reservoir level. From this it can be said that the Srisailam left Bank power house is completely underground and is 50 m below the Krishna River bed level itself.

The pumped storage scheme of the Left bank power house comprises of the following features

- To tap seasonal electric energy varying from 700 MU to 2000 MU annually.
- To put left and right bank power houses on an operational mode with reduced load factors to meet the peak demand.
- To resort to pumping operation and support the electric grid during peak time.
- The left bank units will be put on to 15 percent load factor. For instance for 3rd, 5th and 6th units from 2000 to 2008-09 there was limited loads to the level of 110 unit and 120 units. That is why in some months of a year there was generation loss. Due to this pumping system facility, there was no water shortage.

The merits of the pumped storage scheme can be listed as follows

a) The first and foremost advantage is in the flexibility it imparts to the power system.

b) Units were rated in such a way that to increase the generation to full output/ capacity even in one minute or even less.
c) The pumped storage plant can be used for storing surplus electric energy in upper reservoirs having enough live-capacity for seasonal storage especially during summer season.
d) The plant Load Factor of the power station can be meticulously be improved by providing demand top the power system during night time by taking pumping over.
e) Above all, the units can be operated as synchronous condensers for supplying reactive power and for meeting the increased peaking demands. Therefore it can be rightly remarked that the Srisailam Left Bank Power Station is a totally underground one with a installed capacity of 6 no's each of 150 MW reversible type pump turbine motor generating units.

The Srisailam Left Bank Power House facilitates adding up of surplus off peak thermal power in the system to supply it during peak hours. A part from this, it also generates cheap conventional energy with monsoon surplus flow in the river. Its additional merits are stabilization of the grid and improved voltage are the additional advantages. The Srisailam Left bank Power House with 6x150 MW = 900 MW, comprises the following

Unit 1	26.04.2001
Unit 2	12.11.2001
Unit 3	19.04.2002
Unit 4	29.11.2002
Unit 5	28.03.2003
Unit 6	04.09.2003

Table 11: Srisailam Left Bank Power House: Performance Details

Description	**2001-02**	**2002-03**	**2003-04**	**2004-05**	**2005-06**	**2006-07**	**2007-08**
Target			1430	1420	1155	1826	2180.01
Units Generated in MU	381.517	557.694	327.599	1411.634	2233.214	251.698	1793.804
Running Hrs as Generator	2091:53	2304:22	1516:28	3154:21	15648:44	17660:54	12825:59
Running hrs as pump	1:34	7:31	3:43	0:26	1699:22	2492:12	0
Running hrs as SCG/PC	0:35	7:0	36:12	0:15	252:36	293:35	0
Total Running hrs	2093:22	2318:53	1551:07	3155:02	17600:42	20446:41	12825:59
Max Load in Gen mode(MW)	311 26.02.02	476 25.10.02	721 23.09.03	967 26.08.04	941 01.08-05	932 01.08.05	978 07.07.07

Max Load in Pump mode(MW)	184 23.12.01	185 24.12.02					
Water Drawn for Generation (TMC)					417.6716	463.0349	340.8202
Reservoir Maximum level in Feet	885 15.10.01	847.93 27.08.02	852.12 01.11.03	883.70 28.08.04	885 17.08.05	885 22.09.06	885 29.08.07
Minimum	800.38 15.10.01	752.40 02.08.02	753.28 06.04.03	739.99 15.04.04	760 19.06.05	794.1 08.05.06	806 05.06.07
Total Auxiliary Consumption	3.14	5.67	7.6	7.2	7.3	7.1	3.5
Highest Generation in Month	127.89 in March -2002	136.87 in August -2002	71.59 in November 2003	362.87 in August 2004	571.516 in August 2005	546.966 in August 2006	587.224 in August 2007
Highest Generation in a Day	6.6	10.77	5.2	21.43	20.53	20.67	21.97

The installed capacity of Srisailam Left Bank Power House was 900 MW. The per day installed capacity generation for one unit is calculated as follows: The per day unit generation of electricity is 900 x 24 hrs = 21600 = 21.6 MU. Monthly it

generates electricity to the level of 648 MU. The table 11 clearly reveals the slow performance of Srisailam Left Bank Power House. The actual generation for the years 2001-02 to 2007-08 was much less than the installed generation. For example for the year 2007-08, the actual generation of electricity per month was 587.224 MU, that is much less than the installed generation that stood at 648 MU. The water drawn for generation of electricity for 2005-06 to 2007-08 was on rise from 417.67 TMC to 463.034 on all the dates i.e. from 15/10/01 to 29/08/09 at 885 feet. The maximum load in Generation mode was recorded in the year 2007-08 to the level of 978 MW and the minimum load was notified at 184 MW for the year 2001-02.

Table 12: Generator Vs Pump Mode: Details of Water Usage

Unit No	Generator Mode	Pump Mode	Year	Generation	Discharge in TMC	Water Lifted in TMC
1	26-04-2001	17-05-2002	2001-02	381.5	63.8	0.0305
2	12-11-2001	12-12-2001	2002-03	557.7	106.3	0.1755
3	19-04-2002	16-05-2002	2003-04	327.6	60.4	0.0427
4	29-11-2002	13-11-2003	2004-05	1411.6	235.13	0.0067
5	28-03-2003	01-12-2003	2005-06	2233.2	417.67	35.7685
6	04-09-2003	04-12-2003	2006-07	2511.7	463.03	55.5904

One advantage of the Srisailam Left bank was during the commissioning dates of the units both at the Generator and Pump mode as well as for the later years, there was an increase in generation continuously vis-avis the discharge of water in TMC . For Example both at generation and pump mode for the years 26-04-2001 and 17-05-2002 the generation increased from 381.517 MU to 2511.69 MU till to 04-09-2003 . Simultaneously the discharge of water also increased from 63.82 TMC to 463.03 TMC at generator mode and at pump mode the lifting rose at the level of 0.0305 TMC to 55.5904 TMC.

NAGARJUNA SAGAR LEFT CANAL POWER HOUSE (NSLCPH) IN TELANGANA REGION

The Nagarjuna Sagar dam is the World's largest masonry dam built across Krishna River in Nagarjuna Sagar, Nalgonda District of AP, India. It is a down stream to the Nagarjuna sagar reservoir with a capacity up to 11,472 million cubic meters which is the World's largest manmade lake. The dam is 490 feet tall and 16 km long with 26 gates and the concrete wall is of 6 feet thickness. The hydro electric plant of Nagarjuna Sagar has a power generation capacity of 815.6 MW with 8 units (1 x 110 MW + 7 x 100.8 MW). First unit was commissioned on 7th March 1978 and 8 th unit on 24th December 1985. The Right Canal Plant has a power generation capacity of 90 MW with 3 units of 30 MW each. The Left Canal plant has a power generation capacity of 60 MW with 2 units of 30 MW each.

Nagarjuna sagar Main Power House

The installed capacity of Nagarjuna Sagar main power house (NSMPH) was 815.6 MW. The per day installed capacity generation for one unit is calculated as follows. The per day unit generation of electricity = 815.6 x24 hrs = 19574.4/1000 = 19.57 MU. As far as month is concerned it is supposed to generate electricity of 587.1 MU.

Table 12: Installed Vs Actual Generation of Electricity

2007-08	NSMPH Actual Generation	Installed Generation	NSLCPH Actual Generation	Installed Generation	NSRCPH	Installed Generation
April	10.84	587.1	0	43.2	0	64.8
May	0	587.1	0	43.2	0	64.8
June	5.1	587.1	0	43.2	0	64.8
July	451.1	587.1	3.7	43.2	3.13	64.8
August	594.2	587.1	19.8	43.2	36.8	64.8
September	594.1	587.1	24.86	43.2	49.2	64.8
October	296.1	587.1	29.04	43.2	49.9	64.8
November	38.4	587.1	15.51	43.2	35.6	64.8
December	36.4	587.1	7.1	43.2	24.2	64.8
January	59.6	587.1	0.18	43.2	7.8	64.8
February	16.1	587.1	0	43.2	0	64.8
March	37.3	587.1	0	43.2	0	64.8

The installed capacity of Nagarjuna Sagar Left Canal power house was 60 MW. The per day installed capacity generation for one unit is 60 x 24 = 1440/1000 = 1.44 MU. The per month electricity generation is 1.44 x30 = 43.2 MU. For the year 2007-08 (see table 12), NSMPH the installed generation was more than the actual generation in all the months except during few months. For instance, for the month of October the actual generation of electricity was 296.1 MU which is less than the installed generation i.e. 587.1 MU except for months like August and September, the actual generation was more than the installed, due to surplus water. However during lean seasons i.e. February, March, April, May and June there was meager production of electricity due to chronic shortage of water. For Nagarjuna Sagar Left Canal power house (NSLCPH) the installed capacity generation was higher than the actual in almost for all the months during the year 2007-08 except for September and October 2007-08. For example, during these months the actual generation (i.e. 24.86 MU and 29.01) was much higher than installed generation that stood at 43.2 MU. The installed capacity of Nagarjuna Sagar Right Canal Power House (NSRCPH) was 90 MU. The per day installed capacity generation for one unit = 90x 24 = 2160/1000 = 2.16 MU. The per month electricity generation was 64.8 MU. For NSRCPH, the actual generation of electricity was much less than installed generation that is a clear indication of water shortage. For the year 2007-08, especially during lean seasons there was absolutely nil generation due to acute water shortage or nil water.

LOWER AND UPPER SILERU HYDEL POWER PLANT IN COASTAL REGION

The lower and upper sileru hydel power plants are located in coastal region of Andhra Pradesh. The installed capacity of Lower sileru is 400 MW. The per day generation is calculated as 400 x 24 = 9600/1000 = 9.6 MU. The actual per month generation of electricity is 288 MU.

Table 13: Installed Vs Actual Generation of Electricity

Year 2007-08	Lower Sileru Actual Generation	Installed Capacity	Upper Sileru Actual Generation	Installed Capacity
April	92	288	33	172.8
May	78	288	28	172.8
June	72	288	27	172.8
July	85	288	36	172.8
August	92	288	41	172.8
September	92	288	34	172.8
October	82	288	31	172.8
November	79	288	30	172.8
December	90	288	36	172.8
January	102	288	41	172.8
February	102	288	44	172.8
March	114	288	47	172.8

The installed capacity of upper sileru was 60 x 4 = 240 MW. The per day installed generation of electricity was 5760/1000 = 5.76 MU. The per month electricity generation can be calculated as 5.76 x 30= 172.8 MU. It can be quite evidently clear from the table 13 that for all the months of 2007-08 for both lower and upper sileru the actual generation of electricity was much less than installed generation. For instance for the month of January the actual generation of electricity was only 102 MU, that is far less than installed one's. Similarly in case of Upper Sileru, for January month the actual generation of electricity was 45 MU that is very much lower than the installed capacity generation. Therefore it can be concluded that water shortage is playing a vital role for less actual production of electricity that is not commensurate with the installed capacity generation that was explicitly calculated in 7 hydel and 4 thermal power stations in succeeding sections.

4.0 Approach and Methodology

This study examines the extent of water shortage in Electricity Generation Industry by fuel wise. The study attempts to measure seasonal variation with respect to water availability trends for a power plant by fuel type in light of nature of problem. To elicit information on the extent of water shortage faced by selected power stations in Electricity Supply Industry of Andhra Pradesh, information was collected from secondary sources on various parameters such water withdrawals for electricity generation process, condenser cooling, ash slurry, DM water, make up for domestic purpose, generation particulars, Plant Load Factor, planned and forced Outages, auxiliary consumption, reservoir levels, storage capacity, evaporation losses etc with respect to thermal, hydel, Gas and biomass power stations. Personal visits had been undertaken to Kinnarsani, Mylavaram reservoirs of KTPS and RTPP thermal power plants and to hydel dams to understand the nature and depth of water shortage perceived by respective Electricity Generation Industry. This enabled us to scrutinize whether too much water shortage is taking place or not. Further in power stations by fuel wise, where water shortages have been identified, documentation of case studies relating to water efficiency management in Electricity Supply Industry was conducted.

The methodology adopted in this paper includes the following techniques
I Water Foot Printing Method
II Seasonal Variation Index or Ratio to moving average method
III Performance Evaluation of Cooling Towers: Using Parameters of Bureau of Energy Efficiency
IV Case Study Method: Field Level Experiences

III

5.0 Calculation of Water Foot prints in selected power plants

Despite these looming challenges about water scarcity in Electricity Supply Industry as discussed in the Review of Literature, it is increasingly critical to assess and evaluate the water risks. For this purpose, power stations should pursue to measure the respective power station's water foot print to better understand the potential of water related exposure. This enables to motivate power companies to incorporate water issues in to their climate change strategies. This reminds me a live example of layman's day to day life activity related to electricity. Just remember when we were kids, parents make a big fuss about turning off the light when you left a room? It has been categorically mentioned by researchers at Virginia Water Resources Research Center, (2008), keeping a 60 watt light bulb for 12 hours uses 60 litres of water. They found that Fossil Fuel thermal electric power plants consume more than 95 litres of water on average to produce one Kilowatt hour of electricity. Exclusively for fossil fuel based power plants, 530 litres of water are required to produce 1 MW of electricity. With respect to natural gas based power plants, to produce 1 MW of electricity 38 liters of water are required. In addition to this, 180,000 liters of water are needed to produce enough soyabean based bio-diesel. From, this it is clearly evident that power stations have voracious appetite for water and its shortage is affecting production.

The water foot print indicated the volume of water used (measured in cubic meters per year). A nation's water foot print has two components namely internal and external water foot print. The internal water foot print is defined as the volume of domestic resources used to produce goods and services consumed by inhabitants of the country. The external water foot print is defined as the annual volume of water resources used in other countries to produce goods and services consumed by a population. Both internal and external water foot print includes the

- Consumptive use of blue water originating from ground and surface water.
- Consumptive use of green water (in filtered or harvest water)
- Production of Gray water (polluted ground and surface water) as researched by Hoekstra and Chapagain, 2008.

The water use in any company or sector is tracked with a help of a tool originally developed by Arjen Hoekstra et.al, a professor of water management at University of Twente in the Netherlands.

Taking cue of this, an example of India clearly reveals interesting facts about water foot prints. Among all the countries of the World, India ranks highest in terms of total water foot print adding up to 987 billion m^3 /year. India contributes 17 percent to the global population, while Indian people contribute only 13 percent to the global water foot print. However between 1997 and 2001, there was remarkable decline in terms of global water footprints from 7450 billion m^3 /year to 1240 m^3 per person. India's per capita water foot print is 980 m^3 /year, which is very much lower than that of many other countries in the World. In percentage terms, the internal water foot print for domestic, agricultural constitutes 97 percent where as industry constitutes 2 percent. The percentage of external water foot print relates to 1 percent.

Keeping in view of this sectoral competition for scarce amounts of water in India, it is quite evident that water shortages will become more prominent for Indian industries in years to come. With the given hard core facts of growing, threat of fresh water shortage looms, tracking of water foot prints in Electric- Energy Production Industry is considered as a matter of urgent necessity. This paper tries to analyze the water foot print per unit (the amount of water required to produce one megawatt of electric energy of both non-renewable and renewable sources).

Water foot print particularly in Electric Energy sector is defined as the amount of water directly consumed for fuel development and in the process of producing electricity. Consequently for purpose of simplicity and comparison purpose and as coal for selected thermal power stations is available from singareni collieries, (excluding water required for mining process) the water foot print calculation includes the summation of all the water required in various stages of electricity production. But before going in to further details of methodology about water foot prints, it is vital to demarcate between water withdrawn and water consumed.

Water Withdrawn: It is the gross amount of water removed from any source, either permanently or temporarily. Some or all of the water withdrawn may be returned to the source after use but the gross amount removed or diverted is referred to as water withdrawn.

Water Consumed: It refers to the amount of water withdrawn which is no longer available for use because it has evaporated, transpired, been incorporated in to products and crops, consumed by man or live stock, ejected directly in to sea or other wise removed from fresh water resources.

To calculate the approximate total water consumed in Electricity Generation by Fuel type (Thermal, Natural Gas, Hydro, Wind and Biomass), this paper illustrates the data relating to volumetric water numbers on water consumed for production/ extraction of raw materials (water consumed for refining of raw fuel (if necessary) water consumed for steam generation and process, ash slurry and DM make up water, for cooling purpose depending upon the type of technology adopted. The total arrived figures in power stations of three regions of Andhra Pradesh relating to total amount of water directly consumed for fuel development and in the process of producing electricity have been calculated for various types of electric energy production.
The calculation of water foot print for 1 MW production of electricity is as follows:
Sum of total water consumption (i.e. steam generation & DM make up water in boiler + DM plant back wash +Ash slurry + Condenser cooling + Domestic Purpose)

$$\text{Water Foot print} = \frac{\text{Total Water Consumption}}{\text{Generation}}$$

According to World Energy Vision Report, 2009 as per International Standards: (Right from mining to End Process)

- Water Foot Print--- 2.3 m³/ MWhr-Low capacity plants

- Water Foot Print--- 3.5 m³/ MWhr- High capacity plants
- With Cooling towers--- 3.0 m³/ MWhr-Low capacity plants
- With Cooling towers---4.1 m³/ MWhr- High capacity plants

As a thumb Rule: Thermal Power Plants: Should record Low WFs
Hydel Power plants: Should record high WFs

These are compared with the standard norms of water usage in Indian Power Industry.

Calculation of water footprints in Thermal power stations

Narla Tata Rao Thermal Power Station: Water Source--- Krishna River
Let us consider year 2005-06 for the estimation of water foot print for 1 MW of electricity produced. The appendix table A 5.1 clearly indicates the calculated figures of water foot prints. It shows that the water foot prints in summer season were in the range between 78.72 to 120 m^3 /MWhr, rainy season ranging from the level of 77.4 to 153 m3/MWhr, in winter season varies from 123 to 129 m3/MWhr and in post monsoon season varies from 133 to 143 m3/MWhr. The underlying reason for considerably low level of water footprints in lean season was due to operation of Induced Draft Cooling water technology. For the remaining seasons where there is no induction of cooling technology in some other seasons, the water requirement was high in comparison with World Standards of water requirement for a coal based power plant that stood at 3.4 m3 /MWhr. On the whole, for the year 2005-06, the average water foot print for 1 MWhr of electricity provided in NTTPs is minimum at 115 m^3 /MWhr with cooling technology and with out cooling technology during 2002-03 recorded the WF's 150.6 m^3 /MWhr.

Kothagudaem Thermal Power Plant: Water Source--- Kinnersani Reservoir
From appendix tables A 5.2 and A5.3 it is clearly evident that in KTPS O&M for 2008-09 during summer season the water foot prints varied from 5.9 to 7.5 m³/ MWHR that were considerably low in comparison with other seasons i.e. Rainy Season: 5.2 to 7.6 m³/ MWHR, Winter Season: 6.9 to 7.6 m³/ MWHR and Post monsoon season: 7.2 to 7.5 m³/ MWHR. As far as KTPS V for 2005-06 is concerned, the water foot prints during four seasons were recorded as Summer season: 4.6 to 5.1 m³/ MWHR, Rainy Season: 3.6 to 5.2 m³/ MWHR, Winter Season: 4.6 to 4.9 m³/ MWHR and Post Monsoon Season: 4.9 to 5.1 m³/ MWHR. This range of water foot prints indicates that the typical water consumption for 1 MW of electricity produced was much lower in comparison with NTTPs. The underlying fact behind this is KTPS O& M has an inbuilt cooling tower system, but despite that it encountered water shortage problem that can be discussed in the succeeding sections.

Rayalaseema Thermal Power Plant: Water Source--- Mylavaram Reservoir
The appendix table A5.4 indicates that for the year 2005-06, the water foot prints

in summer season recorded at 4.7 to 6.9 m^3/ MWHR that were considerably low in comparison with other seasons that varied between Rainy Season: 7.8 to 14.9 m^3/ MWH, Winter Season: 5.3 to 14.9 m^3/ MWHR and Post Monsoon Season: 6.1 to 17.1 m^3/ MWHR . This range of water foot prints indicates that the typical water consumption for 1 MW of electricity produced was much lower in comparison with NTTPs due to natural draft cooling towers. But despite that the power station faced water shortages.

Calculation of water footprints in Hydel power Stations

In case of hydro based power plants, water flowing through the turbines is not considered as consumptive. The reason for this is the available water is further used for down stream. However, dams for hydro power create an artificial lake which possesses larger surface area than the river had with out the reservoir. The major lacunae of dams are there will more water evaporation from the surface of the reservoir, when compared with river. All these are dependent on climatic condition with respect to water availability.

Srisailam Left and Right Canal Power House

Based on the field level experiences at power station, water foot prints were calculated for both seasonal water withdrawals (natural water resources) at generation mode and water withdrawals at pump mode. The underlying reasons for switching over to pump mode system are during lean seasons there was no considerable hydel capacity due to seasonal monsoonal fluctuations. The other reason was no major irrigation/hydel projects have not come up in the state. The water foot prints computed for the year 2005-06 (as shown in the table A 5.5). The water foot print calculated during summer season stood at 606892.8 m^3/ MWHR that was lowest due to water shortage in comparison with rainy season that recorded a water foot print of 695487.4 m^3/ MWHR. This has been compensated through an open alternate route i.e. pump mode, where in there was quick add to the water foot prints that stood at 3450814.6 m^3/ MWHR. There was also switch over to pump mode in winter season due to dearth of water. The table A 5.5 also shows that the evaporation losses in the hydel based power projects are serious bottlenecks for increasing shortages of water. The water drawals computed after evaporation loss, exhibited drastic variations. The lost water foot prints in the process of evaporation, also have been emphasized. The table clearly shows that after evaporation loss, it has been found that the loss of water foot prints during Summer Season were 605872.6 m^3/ MWHR that were considerably very high in comparison with other seasons, rainy season: 529812.7 m^3/ MWHR, Post Monsoon Season: 314653 m^3/ MWHR and Winter Season: 190759.6 m^3/ MWHR. This kind of water evaporation from the surface of reservoir is highly dependent solely not only on surface area, but also on reservoir depth and climatic conditions. By observing the evaporation losses level, in Srisailam Left Bank Power House it can be stated that the monthly shortage of water has been aggravated. If we can take an ideal situation of no evaporation losses, the actual generation capacities may go up so that there can be no space for inadequate water in the power sector.

Unlike in comparison with Srisailam left canal power house, the water foot prints in Srisailam Right (A 5.6) were meager that varied in various seasons as Summer Season: 595799.5 m^3/ MWHR, rainy Season: 440367.4 m^3/ MWHR, Post Monsoon Season: 298253.8 m^3/ MWHR and Winter Season: 286751.1 m^3/ MWHR. This power house does not have the facility of pump mode mechanism. However the loss of water foot prints after evaporation losses were more in summer i.e. that stood at 593561.1 m^3/ MWHR in comparison with other seasons rainy Season: 440367.4 m^3/ MWHR, post Monsoon season: 296780.6 m^3/ MWHR and winter Season: 285143.1 m^3/ MWHR.

Nagarjuna Sagar Main Power House:

The data from Nagarjuna Main Power House Station (A 5.7), illustrates that for 2005-06 the fresh water withdrawals for hydel electric energy production are exhibiting varying trends month wise. In summer season, lower water foot prints were recorded at the level of 534094.6 m^3/ MWHR in comparison with rainy season, 635859.88 m^3/ MWHR that recorded higher WFs. whereas during winter season and post monsoon season, lower water foot prints were recorded ranging from 246453.4 m^3/ MWHR and 248802.74 m^3/ MWHR due to occurrence of seasonal fluctuations (that is water scarcity situations) that have become a noticeable reality. The loss of water foot prints after evaporation losses in winter season were more that, stood at 12655131.1 m^3/ MWHR compared to other seasons. For example during summer season the water foot prints stood at 3627107.9 m^3/ MWHR, rainy season water foot prints were at 1407523.1 m^3/ MWHR and Post monsoon season : 1338425.7 m^3/ MWHR. However during summer season lower water foot prints pose a greater burden on hydel electricity production, there by affecting competitiveness of hydel capacity.

Nagarjuna Sagar Left and Right Canal Power House

The table (A 5.8) represents Nagarjuna Sagar left canal that provides estimation of seasonal water foot prints exclusively and also water foot prints along with evaporation losses. Winter Season recorded highest water foot prints at 12655131.1 m^3/ MWHR due to more precipitation levels. The summer, rainy, and post monsoon season recorded lower water foot prints at the level of 3627107.9 m^3/ MWHR, 1407523.1 m^3/ MWHR and 1338425.7 m^3/ MWHR due to looming threat of climate change. The loss of water foot prints after evaporation losses were more in summer season in comparison with other seasons. The table (A5.9) for the nagarjuna sagar right canal power house for the year 2006-07 clearly indicates that , April, May, June and July notified zero water foot prints due to bad performance of monsoons and as a result consequently there was nil generation of hydel capacity. But for the remaining months especially August, September, October and November recorded highest hydel generation capacity ranging from 39.4 MU to 41.4 MU due to no water shortages with good monsoon rainfall.

Vijjeswaram Gas Power Plant

In case of natural gas based power plants from appendix table 5.10 , the water foot prints provided a clear picture to make a comprehensive analysis of electric energy (through feed stock natural gas) and water. For Example in a prospective period of the year i.e. during rainy season for both stage I and Stage II the water foot prints have recorded highest accord at the level of 0.109 m^3/ MWHR and 0.0949 m^3/ MWHR , in comparison with other seasons i.e. stood at 0.104 m^3/ MWHR and 0.08007 m^3/ MWHR for both the stages for summer season, post monsoon season records water foot prints of 0.031 m^3/ MWHR and 0.0303 m^3/ MWHR and in winter absolutely nil WFs were recorded for Stage I and for Stage II the water foot prints stood at 0.0183 m^3/ MWHR.

Biomass Power Plants

MY Home Power Limited

For My Home Power Limited Biomass power plants from appendix table 5.11, the main source of water for generation of electricity was drinking water from Manjeera river that is a tributary of Godavari river. This river is the main drinking water source for medak and Nizambad districts as well as the adjoining twin cities of Hyderabad and Secunderabad. The water foot prints calculated for the year 2009 for My Home Power Limited revealed an interesting picture. It has been found that during the months of summer season the water foot prints varied from 0.01 m^3/MWH to 1.04 m3/MWH due to low availability of fresh drinking water, except for March month. However low water foot print was recorded due to operation of cooling towers more effectively during summer season. However for the prospective months, (i.e. during rainy and winter season), the highest water foot prints were recorded ranging from 8.7 m^3/MWH to 7.8 m^3/MWH. The state government in order to encourage the production of Green electricity through renewable sources of energy is providing water for this biomass power plant through drinking water facility.

Sri Satyakala power Plant

As far as Satyakala Biomass power plant is concerned from appendix table 5.12, the plant totally relies on bore wells for generation of electricity. In this regard for the year 2008-09, the water foot prints estimated recorded highest in the months of October, November and March that ranged from 4.91 m^3/MWH to 7.6 m^3/MWH. For the months of April, May June, July, August and February the water foot prints remained constant. For the month of January there was slight increase of water prints i.e. 0.008 m^3/MWH. In comparison with MY Home Power

Limited Biomass power plant, the water required to generate 1 MWH of electricity was much on a lower footing basis.

Sri Rayalaseema Green Energy Limited

In Case of Sri Rayalaseema Green Energy Limited Biomass power plant from appendix table 5.13, the main source of water for electricity generation is underground water. Henceforth water foot prints were calculated accordingly for the two years 2002-03 and 2003-04. The tables clearly reveal that the water foot prints remained constant through out the months, right from beginning of the year to the end in the range of 0.0046 m^3/MWH. Therefore as far as ground water is concerned there is no seasonality factor. In comparison with My Home Power Limited plant and Sri Satyakala power plant Biomass power plants, the Ralayaseema Green Energy power plant have lower water foot prints.

COMPARATIVE ANALYSIS OF WATER FOOT PRINTS BY FEED STOCK TYPE FOR POWER PLANT

Another advantage of this water foot printing methodology was that, it determined power plant basic water use by energy type (i.e. hydel, thermal, natural gas, biomass) and also provided a standard for comparing and bench marking water use within thermal, hydel, biomass power plants and also among different power plants by energy type. (See appendix table 5.14). The comparative analysis clearly identifies major water consuming power plants. The hydel power plants encompasses a six digit water foot prints, thermal power plants two and one digit water foot print, natural gas and renewable based electric energy plants recorded one or point wise water foot prints.

There fore it is increasingly evident that to produce 1 MW of electricity renewable energy sources (biomass) recorded lesser water foot prints in comparison with hydel and thermal. Therefore water Foot printing methodology was able to address the water scarcity problem in power plants more effectively.

IV

6.0 Application of Seasonal Variation Index in Power Plants of Andhra Pradesh

This paper focuses on the relevance of seasonal variation index or ratio to moving average method for its practical application in Electricity Generation Industry. Seasonal Variations occur within a period of one year or less. It is a component of time series which is defined as repetitive and predictable (seasonal changes) around the trend line in one year or less. It is detected by measuring the quantity of interest for small intervals that is days, weeks, months and quarters. By this strong seasonal movements can be predicted. But when data are expressed annually there is no seasonal variation. A measure of seasonal variation is referred as Seasonal indexes (percent). They are given as percentages of their average. ESI- Exhibits inquisitiveness in knowing their performance w.r.t. to water withdrawals vis-à-vis power generation relative to normal seasonal variation with the aid of SVI

- Electricity Supply Industry affected by seasonal variation (in terms of water availability due to climate variability)
-
    - Expects an increase or decrease in power generation
    - Both in prospective and lean period of a year

This paper makes an effort to estimate seasonal variation with respect to water withdrawal trends and loss of power generation due to water shortage for a particular power plant by fuel type. For this it mainly focuses on computing an index of seasonal variation for quarterly data by using Ratio-to- moving average method. By this method, in a time series data, an analysis of seasonal fluctuations over a period of months i.e., for the period 2000-2001 to 2008-2009 helps in evaluating water withdrawals and loss of generation.

The following are the steps involved in computation of Seasonal variation Index w.r.t to water withdrawals and loss of generation due to water shortage trends for various power plants by fuel type (Thermal and Hydel) (See appendix table A 6.1 for Nagarjuna Sagar Main Power House)

- STEP 1: List the data in chronological order
- STEP 2: Determine the time period to be used for moving average (Here the data used is for quarterly purpose)
- STEP 3: Compute four quarter moving average. The first value in third column is 4 = (3.67 + 5.01+ 4.78 +2.55)/4. The second value is calculated by moving down one quarter. (5.01 +4.78 +2.55+2.02)/4 = 3.6. By moving down 1 quarter at a time, we can calculate the rest of moving averages.
- STEP 4: Compute the centered moving averages by getting the average of two 4 quarter moving averages. EG. 4 + 3.6/2 = 3.8; 3.6 +3.5 /2 = 3.6
- STEP 5: For obtaining specific seasonal, compute the ratio by dividing actual WD by centered moving averages. For Eg: WD value 3 quarter (winter) 4.78/3.8 = 1.25 and so on and so forth.
- STEP 6: Later a seasonal index table is constructed by making use of specific seasonal column. The purpose is to group together all first, second, third and fourth quarters to calculate a typical index per quarter.
- STEP 7: Total all the years for 4 quarters (i.e. summer, rainy, winter and post monsoon seasons) and divide by number of observations to obtain unadjusted seasonal mean. The unadjusted seasonal means obtained are 0.30 , 1.23, 1.59 and 0.52 and the total comes to 3.64
- STEP 8: Determine the correction factor to adjust the unadjusted seasonal mean to adjusted seasonal means.
- For typical quarterly index = 100 x4 = 400. Add all the unadjusted seasonal means.
- Correction Factor = 4/3.64 = 1.09

- Multiply 0.9802 (CF) with unadjusted seasonal mean. Then we obtain adjusted seasonal.
- STEP 9: Then ultimately multiply with 100, to obtain typical seasonal index as 32.7, 134.07, 173.31 and 56.68.
- STEP 10: As per Indian monsoon conditions, the final seasonal index values are calculated for both water withdrawals and loss of generation. For the purpose of Four Quarterly moving average, the SVI analysis has been done by bifurcating the Indian seasons as 3 months in each quarter. But in reality , the Indian monsoon period can be customarily categorized as follows:

Month	**Season**
March April May	Summer (Dry season)
June July August September	Rainy (Wet Season)
December January February	Winter (Cold Season)
October November	Medium wet season

Therefore the final seasonal indexes calculated as per Indian monsoon conditions during summer, rainy, winter and post monsoon season for the period of 2000-2001 to 2008-09 are 90.47, 152.96, 115.54 and 37.79.

- STEP 11: Later deseasonalization of data should be done. By deseasonalized data we mean, that this shows how things would have been provided if there are no seasonal fluctuations. In order to arrive at such data, we have to completely remove the effect of seasonal variations. The deseasonalized data in last column are obtained by dividing original data in column 2 by appropriate typical seasonal index. For Eg. 3.67/0.327 = 11.22 so on and so forth. In other words, we can say that what summer season water withdrawals would have been if there had been no seasonal variation. Hence to obtain deseasonalized data, divide the actual data by the appropriate seasonal indices. Thus the data would be free from seasonal impact.
- STEP 12: For doing seasonalized forecast for 4 quarters for time period 2009-2010 to 2013-2014, code the time period and use the method of least squares to obtain the trend equation. For Eg. Here for water withdrawals the Trend Equation: $y = 2.59 + 0.080 X$. By substituting with the appropriate code for the time period we obtain the trend value. In case

of this for example by substituting X with 33, we obtain the trend value that is unadjusted forecast i.e. 5.23

By multiplying the unadjusted forecast trend with seasonal variation index 0.327 we obtain the seasonally adjusted forecast for summer season i.e. 1.71 hundred million cubic meters for the year 2009-2010, which is very meager in comparison with rainy , winter and post monsoon season that stood at 7.1, 9.3 and 3.1 hundred million cubic meters.

Similar forecast is made for the time period ranging from 2010-2011 to 2013 -2014, and the forecast summer season water withdrawals stood at 1.78, 1.91, 2.024, 2.13 hundred million cubic meters that are regarded as the minimum in comparison with other seasons.

- ❖ Similar procedure applies even for loss of generation. Before going in to intricate details of SVI of LG, let us examine how loss of generation due to water shortage for sample power plants by varied feed stock has been estimated.

Similar procedure applies even for loss of generation. Before going in to intricate details of SVI of LG, let us examine how loss of generation due to water shortage for sample power plants by varied feed stock has been estimated.

6.1 Calculation of Loss of Generation (LG) due to water shortage (WS) in selected power plants

Case of Hydel power plants:

Nagarjuna Sagar Main Power House

This power house consists of 8 units. One unit 110 MW and 7 units 100.8 MW

- Installed Capacity : 1x 110+7x100.8 = 815.6 MW
- Per day generation = 815.6 x 24 = $\frac{19574.4}{1000}$ = 19.57 MU
- Per month Generation: 19.57 x 30 = 587.23 MU

Therefore this power plant is technically supposed to generate for the whole month 587.23 MU.

But in actual scenario, during 2007-08 for the April month actual generation = 10.843. Now the question crops up in mind why there is a huge gap between installed generation and actual generation. The reason is there might be some shortfalls. The first contributory factor is auxillary consumption. For the start up of power plants, its main power parts and ancillaries consume some electricity.

- LG due to auxillary consumption= 0.360628

- LG due to water shortage: Installed Generation – (Actual Generation-Auxiliary Consumption)

  = 587.23- (10.843-0.360628) = 587.23 -10.48 = 576.75

Therefore for the April month the loss of generation due to water shortage is 576.75 MU

- March Month = 587.23 – (37.276- 0.12784) = 587.23-37.148 = 550.082
- May month = 587.23-0 = 587.23
- Therefore loss of generation due to water shortage in summer season = 576.75 + 550.08+ 587.23 = 1714.06/1000 =1.71 thousand million units

For rainy, winter and post monsoon season the calculated figures for loss of generation due to water shortage comes to 0.71, 0.84 and 1.65 thousand million units. In a similar manner the loss of generation due to water shortage during 2001-02 to 2008-09 has been calculated.

Nagarjuna Sagar Left Canal power House

- Installed Capacity ; 1x 30.6 +2 x30.6 = 91.8 MW
- Per day Generation = 91.8 x 24 hr = $\frac{2203.2}{1000}$ = 2.2 MU
- Per month Generation = 2.2 x 30 = 66.09 MU

However, during 2005-06, the LG due to water shortage = Installed Generation – (Actual generation – Auxiliary Consumption)

- April = 66.09- (1.83) = 64.26
- May = 66.09-2.96 = 63.13
- March= 66.09-0 = 66.09

Therefore LG due to WS during summer season = 64.26 + 63.13 + 66.09 = 193.48 MU or 193.48/100 = 1.93 hundred million units. The calculated figures of loss of generation due to water shortage during rainy, winter and post monsoon seasons are 1.79, 1.33 and 1.64. hundred million units. In a similar manner the loss of generation due to water shortage during 2001-02 to 2008-09 has been calculated.

Nagarjuna Sagar Right Canal Power House

Installed Capacity = 2 x 30.6 = 61.2 MW

- Per day generation = 61.2 x 24 hr = 1468.8/1000 = 1.47 MU
- Per month Generation = 1.47 x 30 = 44.06 MU

During 2005-06

- March = 44.06- (16.99- 4.67) =44.06-12.32 = 31.74
- April = 44.06 – (12.09-0.32) = 44.06-11.77 = 32.29
- May 44.06- (0-0) = 44.06

Therefore the LG due to water shortage during summer season = 31.74 +32.29+44.06 = 108.09 MU or 1.08 hundred million units. The calculated figures of loss of generation due to water shortage during rainy, winter and post monsoon seasons are 1.10, 0.069 and 0.51 hundred million units. In a similar manner the loss of generation due to water shortage during 2001-02 to 2008-09 has been calculated.

Srisailam Left Canal Power House

- Installed capacity = 6 X 150 MW
- Per day Generation = 6 x150 x24 = $\frac{21600}{1000}$ = 21.6
- Per month generation = 21.6 x30 = 648 MU

During 2007-08

- March = (actual generation) 107.65 – (auxiliary consumption) 0.53 = 107.12
- LG due to WS = Installed Generation – 107.12 = 540.88
- April = 648- (155.32 -0.52) = 648-154.8 = 493.2
- May = 648- (94.75 -0.52) = 648-94.23 = 553.77

Therefore loss of generation due to WS during summer season = 540.88 +493.2+553.77 = 1587.85/1000 = 1.58 thousand million units. The calculated figures of loss of generation due to water shortage during rainy, winter and post monsoon seasons are 1.60, 0.66 and 1.59 thousand million units. In a similar manner the loss of generation due to water shortage during 2001-02 to 2008-09 has been calculated.

Srisailam Right Canal power House

- Installed Capacity: 7x110 MW
- Per day Generation = 7x 110x 24 hrs = 18480/1000 = 18.48
- Per month = 18.480 x 30 days = 554.4 MU

During 2007-08

- March = 554.4 (151 .55-0.54) = 554.4-151.01 = 403.39
- April = 554.4 (150.14- 0.55) = 554.4- 149.59 = 404.81
- May = 554.4 (103.10 -0.47) = 554.4 – 102.63 = 451.77

Therefore LG due to WS = 403.39 + 404.81+451.77 = 1259.97/1000 = 1.26 thousand million units. The calculated figures of loss of generation due to water shortage during rainy, winter and post monsoon seasons are 0.71, 0.95 and 1.36 thousand million units. In a similar manner the loss of generation due to water shortage during 2001-02 to 2008-09 has been calculated.

Lower Sileru Hydel power House

- Installed Capacity = 100 x4 = 400 MW
- Per day generation = 400 x24hrs= 9600/1000 = 9.6 MU
- Per month generation = 9.6 x 30 = 288 MU, Auxiliary consumption is nil.

During 2008-09

- March : (Installed Generation) 288- (actual Generation) 117 = 171
- May 288-75 = 213
- April 288-90 =198

Therefore LG due to WS during summer season = 171 +213+198 = 582 or 5.82 hundred million units. The calculated figures of loss of generation due to water shortage during rainy, winter and post monsoon seasons are 6.18, 6.14 and 5.58 hundred million units. In a similar manner the loss of generation due to water shortage during 2001-02 to 2008-09 has been calculated.

Upper Sileru Hydel Power House

- Installed Capacity = 60x4 = 240 MW
- Per day generation = 240 x 24 hrs = 5760/1000 = 5.76
- Per month generation = 5.76 x30 = 172.8 MU
- Auxillary consumption is nil.

During 2005-06

- March 172.8-74.32 = 98.48
- April 172.8- 40.76 = 132.04
- May 172.8- 37.57 = 135.23

Therefore LG due to WS during summer season = 98.48+132.04+135.23 = 365.75 or 3.66 hundred million units. The calculated figures of loss of generation due to water shortage during rainy, winter and post monsoon seasons are 4.22, 4.58 and 3.57 hundred million units. In a similar manner the loss of generation due to water shortage during 2001-02 to 2008-09 has been calculated.

Case of Thermal Power Plants:
Narla Tata Rao Thermal Power Plant

- Installed Capacity: 6 x 210 MW
- Per day generation = 210 x 24 hrs = 5040/1000 = 5.04 MU
- Per month generation = 5.04 x6x 30 = 907.2 MU

During 2003-04

- April month actual generation = 876.95 MU
- LG due to high grid frequency, loss due to outages, coal problem, outage of auxiliaries, auxillary consumption = 22.44+3.14+1.10+10.02+78.601 = 115.301 MU
- Actual generation –LG due to other factors = 876.95 – 115.301 = 761.65 MU
- Installed Generation- Final Actual generation (after deduction of LG due to other factors) = 907.2-761.65 = 145 MU
- May month AG = 882.43 MU
- Loss of Generation due to high grid frequency , outages, coal problem and AU = 14.61+ 2.12+ 20.95+ 79.520
  = 117.2 MU
  = 882.43-117.2 = 765.23 MU
- Installed generation - Final actual generation loss = 907.2-765.23 = 141.97 MU
- March month actual generation = 922.10 MU

- LG due to allied factors = 0.66+0.71+ 10.45 +80.485 = 92.305
  = 922.10 -92.305 = 829.79 MU
- Installed Generation- Final Actual generation (after deduction of LG due to other factors)
  = 907.2-829.795 = 77.405 MU

Therefore ultimately the LG due to WS for summer months is 145 +141.97+77.405= 364 or 3.64 hundred million units. The calculated figures of LG during rainy, winter and post monsoon season are 6.62, 7.84 and 5.71 hundred million units. In similar manner for all the quarters (4 seasons), LG due to WS during (2003-04 to 2008-09) has been calculated and SVI has been applied.

Kothagudaem Thermal Power Plant O&M

Installed Capacity

- KTPS A 4x 60 MW
- KTPS B 2x 120 MW 4x60+2x120 +2x120 = 720
- KTPS C 2x120 MW
- As each station A, B and C comprises of different capacities, 720 ICG is taken as standard for calculation of LG.

During 2008-09

- April month Actual Generation= 370.56 MU
- Loss of Generation due to poor quality of coal, outage on auxiliaries, auxiliary consumption and forced outage = 39.05 +23.24+31.33+55.80 = 149.42 MU
- Actual Generation –LG due to other factors = 370.56-149.42
- Installed Generation capacity -221.14 MU
  =720-221.14 =498 MU
- Therefore LG due to water shortage = 498 MU
- May month Actual Generation: 380.921 MU
- LG due to other factors = 33.17+21.05+40.26+33.54+12.54 = 140.56 MU
- Actual Generation-LG due to other factors
  = 380.921-40.56 =240.361 MU

  Therefore LG due to water shortage = 720-240.361 = 479.639 MU
- March month actual generation: 418.921
- LG due to other factors = 49.29+10.82+49.26+36.66+14.3 =153.42 MU
- Actual generation –LG due to other factors
  = 418.921-153.42 = 265.501 MU

Therefore LG due to water shortage = 720-265.501 =454.49

Therefore ultimately the LG due to water shortage during summer season =498+479.64+454.499 =1432.1 MU or 14.32 hundred million units. The calculated figures of LG during rainy, winter and post monsoon season are 21.86, 14.71 and 11.53 hundred million units. In similar manner for all the quarters (4 seasons), LG due to WS during (2003-04 to 2008-09) has been calculated and SVI has been applied.

Kothagudaem Thermal Power Plant Stage V

- Installed Capacity = 2X250 MW
- Per month installed generation = 6x2x30= 360MU
- Loss of generation due to forced losses, poor quality coal, unit auxillary losses, high grid frequency and planned losses = 31.52 MU

During 2002-03

- April month = IG- (AG- LG due to other factors)
- Therefore LG due to WS = 360-(342.77-31.52) = 360-311.25=48.75
- May month = 360-(355.77-31.52) = 360-324.25 = 35.75
- March month = 360-(369.56-31.52) = 360-338.04 = 21.9

Therefore the loss of generation due to WS during summer season = 48.75+35.75+21.9= 106.46/10= 10.64 MU. The calculated figures of LG during rainy, winter and post monsoon season are 21.35, 17.19 and 12.59 million units. In similar manner for all the quarters (4 seasons), LG due to WS during (2003-04 to 2008-09) has been calculated and SVI has been applied.

Rayalaseema Thermal power Plant

- Installed Capacity= 2x210MW
- Per month installed generation = 5.04x2x30= 302.4 MU

During 2005-06

- April month actual generation = 234 MU
- LG due to partial loading due to poor quality coal, auxiliary consumption = 56.99 MU
- = Actual generation- LG due to other factors = 234-56.99 = 177.01 MU
- Installed Generation = 302.4-177.01 =125.39

  Therefore LG due to water shortage = 125.39 MU

  Similarly for May and March month's actual generation and LG due to other factors are 234 MU and 56.99 MU. The loss of generation calculated due to WS is 125.39 MU. Therefore for the summer month as a whole LG due to WS can be calculated as 125.39+125.39+125.39 = 376.17 MU or 3.76 hundred million units. The calculated figures of LG during rainy, winter and post monsoon season are 5.75, 4.83 and 3.06 million units. In similar manner for all the quarters (4 seasons), LG due to WS during (2003-04 to 2008-09) has been calculated and SVI has been applied.

In Nagarjuna Sagar Main Power House, for loss of generation due to water shortage component the seasonal variation index method has been applied similar to water withdrawals (See Appendix table: 6.1)

- After following all the 5 steps the specific seasonal values are arranged for four quarters for the years 2001-02 to 2008-2009, the unadjusted mean and adjusted seasonal index has been calculated.
- For this purpose the correction factor is also determined where in all the unadjusted seasonal means comes to 1.12, 0.92, 0.901 and 1.14. The total of all these comes to 4.081. The correction factor = 4/4.081 = 0.9802. Therefore the ultimate typical seasonal indexes obtained are 109.78, 90.17, 88.32 and 111.7.
- The final seasonal indexes calculated as per Indian monsoon conditions during summer, rainy, winter and post monsoon season for the period of 2000-2001 to 2008-09 are139.22, 127.4, 58.88 and 74.47.
- The deseasonalized data in last column are obtained by dividing original data in column 2 by appropriate typical seasonal index. For Eg. 1.42/0.95 = 1.61 so on and so forth. In other words, we can say that what summer season loss of generation would have been if there had been no seasonal variation.
- For doing seasonalized forecast for 4 quarters for time period 2009-2010 to 2013-2014, code the time period and use the method of least squares to obtain the trend equation. For Eg. Here for loss of generation due to water shortage the Trend Equation obtained is y = 1.55 - 0.03 x
- By substituting with the appropriate code for the time period we obtain the trend value. In case of this for example by substituting X with 33, we obtain the trend value that is unadjusted forecast 0.56.
    - By multiplying the unadjusted forecast trend with seasonal variation index 1.0978, we obtain the seasonally adjusted forecast of loss of generation due to water shortage for summer season i.e. 0.65 for the year 2009-2010, which is high in comparison with rainy, winter and post monsoon season that stood at 0.48, 0.44 and 0.53 MU.

Similar forecast is made for the time period ranging from 2010-2011 to 2013 -2014, and the forecast summer season loss of generation due to water shortage stood at 0.48, 0.35, 0.22 and 0.087 MU that are regarded as the maximum in comparison with other seasons.

Finally as per Indian monsoon conditions, the final seasonalized forecast for water withdrawals Vs Loss of generation appendix table 5.1 indicates that for the years 2009-2010, 2010-2011, 2011-2012 and 2013-2014 especially during summer season the water withdrawals are very meager that stood at 4.8, 5.1, 5.39, 5.69 and 5.98 hundred million cubic meters due to seasonal fluctuations. In accordance with it, the loss of generation was rated high at 0.8, 0.59, 0.43, 0.26 and 0.093 MU in comparison with rainy, winter and post monsoon seasons. For the rainy season the forecast values indicates that the highest water withdrawals for the years 2009-2010, 2010-2011, 2011-2012 and 2013-2014 were recorded at the level of 8.13, 8.53, 9.2, 9.62 and 10.1 thousand million units and less loss of generation were recorded at the level of 0.66,0.5,0.35,0.15 and 0.0413 MU. For the rest of the seasons i.e. winter season recorded moderate water withdrawals and moderate loss of generation. In case of post monsoon season, meager water withdrawals were recorded with moderate loss of generation.

In a similar manner for all the seven selected hydel and four thermal power stations, the Seasonal variation has been applied by following the above mentioned procedures.

6.2 Findings of selected power plants w.r.t to water withdrawals (WD) Vs Loss of Generation (LG) after application of Seasonal Variation Index

Case of Hydel Power Plants: Water Withdrawals and Loss of Generation

Nagarjuna Sagar Main Power House: (2001-02 to 2008-09)

Over a period of 9 years, the application of seasonal variation index revealed the following results: (Appendix Table 6.1)

- The rainy season ranks I with more water withdrawals in comparison with summer. Less loss of generation was reported in rainy season due to the effect of higher water withdrawals.
  - More WD yielded an index of 152.96
    Less LG capitulated an index of 127.40
- The summer season ranks III with meager water withdrawals in comparison with rainy. High loss of generation was reported in summer season due to the influence of lower water withdrawals
  - Less WD- with an index of 90.47
    More LG- with an index of 139.22
- The winter season ranks II with moderate water withdrawals and moderate loss of generation
  - ModerateWD- with an index of 115.54
    Moderate LG – with an index of 29.44
- The Post monsoon ranks IV with meager water withdrawals and more Loss of generation.
  - Meager WD- with an index of 37.79
    More LG- with an index of 74.47

The Future Projections of water withdrawals and loss of generation due to water shortage have been done for the period ranging from 2009-2010 to 2013-2014 with the aid of trend equations.

WD- Y= 2.59 +0.080X
LG- Y=1.55-0.03 X

- Rainy Season Ranks I –with more WD (varying from 8 to 10.1 hundred million cubic meters) and less LG (that varies from 0.66 thousand MU to 0.0413 thousand MU) ---Good Monsoonal Effect
- Summer Season Ranks III- with less WD (varying from 4.8 to 5.98 hundred million cubic meters and more LG (that varies from 0.8 thousand million units to 0.093 thousand million units) ----Dearth of Water.
- Winter Season Ranks II- with moderate WD (varying from 6.24 to 7.71 hundred million cubic meters and moderate LG (that varies from 0.29 thousand MU to 0.011 thousand MU)---Dearth of water
- Post Monsoon Season Ranks IV- with meager WD(varying from 2.06 to 2.6 hundred million cubic meters and moderate LG (that varies from 0.35 thousand MU to -0.0073 thousand MU)---Dearth of water

  Higher or lower level water withdrawals during varied monsoon seasons (summer, Rainy, winter and Post Monsoon Season) ends up with varying levels of (high or Low) LG vis-à-vis with varying PLF. (Exhibits its Quality).
- ***Low Case Scenario: During 2001-02***
  EG: 3.67 hundred million cubic meters – Low WD
  1.53 thousand million units- High LG
  28.96 PLF- Low PLF
- ***High Case Scenario: During 2001-02***
  EG: 4.78 hundred million cubic meters- high WD
  1.42 thousand million units- Low LG
  42.29 PLF- recorded high level of PLF

  Similar is the case with all other hydel power plants.

Nagarjuna Sagar left canal power house: 2001-02 to 2008-09
(Appendix table 6.2)

- The winter season ranks I with more water withdrawals in comparison with summer. Less loss of generation was reported in winter season due to the effect of higher water withdrawals.
  - more WD- with an index of 135
    Less LG- with an index of 58
- The summer season ranks II with meager water withdrawals in comparison with winter. High loss of generation was reported in summer season due to the influence of lower water withdrawals.
  - Less WD- with an index of 128
    More LG- with an index of 138
- The rainy season ranks III with moderate water withdrawals and more loss of generation.
  - Moderate WD-with an index of 78
    More LG-with an index of 136
- The post monsoon season ranks IV with moderate water withdrawals and moderate loss of generation.

    - Moderate WD- with an index of 60
      Moderate LG with an index of 67

Future Projections: 2009-2010 to 2013-2014

Trend Equations
WD- Y= -11.8+2.0X
LG-Y= 20.2-0.012X

- Winter Season: Ranks I: more WD (varying from 78.38 to 121.47 hundred million cubic meters) and Less LG (that varies from 11.47 to 11.36 hundred million units) ---Good precipitation levels.
- Summer Season: Ranks II: Less WD (varying from 72.24 to 113.31 hundred million cubic meters and more LG (that varies from 27.32 to 27.06 hundred MU) ----Shortage of water.
- Rainy Season: Ranks III: Moderate WDs (Varying from 45.4 to 70.57 hundred million cubic meters and moderate LG (that varies from 26.85 hundred MU to 26.58 hundred MU) - Shortage of water due to poor rainfall.
- Post Monsoon season: Ranks IV : Moderate WD- (varying from 35.72 to 54.71 hundred million cubic meters and moderate LG (that varies from 13.31 hundred MU to 13.18 hundred MU) --- Shortage of water

Nagarjuna Sagar Right Canal Power House: 2001-02 to 2008-09
(Appendix Table 6.3)

- The summer season ranks I with more water withdrawals in comparison with rainy. Less loss of generation was reported in summer season due to the effect of higher water withdrawals.
    - More WD with an index of 156
      Less LG with an index of 111
- The rainy season ranks III with meager water withdrawals in comparison with summer. High loss of generation was reported in rainy season due to the influence of lower water withdrawals.
    - Less WD with an index of 58
      More LG with an index of 133
- The winter season ranks II with moderate water withdrawals and moderate loss of generation.
    - Moderate WD with an index of 116
      Moderate LG with an index of 87

- The post monsoon season ranks IV with moderate water withdrawals and moderate loss of generation.
    - Moderate WD with an index of 71
      Moderate LG with an index of 69

Future Projections: 2009-2010 to 2013-2014

Trend Equations
WD- Y= -4.14+0.59X
LG- Y= 14.2-0.26 X

- Summer Season ranks I with more WD (varying from 24.64 to 39.14 hundred million cubic meters with less LG (that varies from 6.03 to 1.39 MU) – Judicious Utilization of water.
- Rainy Season ranks IV with minimal WD (that varies from 9.63 to 15.13 hundred million cubic meters) with more LG (that varies from 6.96 to 1.42 MU) - poor monsoonal rainfall.
- Winter Season ranks II with moderate WD (that varies from 19.15 to 30.1 hundred million cubic meters with moderate LG (that varies from 4.47 to 0.82 MU-- (Dearth of water)
- Post Monsoon Season ranks III with moderate WD (varying from 12.07 to 18.78 hundred million cubic meters with moderate LG (that varies from 3.33 to 0.97 MU) – Shortage of water.

Srisailam Left Canal Power House: 2001-02 to 2007-08
(Appendix table 6.4)

- The summer season ranks I with more water withdrawals in comparison with rainy. Less loss of generation was reported in summer season due to the effect of higher water withdrawals.
  - more WD- with an index of 139.23
    Less LG- with an index of 133.98
- The rainy season ranks III with meager water withdrawals in comparison with summer. High loss of generation was reported in rainy season due to the influence of lower water withdrawals.
  - less WD- with an index of 81.36
    More LG- with an index of 142.57
- The winter season ranks II with more water withdrawals and less loss of generation.
  - More WD-with an index of 103.67
    Less LG with an index of 56.1
- The post monsoon season ranks IV with moderate water withdrawals and moderate loss of generation.
  - Moderate WD- with an index of 93.6
    Moderate LG-with an index of 65.34

Future Projections: 2009-2010 to 2013-2014
Trend Equations
WD- Y=23.0 +0.57 X

LG- Y=1.79-0.015 X

- Summer season ranks I with more WD (varying from 55.63 to 71.48 hundred million cubic meters with less LG (that varies from 1.81 to 1.41thousand MU) ---Judicious utilization of water.
- Winter Season ranks II with more WD (varying from 42.17 to 53.93 hundred million cubic meters) with less LG (that varies from 0.57 to 0.74 thousand MU)—Good precipitation levels.
- Post Monsoon Season ranks III with moderate WD (that varies from 38.45 to 49.13 hundred million cubic meters with moderate LG (0.85 to 0.66 thousand MU)
- Rainy Season ranks IV with less WD(varying from 33.13 to 69.57 hundred million cubic meters and LG (that varies from 1.9 to 1.47 thousand million units)

Srisailam Right Canal Power House: 2000-01 to 2007-08

(Appendix Table 6.5)

- The winter season ranks I with more water withdrawals in comparison with summer. Less loss of generation was reported in winter season due to the effect of higher water withdrawals.

  - more WD with an index of 120
    Less LG with an index of 60.67

- The summer season ranks III with meager water withdrawals in comparison with winter. High loss of generation was reported in summer season due to the influence of lower water withdrawals.

  - Less WD with an index of 97
    More LG with an index of 63.33

- The rainy season ranks II with moderate water withdrawals and more loss of generation.

  - Moderate WD with an index of 118.67
    More LG with an index of 144

- The post monsoon season ranks IV with less water withdrawals and moderate loss of generation

  - Less WD with an index of 63.33
    Moderate LG with an index of 72

Future Projections: 2008-2009 to 2013-2014

Trend Equations

WD- Y = 7.70-0.23 X

LG-Y=12.7-0.10X

- Summer Season ranks I with more WD (varying from 0.72 to 1.08 hundred million cubic meters) with less LG (0.79 to 9.7 thousand MU) ---Judicious management of water.
- Post Monsoon season ranks II with moderate WD (varying from 0.21 to -2.7 hundred million cubic meters with moderate LG (that varies from 6.84 to 5.4 thousand MU) –Shortage of water.
- Rainy Season ranks III with meager WD (varying from 0.79 to negative WD's) with very high LG (that varies from 14.11 to 11.02 thousand MU) ---Dearth of water due to monsoonal rainfall variability.
- Winter Season ranks IV with meager WD (varying from 0.78 to negative WD's) with high LG (0.61 to 406 thousand MU)—Shortage of water.

Lower Sileru Hydel power Station: 2001-02 to 2008-09
(Appendix table 6.6)

- The summer season ranks I with more water withdrawals in comparison with rainy. Less loss of generation was reported in summer season due to the effect of higher water withdrawals.

  - More WD with an index of 141.33
    Less LG with an index of 108.2

- The rainy season ranks II with meager water withdrawals in comparison with summer. High loss of generation was reported in rainy season due to the influence of lower water withdrawals.

  - Less WD with an index of 124.67
    More LG with an index of 112.1

- The winter season ranks III with moderate water withdrawals and moderate loss of generation.

  - Moderate WD with an index of 58.67
    Moderate LG with an index of 65

- The post monsoon season ranks IV with moderate water withdrawals and moderate loss of generation.
  - Moderate WD with an index of 75.33
    Moderate LG with an index of 58.8

Future Projections: 2009-2010 to 2013-2014
Trend Equations
WD- Y= 2.30+0.025X
LG –Y= 6.46-0.023X

- Summer Season ranks I with more WD (varying from 4.4 to 4.95 hundred million cubic meters) with less LG (that varies from 9.62 to 7 hundred million units)—Judicious utilization of water.

- Rainy Season ranks II with less WD (varying from 4 to 4.69 hundred million cubic meters) and more LG (that varies from 9.82 to 7.17 hundred MU) ---Dearth of water due to climate variability.
- Post Monsoon season ranks III with moderate WD (varying from 1.87 to 2.05 hundred million cubic meters with moderate LG (that varies from 5.23 to 3.8 thousand MU)
- Winter Season ranks IV with moderate WD (varying from 2.4 to 3.12 hundred million cubic meters with moderate LG (that varies from 4.03 to 2.93 thousand MU)

Upper Sileru Hydel Power Station: 2001-02 to 2008-09
(Appendix table 6.7)

- Rainy season ranks I with more water withdrawals and with more loss of generation in comparison with summer season. The underlying fact for this poor quality of water.
  - More WD with an index of 148.3
    More LG- with an index of 111.5
- Summer season ranks II with meager water withdrawals in comparison with rainy and high loss of generation (same LG as that of rainy)
  - Less WD –with an index of 138.3
    More LG with an index of 111.1
- The winter season ranks IV with moderate water withdrawals and moderate loss of generation.
  - Moderate WD with an index of 58.7
    Moderate LG with an index of 65.54
- The post monsoon season ranks III with moderate water withdrawals and moderate loss of generation.
  - Moderate WD with an index of 94.7
    Moderate LG with an index of 57.87

Future Projections: 2009-2010 to 2013-2014
Trend Equations
WD- Y= 9.90+0.087X
LG-Y=4.24-0.083X

- Rainy Season ranks I with more WD (varying from 19.18 to 21.22 hundred million cubic meters) with less LG (that varies from 9.42 to 0.068 hundred million units) –Good Monsoon rainfall.
- Summer season ranks II with less WD (varying from 17.68 to 19.63 hundred million cubic meters with more LG (that varies from 9.65 to 0.17 hundred million cubic meters) ---Dearth of water.

- Post Monsoon Season ranks III with moderate WD (varying from 12.31 to 13.65 hundred million cubic meters) with moderate LG (that varies from 4.05 to -0.0447 hundred million units)
- Winter Season ranks IV with moderate WD (varying from 5.2 to 8.4 hundred million cubic meters) with moderate LG (that varies from 5.2 to 0.0054 hundred million units)

  - The whole crux of the summary explicitly drives out the core fact that Nagarjuna Sagar Main Power House, Nagarjuna Sagar Left Canal Power House, Srisailam Right Canal Power House and Upper Sileru Hydel Power Station for the period 2001-2002 to 2008-09 exhibited different patterns of water withdrawals and loss of generation and their future projections also varied from each other.
  - The Srisailam Left Canal Power House, Nagarjuna Sagar Right Canal power House and Lower Sileru Hydel power Station exhibited similar pattern of water withdrawals and loss of generation for the period of 2000-2001 to 2008-2009 and future projections also exhibited the same results.
  - The thumb rule of encompassing more water withdrawals was evidently in the back seat for summer, post monsoon seasons except in rainy season that recorded more WD's and for some power houses winter season recorded more water withdrawals.

Case of Thermal Power Plants: Water Withdrawals and Loss of Generation

Kothagudaem Thermal Power Station O &M: 2003-04 to 2008-09
(Appendix table: 6.8)

For a period of seven years, the four quarter wise results after application of seasonal variation index indicate that

- Summer Season with water temperature of 38^0 C ranks I , that recorded less water withdrawals in comparison with rainy , moderately high loss of generation

  - Less WD- with an index of 137.67
    Moderately high LG- with an index of 105.67
- Rainy Season with water temperature of 32^0 C to 34 ^{0} C ranks II with more water withdrawals and high loss of generation.

  - More WD-with an index of 152.37
    High LG- with an index of 153.75
- Winter Season with water temperature of 27^0 C to 32 ^{0} C ranks III with moderate water withdrawals and moderate loss of generation.

  - Moderate WD- with an index of 65.33

Moderate LG with an index of 79.33

- Post Monsoon season with water temperature of 31 ^{0} C ranks IV with moderate water withdrawals and moderate loss of generation.
  - Moderate WD- with an index of 62.73
    Moderate LG with an index of 59.5

Future Projections: 2009-2010 to 2013-2014
Trend Equations
WD- Y=1.97-0.09X
LG-Y=1.7+0.15X

- Post Monsoon Season ranks I with more negative WD (varying from -0.69 to -1.27 hundred million cubic meters with very moderate LG (that varies from 3.5 to 4.92 thousand million units)
- Winter Season ranks II with more negative WD (varying from -0.3 to -0.2 hundred million cubic meters with moderate loss of generation (that varies from 4.56 to 6.46 thousand MU)
- Summer and Rainy Season ranks III and IV: moderate negative WDs with very high loss of Generation.

Kothagudaem Thermal power plant- Stage V: 2001-02 to 2008-09
(Appendix Table: 6.9)

- Rainy Season with water temperature of 32^0 C to 34 ^{0} C ranks I with more water withdrawals and high loss of generation.
  - More WD-with an index of 135.67
    High LG- with an index of 141.33
- Summer Season with water temperature of 38^0 C ranks II , that recorded more water withdrawals with very slightest variation of decrease (though in comparison with rainy) , moderately high loss of generation (with slightest variation of decrease)
  - More WD- with an index of 129.33
    High LG- with an index of 112
- Winter Season with water temperature of 27^0 C to 32 ^{0} C ranks III with moderate water withdrawals and moderate loss of generation.
  - Moderate WD- with an index of 64.67
    Moderate LG with an index of 84
- Post Monsoon season with water temperature of 31 ^{0} C ranks IV with moderate water withdrawals and moderate loss of generation.
  - Moderate WD- with an index of 77.33
    Moderate LG with an index of 60.67

Future Projections: 2009-2010 to 2013-2014

Trend Equations
WD- Y=5.94-0.01X
LG-Y=14.33 +0.45 X

- Rainy season ranks I with more water withdrawals (varying from 7.4 to 7.57 hundred million cubic meters) and more LG that varies from 42.15 to 52.32 MU
- Summer season ranks II with more water withdrawals (varying from 7.2 to 7.53 hundred million cubic meters) and more LG that varies from 33.05 to 27.79 MU
- Post monsoon season ranks III with moderate water withdrawals (varying from 4.2 to 4.33 hundred million cubic meters) and moderate LG that varies from 18.52 to 22.89 MU
- Winter season ranks IV with moderate water withdrawals (varying from 3.6 to 3.17 hundred million cubic meters) and moderate LG that varies from 4.65 to 29.8 MU

NarlaTata Rao Thermal Power Station: 2003-04 to 2008-09

(Appendix Table: 6.10)

- Rainy Season with water temperature of 31^0 C to 34 ^{0} C ranks I with more water withdrawals and high loss of generation.
  - More WD – with an index of 119.33
    More LG- with an index of 152.33
- Summer Season with water temperature of 38^0 C ranks II , that recorded more water withdrawals and moderately high loss of generation (with slightest variation of decrease)
  - More WD –with an index of 119.33
    More LG- with an index of 107
- Winter Season with water temperature of 27^0 C ranks II with moderate water withdrawals and moderate loss of generation.
  - Moderate WD- with an index of 60.67
    Moderate LG- with an index of 98
- Post monsoon Season with water temperature of 31^0 C ranks II with moderate water withdrawals and moderate loss of generation.
  - Moderate WD- with an index of 60.67
    Moderate LG with an index of 40.67

Future Projections: 2009-2010 to 2013-2014
Trend Equations
WD- y = 24 - 0.33 x
LG- y = 65.0 – 0.12 x

- Summer season ranks I with more WD (varying from 18.58 to 12.27 hundred million cubic meters with more LG (that varies from 66.17 to 64.16 hundred MU)

- Rainy season ranks II with more WD (varying from 18.2 to 11.89 hundred million cubic meters) with more LG (that varies from 94.21 to 91.28 hundred MU)
- Winter season ranks III with moderate WD (varying from 9.13 to 5.93 hundred million cubic meters with more LG (that varies from 60.53 to 57.94 hundred MU)
- Post Monsoon season ranks II with moderate WD (varying from 8.95 to 5.73 hundred million cubic meters with moderate LG (that varies from 25.07 to 24.28 hundred MU)

Rayalaseema Thermal Power Plant: 2005-06 to 2008-09
(Appendix Table: 6.11)

- Summer Season with water temperature of 37^0 C ranks I with more water withdrawals and high loss of generation.
  - More WD- with an index of 123.33
    More LG- with an index of 109.67
- Rainy season with water temperature 31^0 C to 33 ^{0} C of ranks II with more water withdrawals and high loss of generation.

  - More WD- with an index of 119.33
    More LG with an index of 162

- Winter season with water temperature 28^0 C to 30 ^{0} C of ranks III with moderate water withdrawals and moderate loss of generation.

  - Moderate WD- with an index of 82.67
    Moderate LG with an index of 85.33

- Post monsoon season with water temperature 31 ^{0} C of ranks IV with moderate water withdrawals and moderate loss of generation.
  - Moderate WD-with an index of 74.67
    Moderate LG- with an index of 42

Future Projections: 2009-2010 to 2013-2014
Trend Equations
WD- y = 2.1 + 0.27 x
LG- y = 4.09 - 0.19 x

- Rainy season ranks I with more WD (varying from 8.5 to 32.48 hundred million cubic meters) with negative values of LG (that varies from 0.95 to -2.73 MU) – Poor quality of water and shortage of quality water.
- Summer season ranks II with more WD (varying from 8.46 to 15.2 hundred million cubic meters) with negative values of LG (that varies from 0.75 to -2.53 MU) – Poor quality of water and shortage of quality water.

- Winter season ranks III with moderate WD (varying from 5.94 to 6.21 hundred million cubic meters) with negative values of LG (that varies from 0.38 to-2.13 MU)—Shortage of quality water.
- Post monsoon season with moderate WD (varying from 5.6 to 7.03 hundred million cubic meters) with negative values of LG (that varies from 0.107 to-1.13 MU)—Shortage of quality water.

The major findings of these thermal plants can be enlisted as follows

- KTPS O&M faced Less Water withdrawals and More Loss of Generation –in summer.---poor quality of water
- More water withdrawals and high loss of generation– in rainy—Dearth of quality water.
- Moderate Water WD's and moderate Loss of generation- Winter and post monsoon season.---Dearth of water
- Future projections also indicated similar pattern.

- All power stations (i.e. KTPS V, RTPP and NTTPS) with the application of SVI exhibited similar pattern.
- More Water withdrawals and high Loss of generation in summer and rainy---Due to insufficiency of water and poor quality
- Moderate water withdrawals and moderate loss of generation in winter and post monsoon season---Dearth of water
- Future projections also exhibited the similar trends
- All the thermal power stations exhibited varying levels of plant load factor depending upon the increase or decrease in water withdrawals.

The thumb rule of encompassing lower water withdrawals in thermal power plants as a sign water efficiency has been ruled out to maximum extent in selected power plants due to drawls of more water due to rise in water temperature especially during summer and also in other season was quite evident except in few power plants.

V

7.0 Performance Evaluation of Cooling towers in selected power plants

Cooling Towers are a very important part of power plants. Cooling towers are designed to provide intimate air/water contact. The steam based thermal power plants are requiring the steam to be condensate to return to the boiler in a liquid phase i.e. water. The process of condensation entails heat rejection from the working fluid, the steam. The heat rejection process needs supply of cold water to the condenser. Usually this cold water is supplied from continuous water resources such as rivers, ponds, sea water. This kind of water supplied to the condenser is cold. In case of shortage of the cold water supply for any reason, e.g. Due to erratic seasonal monsoons in summer season, the cooling towers mechanism installation is preferred. It works as a heat sink for turbine. The primary objective of these cooling towers is to reject heat to atmosphere. They symbolize a relatively dependable means of removing low-grade heat from cooling water. Most of the heat losses occur in cooling tower, in the form of evaporation losses. The make up water source is used to replenish water lost to evaporation. Hot water from heat exchangers is sent to the cooling tower. The water exits the cooling tower and is sent back to the exchangers or to other units for further cooling. Hence the efficiency of cooling water system is vital to maintain the over all efficiency of power plant.

The cooling tower system comprises of natural draft and Induced draft. Natural draft towers employ large concrete chimneys to introduce air through the media. Due to very big size of these towers, they are usually used for water flow rates above 45000 m^3/hr. The induced draft cooling towers utilize large fans to force or suck air through circulated water. In this the water falls down ward over fill surfaces, which helps to increase contact time between water and air. This helps to maximize heat transfer between two.

The induced draft includes open loop and closed loop systems, where in the open loop possess with two types of mechanisms that is once through and recirculating. The recirculating mechanism in turn includes cross flow and counter flow types. In counter flow, the hot water enters at the top while the air is introduced at the bottom and exits at the top. Forced induced draft fans are used. In cross flow, water enters at the top and passes over the fill. The air is introduced at either on one side or opposite side. Induced draft fans are used. It is important to demarcate the potential merits and demerits of these two types of cooling tower mechanisms that is natural draft and mechanical draft, by conducting a performance evaluation keeping in view the of water shortage in different power stations across selected regions of Andhra Pradesh, that are very essential for this paper.

The respective cooling towers of Narla Tata Rao Thermal Power station in Coastal region are of Induced Draft counter flow with a fill. Where as Kothagudem Thermal power station in Telangana region and Rayalaseema Thermal Power station in Rayalaseema region are considered, the cooling towers are of Natural Drafts type.

In Narla Tata Rao Thermal Power station and Biomass power plants (My Home Power Limited, Sri Rayalaseema Green Energy Limited and Satyakala Biomass Power plant, induced draft cooling towers were in existence, with the facility of open recirculating type of cooling system in NTTPs. Big power plants like NTTPs use this system, where there is limitation of water especially during lean seasons. In this system, one more technical system that is cooling tower is added by mounting up more problem efficiency to the entire cooling system. This in turn depends upon the performance of cooling towers. The advantage of this system, is differential temperature can be achieved higher in comparison with once through system of cooling. Therefore minimum quantity of water is required for cooling. The biggest demerit of this system involves washing of atmospheric air with circulating water. Air constitutes number of contaminants that intensify all types of problem of biological fouling. Cycle of concentration of salts and floating materials contamination takes place. High CoC increases scaling and corrosion problem.

Nevertheless, open recirculating cooling system in ACWs, are inherently prone to multifaceted problems than once through systems. They can be listed as follows:

i) Cooling by evaporation intensifies the dissolved solids concentration in the water, raising corrosion and deposition propensities. This problem is further aggravated by higher temperatures.
ii) The longer withholding of warmer water in open recirculating system increases the biological species growth.
iii) Airborne gases such as sulphur di oxide, ammonia or hydrogen sulphide can be absorbed from the air, causing high corrosion rates.

7.1 Performance evaluation of cooling towers (Induced Draft) in Narla Tata Rao Thermal Power Station

As per Bureau of Energy Efficiency [6] there are eight important parameters from the point of assessing the performance of cooling towers. They can be elaborated as follows

- **Range:** It is the difference between the cooling tower water inlet and outlet temperature.
- **Approach:** It is the difference between the cooling tower outlet cold water temperature and ambient wet bulb temperature. Of these two, approach is considered as best indicator of cooling tower performance.
- **Cooling tower effectiveness (in percentage)** is the ratio of range, to the ideal range. That is the difference between cooling water inlet temperature and ambient wet bulb temperature.
- **Cooling Capacity:** It is defined as the heat rejected in Kcal/hr , given as product of mass flow rate of water, specific heat and temperature difference.
- **Evaporation loss** is the water quantity evaporated for cooling duty and theoretically for every 10, 00,000 Kcal heat rejected, evaporation quantity by default is taken as 1.8 m^{3}.

  Empirically it can be represented as:

  $$\text{M3/hr, Evaporation loss} = \frac{\text{Circulation rate } (m^3/hr) * \text{Temperature in } {}^0C}{675}$$

- **Cycles of Concentration:** It is defined as ratio of dissolved solids in circulating water of the dissolved solids in make up water.

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[6] It is an agency of the Government of India, under the Ministry of power created in March 2002 under the provisions of the nation's 2001 Energy Conservation Act. The agency's function is to develop programs which will increase the conservation and efficient use of energy in India

- **Blow down losses** are other important for determining the performance of cooling tower. It depends upon cycles of concentration and evaporation losses and is represented as

  $$\text{Blow down} = \frac{\text{Evaporation loss}}{\text{COC-1}}$$

- **Liquid/gas ratio** of a cooling tower: It is defined as the ratio between water and the air mass flow rates. Against design values, seasonal variation on water availability requires adjustment and tuning of water and air flow rates in order to get the best of cooling tower effectiveness. Thermodynamics also indicates that the heat removed from water must be equal to the heat absorbed by the surrounding air:

  $$L\,(T_1-T_2) = G(h_2-h_1)$$

  $$\frac{L}{G} = \frac{h_2-h_1}{T_1-T_2}$$

Where, L/G = Liquid to gas mass flow ratio (Kg/Kg)

T_1 = Hot water Temperature ^0C

T_2 = Cold water Temperature ^0C

h_2 = enthalpy of air-water vapor mixture at exhaust wet bulb temperature

h_1 = enthalpy of air-water vapor mixture at inlet wet bulb temperature

The other factors affecting cooling tower performance are:

For exclusive understanding of CT performance, heat dissipation and circulated flow rate m^3/hr are not only sufficient. Capacity is also another factor that plays a key role. As a common phenomenon, the closer the approach to the wet bulb, the more costly the cooling tower due to increased size. Usually, a 2.8 ^0C approach to the design wet bulb is the coldest water temperature that the manufacturers guarantee. In order of preference, the ranking order should be flow rate, range, approach and wet bulb.

Heat Load: The heat load put on cooling tower is assessed by the process being served. The degree of cooling required is monitored by the desired operating temperature level of the process. In many cases, low operating temperature is desirable to increase process efficiency to enhance the quantity and quality of production.

Wet Bulb Temperature: It is another main factor responsible for monitoring the performance of evaporative water cooling equipment. From the view point of minimum cold water temperature to which water can be cooled by evaporative method, should also be monitored. Hence the wet bulb temperature of the air entering the cooling tower finds out operating temperature levels through out the process.

Theoretically, a cooling tower will cool water to the entering wet bulb temperature, when operating with out heat load. However a thermal potential is necessary to reject heat, so it is not possible to cool water to the entering air wet bulb temperature, when a heat load is applied. The main aspect of wet bulb selection is whether it is ambient or inlet. The ambient wet bulb is the temperature, which exists generally in the cooling tower area, where as inlet wet bulb is the wet bulb temperature of the air entering the tower. The later can be very much affected by the discharge vapors being recirculated in to the tower. Recirculation increases the effective wet bulb temperature of the air entering the tower with corresponding increase in the cold water temperature.

Narla Tata Rao Thermal Power plant

The finding of one typical trial concerning to the cooling towers of NTPPS 6x 210 MW is given below:

Observations

1) Unit load of the power station	1260 MW
2) Mains Frequency	23.3
3) Inlet cooling water Temperature ^{0}C	42.09 ^{0} C (Designed 41^{0}C)
4) Outlet Cooling Tower water Temperature ^{0}C	34.37 ^{0} C (Designed 32.50 ^{0} C)
5) Air wet bulb Temperature near cell ^{0}C	24.58 ^{0} C (28.2 ^{0} C)
6) Air dry bulb temperature near CT cell	34.60 ^{0} C (37.15 ^{0} C)
7) No: of CT Cells on line with water flow	12
8) Total measured cooling water flow m^3/hr	39637.50
9) Measured CT fan flow m^3/hr	589544

Analysis

- CT Flow/Cell, m^3/hr — 3303.12 (Rated 2750)
- CT Fan Flow, m^3/hr (Avg) — 589544
- $L (T_1 - T_2) = G(h_2 - h_1)$

$$\frac{L}{G} = \frac{h_2 - h_1}{T_1 - T_2}$$

$$= \frac{40.82 - 22.70}{42.09 - 34.37} = \frac{18.12}{7.72}$$ 2.3 (Rated 0.38)

- CT Range — 7.72 ^{0} C (Rated 8.5 ^{0} C)
- CT Approach — 5.17 ^{0} C (Rated 4.5^0 C)
- % CT Effectiveness (100* (Range / Range + Approach)
  = 100(7.72)/(7.72 + 5.17) = 59.89
  - Rated % CT Effectiveness = (100* 8.5/ (8.5+ 4.5) = 65.38
  - Cooling Duty handled /Cell in Kcal = 3303*7.72*10^3
    = 25499.16*10^3 (Rated 23375*10^3 Kcal/hr)

Evaporation losses in m^3/hr = $\frac{\text{Circulation rate (m}^3\text{/hr)* Temperature in }^0\text{C}}{675}$

= $\frac{3303.12 \times 7.72}{675}$ = 37.78 = 37.78 m^3 /hr per cell

- Percentage Evaporation loss = 37.78 /3303 *100 = 1.14 percent
- Blow down requirement for site COC of 2.7 = Evaporation loss/COC -1

  = 37.78/2.7-1

  = 37.78/1.7 = 22.22 m^3/hr

  - Make up water requirement /Cell in m^3 /hr = Evaporation loss + Blow Down loss

    = 37.78 + 22.22 = 60

Comments

- The actual percentage of cooling tower effectiveness is 58.89 percent whereas the designed percentage should be 65.38 percent.
- Algae growth found in cooling tower cells.
- The operating CT range is 7.72 ^{0}C , where as the design one was 8.5 ^{0} C.

Kothagudaem Thermal Power Station (KTPS) - Stage V

The findings of KTPS Stage v for 2 x 250 MW is provided as follows

Observations/ Technical parameters

Type of Cooling towers	Natural Draught cooling
Unit load of the station	2 x 250 = 500 MW
Design Capacity per tower	37,500 m^3 per hour
Type /quantity /Hyperbolic	: PVC fills, counter flow
Hot water inlet cooling tower water temperature	: 46^0 C (Rated 42^0 C)
Out let cooling temperature	: 35 ^{0} C (Rated 33^0 C)
Ambient wet bulb temperature	: 28 ^{0} C (Rated 28 ^{0} C)
Dry bulb Temperature	: 37^0 C (Rated 39 ^{0} C)
Relative humidity	: 50 ^{0} C
Diameter at sill level	: 99.10 m
Diameter at top	: 5907 m
Diameter at throat s	: 55.44 m
Tower height above sill	: 8910 m
Height up to bottom of fill above sill	: 6.30 m
Water trough top level above sill	: 9.15 m
Fill Material	: PVC
Fill Depth	: 1.20
Fill Volume	: 7440 m^3
Water basin Capacity	: 23199 m^3

Analysis

CT Range	: 11^0 C
CT Approach	: 5 ^{0} C
Humidity	: 50 percent
Depression: Dry bulb- Wet bulb =	39-28 = 11^{0}C
Percentage CT Effectiveness	: (100* (Range/Range + Approach)

= 100(11 /11+5) = 100 (11/16) = 100 x 0.6875 = 68.75 percent

Percentage Rated CT Effectiveness = (100* (9/9+5) = 100x 0.64285 = 64.28 percent

Evaporation losses = Condenser Capacity x % of evaporation

Evaporation losses - Rainy Season: 1.5 percent
Winter Season: 1 percent
Summer Season: 2.5 percent

Rainy = 32370 x 1.5% x 24 hrs = 11653.2 m^3/hr
Winter = 32370x 1%x 24 hrs = 7768.8 m3 /hr
Summer = 32370 x 2.5 % x 24 hrs= 19422 m3 /hr

Comments

- The actual percentage of cooling tower performance that stood at 68.75 is seemingly good in comparison with rated percentage that stood at 64.28 percent.
- The evaporation losses are high during summer, medium during rainy and lower during winter.
- The depression varies to the level of 11 ^{0}C.

Rayalaseema Thermal Power Station (RTPP)- Stage II

The findings of RTPP Stage II cooling towers for 2 x 210 MW is given as follows

Observations/ Technical Parameters

Type of Cooling	: Natural tower Draught Hyperbolic
Unit Load of the Station	: 420 MW
Design capacity per tower	: 37500 m^3/hr
Type of air flow	: Counter Flow
Inlet cooling tower water temperature	: 45 ^{0} C (Designed 43 ^{0} C)
Outlet Cooling tower water temperature	: 35 ^{0} C (Designed 33 ^{0} C)
Design Approach	: 5.8 ^{0} C
Cooling range	: 10 ^{0} C
Ambient Wet Bulb Temperature	: 25 ^{0} C (Designed 27.2^0 C)
Dry Bulb Temperature	: 36 ^{0} C
Relative Humidity	: 40 percent
Diameter at foundation Center line	: 108.054 mtrs
Diameter at sill level center line	: 105.500 mtrs
Diameter at throat level center line	: 61.200 mtrs
Diameter at top of cooling tower Center line	: 63.200 mtrs
Height of the tower	: p + 126.75 mtr

Analysis

CT Range	: 10^0 C
CT Approach	: 10^0 C
Humidity	: 42 percent
Depression	: Dry bulb temperature – Wet Bulb Temperature = 11^0 C

% CT Effectiveness = (100 * (Range /Range + Approach)

= 100 (10/10+10) = 100 (10/20) = 100 x 0.50 = 50 percent

% Rated CT Effectiveness = 100 (10/10+8) = 100 x 0.56 = 56 percent
Evaporation losses = Condenser Capacity x % of evaporation
Rainy Season – 1.5%
Winter Season- 1%
Summer Season- 2%
Rainy Season= 28900 x 0.015 x 24 hrs = 10404 m^3/hr
Winter Season = 28900 x 0.01x 24 hrs = 6936 m^3/hr
Summer Season = 28900x 0.02x 24 hrs = 13872 m^3/hr

Comments

- The actual percentage of CT effectiveness is 50 percent where as the designed percentage should be 56 percent.
- The evaporation losses are high during summer season, medium during rainy season and lower during winter season.
- The depression varies to the level of 11^0 C.

My Home Power Limited (Biomass Power Plant)

Observations/Technical Parameters

Unit Load	: 9 MW
Main Frequency	: 1
Inlet cooling water Temperature	: 42 ^{0}C (Designed 44.8 ^{0}C)
Cooling water temperature	: 30 ^{0}C(Designed 31 ^{0}C)
Air wet bulb Temperature	: 24.4 ^{0}C (Designed 28.4 ^{0}C)
Air dry bulb temperature	: 34 ^{0}C (Designed 36.5 ^{0}C)
No: of CT cells on line with water flow	: 6
Total measured cooling water flow	: 2568 m3/hr
Measured CT fan flow	: 43457 m^3/hr

Analysis

CT Flow Cell : 428 m^3/hr
CT Fan Flow : 43457 m^3/hr
L/G ratio of CT Kg/Kg $= \frac{h_2 - h_1}{T_1 - T_2}$

$= \frac{40-24.4}{42-30}$

= 15.6/12 = 1.3

CT Range 42-30 = 12^0C (13.3 ^{0}C)
CT Approach : 30-24.4 = 5.6 ^{0}C (3.1 ^{0}C)
% CT effectiveness = 100 (12/ (12 +5.6) = 100 (12/17.6)
= 100 x 0.682 = 68.18

Rated % CT Effectiveness = 100 (13.3/16.4) = 100 x 0.811 = 81.09
Cooling duty handled /cell in Kcal = 428* 12* 10^3 = 5136* 10^3
(Rated 527172*10^3)
Evaporation losses in m^3/hr = 428 x 12 / 675 = 7.61 m^3/hr per cell

Percentage Evaporation loss = 7.61/428 *100 =1.78 percent

Blow down requirement for site Coc of 2.7 = Evaporation losses /Coc-1
= 7.61/2.7 -1
= 7.61/1.7 = 4.48 m^3/hr
Make Up water requirement per cell in m^3/hr = 7.61+ 4.48 = 12.09

Comments

- The actual percentage of cooling tower performance that is 68.18 percent is much less in comparison with rated percentage that stood at 81.09 percent.
- Algae growth is present in the cooling tower cells.
- The operating CT range and CT approach are less than the designed one's.

Sri Rayalaseema Green Energy Limited (Biomass Power Plant)

The findings of Green Energy Limited Biomass power plant are mentioned as follows:

Observations/Technical Parameters

Type of Cooling Towers : Induced draught counter flow
Unit Load of the Station : 5.5 MW
Quantity /Type : MM Aqua film flow fills
No: of Cells : Two
Cell size filled volume : 43.16 m3
Type of fill splash /film/others : Film Flow fill
Total height of Fill material in each cell : 0.9
Film Volume : 48.16 m3/cell
Hot Water inlet water temperature : 44 ^{0}C (Designed 42 ^{0}C)
Outlet water temperature : 35 ^{0}C (Designed 32 ^{0}C)
Design Wet Bulb Temperature : 25 ^{0}C (Designed 28 ^{0}C)
Total Measured rated capacity at design temperature: 1500 m3/hr
Water flow rate per cell : 750 m3/hr
Recommended blow down : 12.3 m3/hr
Measured CT Fan Flow : 529716 m3/hr

Analysis

CT Flow Cell , m^3/hr : 58.24 ^{0}C (Rated 48.16)
L/G : 1.33 (Rated 0.25)
CT Range : 5^{0} C (Rated 10 ^{0} C)
CT Approach : 10 ^{0} C (Rated 4 ^{0} C)

% of CT effectiveness : 100 (Range/Range + Approach)
= 100 (5/5+10) = 10(5/15) = 100(0.33) =33.33

Rated % of CT Effectiveness = (100*(10/10+4) = 100(10/14)
= 100 x 0.714 = 71.4

Cooling duty handled /cell in K cal = 58.24 $*10^3$ = 29.12
(Rated 48.16 * 10^3) Kcal/hr

Evaporation losses : 0.43 m^3/hr per cell

Or $\frac{\text{Circulation rate } m^3/\text{hr. Temperature Difference } {}^0C}{675}$

$= \frac{58.24 \times 5}{675}$

= 0.43 m^3/hr per cell

Percentage Evaporation loss = 0.43/58.24 x 100 = 0.74 percent

Blow down Requirement for site CoC of 2.7 percent = 0.43/2.7 -1 = 0.25 m^3/hr

Make up water requirement in m^3/hr = Evaporation loss + Blow down loss
= 0.43 + 0.25 = 0.68

Comments

- The actual percentage of cooling towers effectiveness is much lower that is 33.33 in comparison with rated CT effectiveness ie.71.4 percent
- The operating CT Range is 5^0 C where as the rated one is 10 ^{0}C

The following are the distinctive problems faced by cooling towers (Natural draft and Induced Draft)

Problem	Factors responsible for problem	Counteracting measures
Unwarranted Electrical Load	a) Voltage Reduction b) Inaccurate angle of axial fan blades c) Over filling owing to excessive air flow fill has minimum water loading per m^2 of tower section. d) Low ambient air temperature	a) Test the Voltage b) Adjust the blade angle c) Standardize the water flow by means of valve d) The motor is cooled proportionately and hence distributed more than name plate over.
Carry over of water outside the unit	a) Blockage of the fill pack b) Over loading of circulating water	a) To eradicate any dirt in the top of the fill. b) Adjust the water flow rate by means of

	flow	regulating valves
Loss of water from basins	a) Float value not at correct level b) Being deficient in having equalizing connections	a) Regulate the make-up valve b) Equalize the basins of towers operating in parallel
Lack of cooling and therefore increase in temperature's owing to increased temperature range	a)Irregular air flow or lack of air b) Intake of hot air from other sources.	a) Check the direction of rotation of the fans. b) Install deflectors.

The reasons for disruptive performance of cooling towers are as follows:

- The factors affecting corrosion are of two types. One is chemical and other is physical. The chemical constitutes PH, dissolved solids, gases, suspended solids, micro organisms and physical area includes temperature velocity, heat transfer and metallurgy.
- Problems caused by deposition are blocked exchanger tubes and reduced water flow, reduced heat transfer, increased corrosion, shortened equipment life and generation loss.
- Factors causing biofilm growth are water temperature, PH and nutrients.

In this context, it can be rightly remarked that the chemical analysis of cooling water is of urgent necessity. These include

- Adherence to strict maintenance of chemical dosages
- Strict PH control, FRC within specified limit
- COC control at specified range and maintenance of recommended limits of water parameters.

Therefore, the assessment of cooling towers in selected power stations clearly indicates that, technology was not able to counteract the water shortage problem in the respective power stations. This water shortage problem was further exacerbated that was explicitly dealt with in the succeeding sections.

VI

8.0 Water Efficiency Management in Selected Power Stations of Andhra Pradesh

CASE STUDY 1: Narla Tata Rao Thermal Power Station (NTTPS): Alternative Cooling Water System with River and Hot Water Pump Houses

The main source of water for carrying out the operations of NTTPS is River Krishna at Vijayawada. For the full-fledged requirement of cooling water for 6 units of NTTPS, the Krishna river level (pond level) should be maintained at 17.2 meters. But keeping in view of water shortage due to fast depletion of pond level in prakasam barrage to the crest level during summer season, two major points need to be considered.

(i) The crest level of the barrage is equal to 45.05 feet (13.7 meters) which is lower than the crest level of the Cooling Water (CW) intake (14.34 meters). As a result, when the pond water level is lowered to the crest level in the Prakasam Barrage, water would not flow with the required gravitational force in to the Cooling water canal of the NTTPS.

(ii) In general practice, hot return water from the VTPS is discharged in to the river Krishna at the confluence of Budameru Diversion Channel. (BDC) The starting point of the CW intake is near the Barrage, which is on the downstream side of the BDC confluence point. Usually the water spread in the river Krishna between the BDC confluence and the CW intake corresponding to the present pond level conditions (i.e. 17.39) is sufficient to cool hot return water from all six units of the VTPS. But, lowering of water level in the Prakasam Barrage resulted in the decrease of cooling area available for minimizing the temperature of hot return water from the NTTPS.

In order to avert from this adverse situation, the best option chosen is "***Pumping of Required Water for Three units With Cooling Towers***". In this Option, the CW canal and BDC are used for managing both cold water and hot water. The currently available CW canal would be used for transporting the cold water from the river Krishna to NTTPS and the BDC would be utilized for returning the hot water from NTTPS to river Krishna. As the pond level in the Barrage is depleted to the crest level, the cooling area available between the BDC confluence and the Bhavanipuram (BVPM) regulator (CW intake) would be reduced to 644 hectares. This cooling area is sufficient to cool hot return water for three units of 210 MW each of the NTTPS. Hence, in this option cooling towers are installed for three units, while the remaining units will be operated as at present.

Table: 14 Practical Operational Mode of Induced Draft Cooling Towers

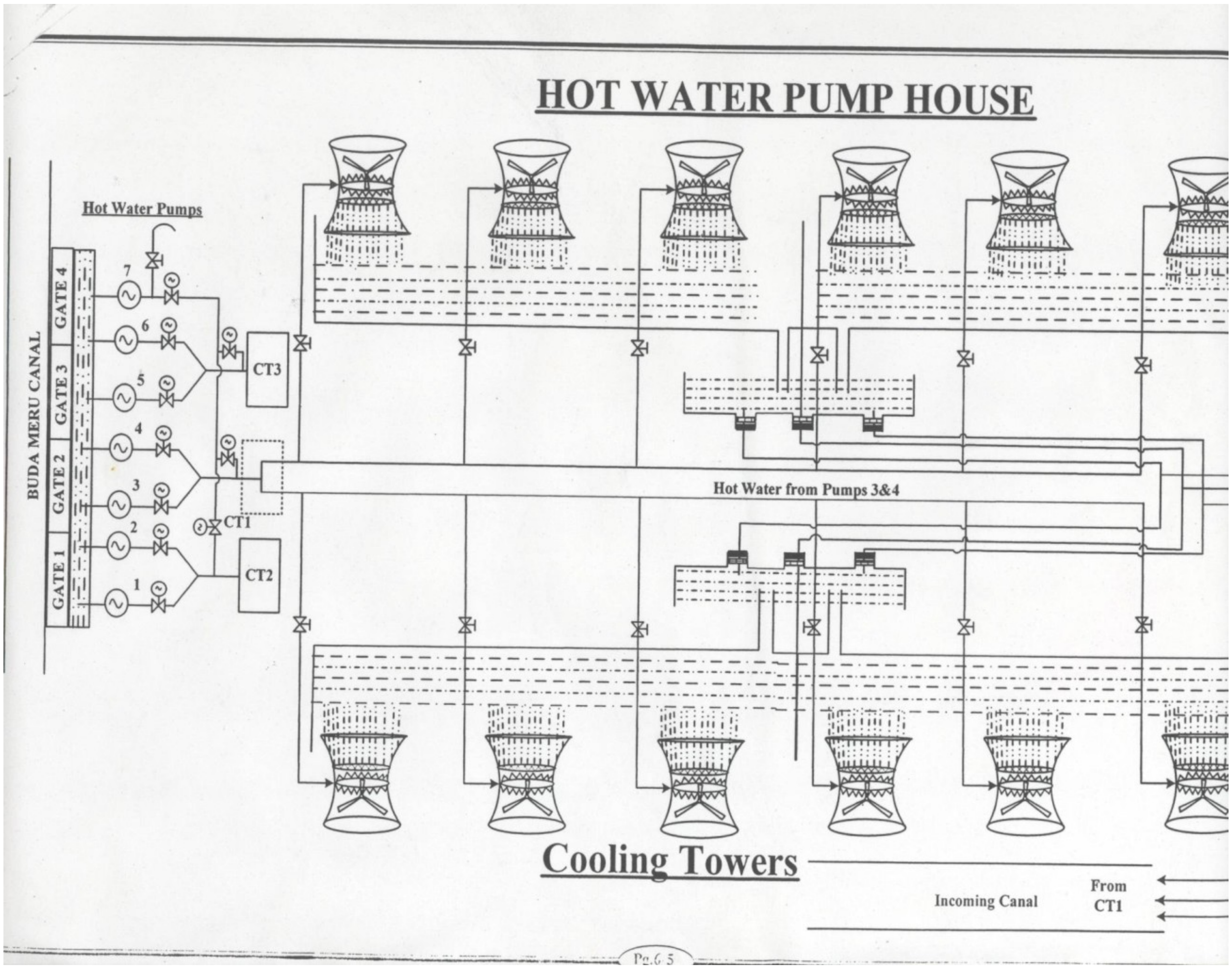
Year	Date/Month	River level Depletion/ Excess water Flow	Underlying Reasons
2004	2/May to 26/August	14.0 meters	Apron Inspection and repair works of Irrigation Department of Andhra Pradesh
2005	5/March to 24/ July	< 17.2 meters	Inspection of Apron after floods
2008 2008	18/ June to 26/June 1/September to 5/September	< 17.2 meters < 17.2 meters	 Low Fresh Water level in River Krishna

2009	29/August to 10/September	< 17.2 meters	Low Fresh water level in river due to opening of gates before flood water is reached.
2009	2/October to 3/November	<17.2 meters	Low Fresh Water level due to high discharges from Nagarjuna Sagar , sagardi and canal discharges (Irrigation)

From the table 14 it is clearly evident that the first depletion of river took place on 2-5-2004. The ACWs had been kept in service from 2-5-2004 to 26-8-2004. The river level was maintained at around 14.0 meters. All 70 gates of Prakasam Barrage were fully opened. Coffer dam was installed; in addition to this Apron inspection and smoothening of repair works at Prakasam Barrage for the purpose of irrigation, was carried out by the Irrigation Department of Government of Andhra Pradesh. The second depletion occurred on 5-3-2005 after floods. The river level was very much below that of 17.2 meters. The inspection by Apron was carried forward and from 5-3-2005 to 24-7-2005, the ACWs were in vogue. During the period i.e. from 18-6-2008 to 26-6-2008 and 1-9-2008 to 5-9-2008, ACWSs were kept in use as fresh water level was maintained as low as 1.7.2 meters. Similarly, same is the situation for the period between 29-8-2009 to 10-9-2009. However during the period from 2-10-2009 to 3-11-2009, there was low fresh water level due to excessive inflow of water discharges from Nagarjuna Sagar and canal's discharge to the level of 18,330 cusec and 17,419 cusec. In addition to this, more water discharges from Sagardi and canal discharges (irrigation) to the quantity of 20,228 cusecs and 17,420 cusecs have put mounting pressures on the supply of fresh water.

From the view point of cost estimate also, this option of cooling towers is desirable, as they can be put in to practice in maximum possible way at least cost.

Schematic Representation of Hot Water Pump House



The Hot Water Pump House is outfitted with 7 Hot Water Pumps, 6 running and 1 standby. The pumps 1-2, 3-4, 5-6 are connected to the common headers 1, 2 and 3 2450 mm diameter. Pumps 1 and 2 connected to Cooling Tower -2. Pumps 3 and 4 connected to Cooling Tower-1. Pumps 5 and 6 connected to Cooling Tower-3. The 7 th pump is connected to the common headers through Butterfly Valves and can be connected to either Cooling Tower 1, 2 or 3.The discharge of water through Hot Water pumps is 17,250 M^3/Hr and the rated water pressure @discharge constitutes 2.3 Kg/Cm^2. The number of motors attached to hot water pumps is 7. The voltage supplied for motor operation in case of Hot water pumps is 6.6 KV, 50 Hz with a full load current of 164 Amps and the rated speed of the pump is 460 RPM. The 6.6 KV supply for running the Hot water pump house is availed from CWA and CWB of Stage I cooling water pump house (CW). CWA and CWB are fed from SA and SB Boards, which are station supplies from station transformer 1 and 2. In order to accommodate the additional load station transformer No. 5 is procured and commissioned.

The make up water required for another three units, that are not connected to cooling towers is 1100 cusecs. As a consequence, this much quantity of water is transported through CW canal from the Prakasam Barrage at BVPM. In view of the fact that, water cannot be drawn in to this canal by gravity during 45 days in summer due to lowering of pond level, pumps are used to lift water in to the CW canal. To facilitate, the entire mode of operation, a pump intake structure was constructed in the vicinity of the existing BVPM regulator.

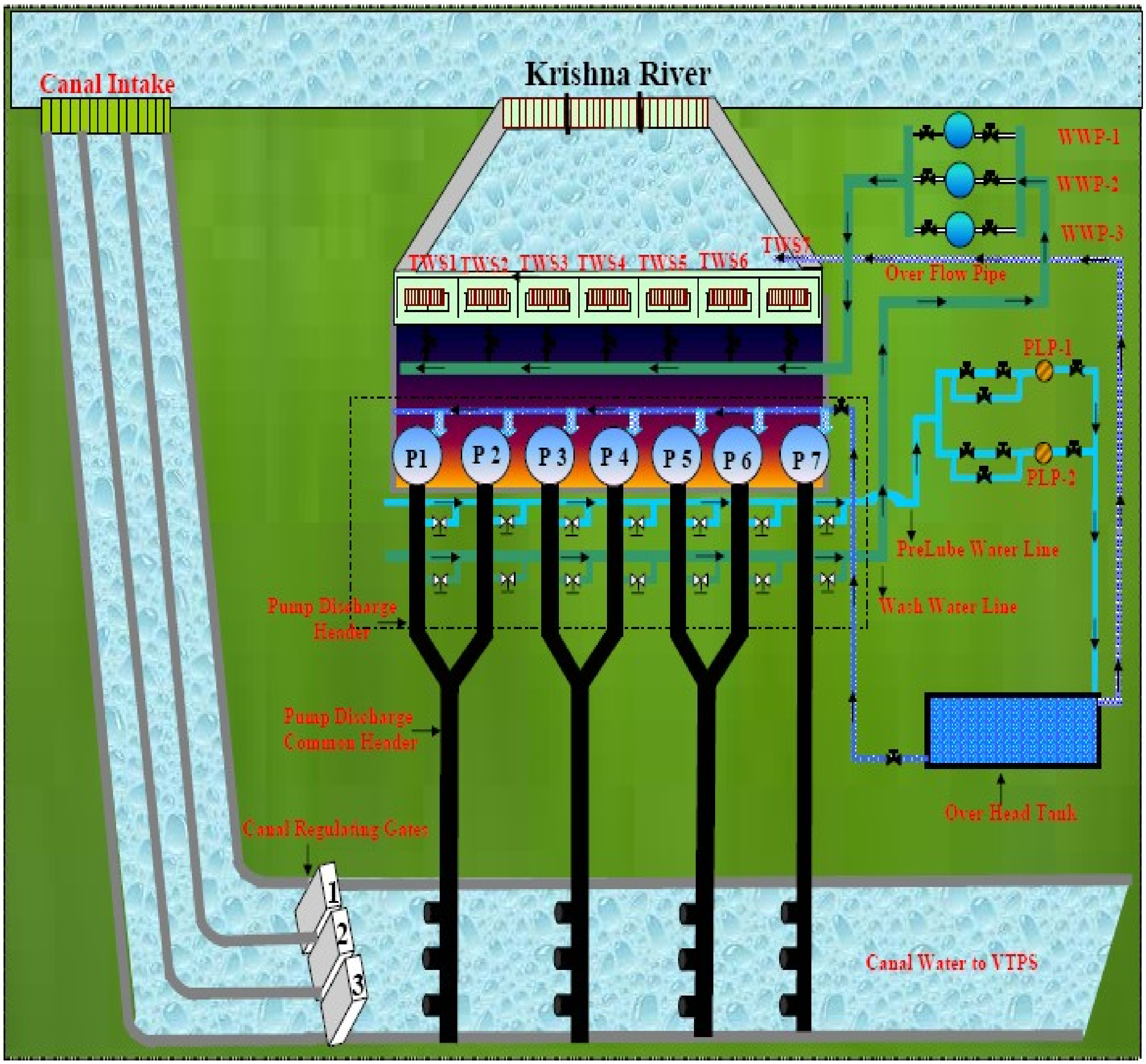
Finally, the major observation is that out of 365 days in a year, all the six units of NTTPS are functioning as they are now for 320 days of the year. During this period, the water can be drawn in to the CW canal by gravity because of available pond level at 17.39 meters. For the remaining days, i.e. for 45 days during summer there units are availing the facility of cooling towers. The type of cooling towers that used in NTTPS is induced draft. The pumping of 1100 cusecs of water in to CW canal is necessitated during this 45 day period.

The Alternate Cooling Water System (ACWs) at NTTPS was commissioned on 28-3- 2004. This system comprises of River Water Pump House and Hot Water Pump House.
The system consists of:

(a) 7 No's River water pumps located at River Water Pump House in Bhavanipuram (6 + 1 No's Pumps).
(b) 7 No's Hot water pumps located at Hot Water Pump House in NTTPS Campus (6 + 1 No's pumps)
(c) 3 No's Induced Draft counter flow cooling towers with a fill in NTTPS Campus. Each tower is having 12 numbers fans.

The figure depicts mainly the portrayal of River Krishna, canal intake (water drawn from river), canal regulating gates (Gates that regulate the flow of water) and there by through canal passes to NTTPS. The River Water Pump House is equipped with 7 River Water Pumps (vertical type), 6 running and 1 standby. All the pumps are provided with individual Travelling Water Screens. The pumps 1-2, 3-4, 5-6 are connected to the common headers 1, 2 and 3 2450 mm diameter. The 7 th pump is connected to individual header 1600diameter.The discharge of water through pumps is 20,875 cubic meter per hour and the rated water pressure at discharge is 0.065 Kg/Cm^2. The rated speed of the pumps per minute is 330RPM. The number of motors attached to pumps is 7. (Induction

Figure: 1 Schematic Representation of River Water Pump House



Type). The voltage supplied for motor operation is 6.6 Kilovolts, with a full load current of 115 Amps, rated speed is 330 RPM. The figure 3 depicts the 7 Travelling Water screens (TWS) that are entangled above water pumps, with a capacity of 23000M³/hr. The maximum screen speed is 3 meter/ minute and the voltage supplied for TWS motor is ~415V/3.7 KW. Adjacent to TWS, 3 wash water pumps are adjoined with a capacity of 415 V/45 KW. In order to have a reliable supply of power to water pumps at Bhavanipuram a 132 /6.6 KV substation is constructed. This kind of sub-station was commissioned in 14-9-2003.

In order to have a dedicated and reliable supply of power to Bhavanipuram substation 220/132 KV substation with 25 MVA Transformer is constructed duly extending the existing 220 KV Busbar-2. It was commissioned on 26-4-2004. The 132 KV Kondapally- Bhavanipuram line is made LILO at VTPS. Now the Bhavanipuram substation has three alternative supplies.

- Alternative 1: Dedicated radial feeding to Bhavanipuram through 25 MVA Transformer, which is fed from Busbar-2 of NTTPS.
- Alternative 2: From KONDAPALLI SS through 132 KV bus at NTTPS
- .Alternative 3: From VIJAYAWADA SS 132 KV directly to Bhavanipuram.

Regularly the supply is from NTPPS .For this the 132 KV NTPPS-KONDAPALLY Breaker is kept open at NTPPS and 132 KV Bhavanipuram-Vijayawada feeder breaker kept open at Bhavanipuram Station.

In case of emergency situations, the 220V DC (direct current) supply to the protection system, indications and DC emergency lighting is supplied with 60 Amp Charger with battery bank back up. Apart from this, there are two individual battery banks each 170 cells, 145 Ah, 1.2 V Ni-Cd cells. The two battery banks are provided with two battery chargers each capable of supplying both battery banks. A third charger is standby.

The running hour's details of river water pumps at river water pump house, Bhavanipuram for the months of April month for the year 2009 are as follows:

Table 15: Details of River water Pump (RWP) House: April Month running hours

Date	Pump	Running Time	Cumulative running (Hrs-Min)	Reasons
01-04-2009	RWP-7	3.50 Hr	5081.15	Fresh Water River level low
03-04-2009	RWP-6	3.55 Hr	6120.05	Fresh Water River level low
04-04-2009	RWP-6	18.10 Hr	6138.15	Fresh Water River level low
09-04-2009	RWP-5	0.50 Hr	5515.44	Fresh Water River level low
10-04-2009	RWP-4	10.25 Hr	5422.4	Fresh Water River level low
11-04-2009	RWP-4	5.00 Hr	5427.4	Fresh Water River level low

27-04-2009	RWP-2	1.00 Hr	5360.31	Trail Run
28-04-2009	RWP-3	1.00 Hr	5781.25	Trail Run
29-04-2009	RWP-1	1.00 Hr	5302.43	Trail Run

For the month of April the table 15 indicates the highest running hour is 18.10 hr for the River Water Pump No. 6 hr on 4-04-2009 due to low level of river. The lowest level of running hour was recorded i.e. 0.50 hr for the RWP-5 on 9- 4-2009. On 27-04-2009, 28-04-2009 and 29-04-2009, the RWP-2, 3 and 1 were run on a trail basis for one hour.

CASE STUDY: 2 Rayalaseema Thermal Power Plant (RTPP): Technological Break through for Fly Ash Disposal (High Concentration Slurry Disposal Pump)

In any thermal power plant fly ash disposal involves huge process where in we require large quantities of water. Generally, in RTPP for disposal of fly ash the ratio is in the form of 1:6. This means for disposal of 1 percent of fly ash, normally 6 percent of water is required. This at times mostly during lean seasons is leading to water shortage for core process of electricity generation. Under these circumstances, technology (GEHO) played a vital role, by bringing down the ratio to 1:0.7. The Ash Disposal System for RTPP stage II, unit 3 and unit 4 is to supply to the plant requirement of fly ash disposal in a high concentration slurry mix form (HCSD). The entire system consists of the following mechanism that involves the following stages

i) Fly Ash Silo Unloading System
ii) Silo Top Bag Filters
iii) Ash Conditioner Water (ACW) Pumps
iv) Agitated Mixing Tanks (ART)
v) Charge Pump System
vi) HCSD Pump System

Stage I: Fly Ash Silo Unloading System

One number fly ash silo unloading system is provided below each silo for feeding the fly ash to two independent Mixing tanks (ARTs). Each unloading system comprises of manual knife gate valve provided below the silo opening, cylinder operated knife gate valve endowed with manual knife gate valve, and VFD operated Rotary Vane Feeder, Solid Flow meter, Ash conditioner, Water line system for Ash Conditioner and bag filter with fan and plate valve at silo top. The water line system includes one number actuator operated valve with bypass arrangement at header; one number flow transmitter, two numbers branch isolation valves and direct water feed nozzles to the ash conditioner.

Stage II: Silo Top Bag Filters

One number bag filter is present on the top of each silo. In addition to this, one more bag filter with fan and plate valve is arranged on top of each silo for expelling of silo unloading system. Solid flow meter and Ash conditioner are both arranged with individual manual damper valves in their venting line connected to bag filter.

For automatic cleaning of bags, each bag filter is fitted with a timer unit. This unit helps in managing the washing out sequence of Bag Filters solenoids. Whenever power supply is fed to this timer unit, all the solenoids of the Bag filter unit start purging at fixed interval of time (say 30 seconds) one after the other for a fixed time (say 100 m sec). One number ON/ OFF selector switch is arranged for the Bag Filter. This again in turn is fitted with a suction fan to suck the dust from unloading equipment. This fan is continuously ON when the Silo Unloading system is running. To dump the entire ash dust in the bag filter back to the Silo, a cylinder operated plate valve is fitted below the bag filter unit. Fluidizing pads with instrument air connection are also provided. Plate valve is also opened up for 10 seconds at every 30 minute interval. As fluidizing solenoid is essential, it is switched ON 1 second before opening the plate valve and is turned off after 5 second.

Stage III: Ash Conditioner water (ACW) Pumps

In the ash water tank, three number of Ash Conditioner water pumps are installed. All these three pumps are connected to a common header. This water header is mainly used to feed water to water line to 2 nos. ash conditioners, make up water to 2 nos. ARTs, Seal water to 4 nos. charge pumps, inlet and outlet side of 3 nos. suction strainers and Hose pump /loop cleaning line to 2 no. ART loops. These three ACW pumps are provided with 1 no. manual valve at the suction side and 1 no. motorized valve at discharge side of the pump. One no. pressure switch and transmitter is also availed on a common discharge header of the ACW pumps.

Stage IV: Agitated Mixing Tanks (ART)

For preparation of ash slurry, two numbers ARTs are installed. Each ART is endowed with an agitator to facilitate proper mix of fly ash and water to arrive at the right concentration of the high concentration slurry for disposal. A make up water facility is also entailed to it, to allow sudden make up of water depending on the working / design condition of the system. To make certain that there is absolutely correct concentration of fly ash mix, a control loop of instrumentation is provided across ART. 1 No. Loop PLC panel is installed locally for putting together the controls of loop items of each loop. This PLC further communicates with the main PLC system for entire system operation. ART is also equipped with an Ultrasonic type level transmitter to monitor the slurry level in ART. The highly concentrated slurry prepared in the ART is pumped through a charge pump system to the high concentration slurry disposal (HCSD) pump.

Stage V: Charge Pump System

2 nos. charge pump systems are provided at the outlet of each ART. The main purpose of this system is to see that the flooded suction and filtered slurry to

HCSD pump, a charge pump and a suction strainer are provided in the slurry pipe line between ART and HCSD pump. The major advantage of suction strainer is to have a high screening area to have less slurry velocity through the filtering mesh for longer life. Another advantage of this is, the strainer has been put in service to drain and recycle the bigger particles from the slurry for quite some time whenever required. In the strainer, a drain connection with a valve is provided to take out bigger particles online from the strainer.

Stage VI: HCSD Pump System

For disposing of high density of slurry to the Ash Pond, three sets of HCSD pumps are provided. The concentrated slurry disposal is made through three sets of pipe work comprising of 125 NB seamless pipes up to the ash ponds. The HCSD Pump-1 is connected to ART-1 through charge pump system-1. Similarly, HCSD pump-3 is connected to ART-2 through charge pump system-4. Charge pump systems- 2 & 3 (connected to ART 1 & 2 respectively) feed to HCSD pump-2. Any of the two pumps can be run at a time to meet the system requirement. Both HSCD pumps can be fed from same ART also. No.1 pump PLC panel is installed near each pump house for integrating the controls of each pump. These PLC panels in turn communicate with the main PLC system for entire system operation.

Thus, it can be said that technology imparts more of energy efficiency in the form of water conservation and eliminates the traditional outmoded type of water recycling from the existing Ash pond of RTPP. However the disposal is made to existing Ash pond via distribution piping and discharge through blinds/through flanges located at suitable intervals.

CASE STUDY 3: Setting a mile stone through Effluent Treatment Plant and Recycling System: RTPP- Stage II- Unit 3 and 4

Huge amount of fossil fuels like coal, oil and gas are burnt in power stations to heat up water, to produce steam which further runs the turbines to produce electricity. In the process huge effluents are transmitted from the power plants. Judicious management of these main sources of effluents in the power plant, have been considered for treatment. The main effluents that can be listed are as follows:

- Oily water from fuel oil area
- Wash water from Thomas Gagne-Hall
- Effluents from transformer yard area
- Boiler Blow down and Associated effluents
- Boiler area oily effluents
- Sludge from pre-treatment plant
- DM plant regeneration waste
- Side Stream Filter Back wash
- Cooling tower blow down
- Coal Handling plant Effluents

- Ash silo area effluent
- Remote Ash Silo area effluent

(1) Waste oil from the fuel oil pump house is collected in existing local sump. This effluent shall be pumped by existing pumps to an oil water separator (API design) for treatment .The separated oil in drums will be collected for reuse suitably. Clear water shall be pumped to the Circulating Moving Bed.

(2) Another effluent i.e. the wash water from TG hall washing from stage 1 and 2 shall be collected through drain channels in a collection sump located outside TG building towards south. This water contains oil (maximum parts per million). The estimated flow of this effluent is at 5 m^3/hr. The oily water collected in the sump will be pumped using 2 x 100 percent duty screw pumps and be treated in a Chemical Process Industries (CPI) type oil water separator. Clear water from CPI will flow through pipes to boiler blow down collection sump by gravity. Sludge will be manually disposed by APGENCO in environment friendly manner.

(3) The effluents generated from the transformer yard area occur in the case of fire. Hence water spray is necessary and there is huge loss of containment of oil from transformer. For collecting this oil common oil pits are provided as per TAC requirements. The collected oil is traditionally pumped in to drums. Some residual oil is not recoverable and this left out oily water needs treatment before disposal. This effluent will be treated by passing this effluent through CPI separator. Such phenomenon is very uncommon and therefore no in-situ installed pump is planned for. Two screw pumps will be supplied that will be kept under APGENCO's custody. Indispensable delivery piping from the transformer yard common oil pit up to the inlet of the CPI shall be provided. In case of requirement one pump can be used to serve the purpose. For facilitating, installation of the screw pump in case of necessity, a dry sump each outside each retention oil pits for stage -2. A suction pipe for the screw pump shall be entrenched during the construction of the oil pit. This suction pipe will be endowed with a sluice valve and a blank flange.

(4) The other effluents from boiler blow down from stage –I and stage-II will be channelised through one common trench. The trench that will take carry boiler blow down will also receive effluents namely IBD and boiler bottom ash seal trough over flow. This combined effluent will be accumulated in a separate sump. This effluent will be pumped directly to the Central Monitoring Basin (CMB) envisaged as an equalization basin from where treated effluent will be reused/disposed off. A tee-off line with valve will be made available for sending this effluent via a lamella Clarifier conceived for treating other regular effluents polluted principally with suspended solids. The total flow of this stream is estimated as 50 m^3/hr.

(5) The other effluents from boiler area are oily one's. The effluents from floor washing in boiler area and oil leakages from oil burners etc may enclose suspended solids up to 200 ppm. In addition to this, it also contains oil and grease up to 200 ppm. This effluent will be collected in a separate oily effluent sump and then pumped to the same CPI separator above for primary removal of oil and secondary suspended solids. The average flow rate of the stream shall be 10 m^3 /hr.

(6) The effluent in the form of sludge from Stage –I clarifier sludge sump shall be pumped by existing pumps to a common collection sump 1 envisaged to be located in Stage-I WTP area. Filter backwash water from Stage-I filters shall also be brought to this sump using gravity pipe. The remaining sludge from Stage- II clarifier sludge pump will be brought in to the common collection sump-1 by extending the stage II sludge pump discharge line only. All the effluent collected in this sump shall be pumped to the existing Ash Slurry Pump House.

(7) The effluent from the neutralization pit of the DM plant will be pumped to the common collection sump-1 indicated under using existing pumps. The average flow rate shall be 10 m^3/hr. In this regard, essential extension of the discharge pipeline will be provided.

(8) The back wash water will be collected in a sump defined as Back wash Sump. This effluent may contain suspended solids (max 500 ppm). 2 x 100 percent duty pumps are endowed with to feed this effluent to Lamella clarifier inlet. Clarified water will flow to CMB by gravity.

(9) The excess blow down from the cooling tower of Stage –II and intermittent blow down from the cooling tower of Stage- I shall be directly taken to the Lamella Clarifier by taking tap off connection from the CW return headers. Butterfly valves and piping from CW return handers to the Lamella Clarifier is included in ETP scope.

(10) The excess water from Dust suppression in crushed coal pipe areas shall be drained by natural slope to garland drain to be embedded around the coal stockpile. The drain shall be led to twin coal settling ponds (One operating and other Stand- by) It's very uncommon, that during rainy season, heavy rainfall will flush out all the effluent through garland drains. Overflow water from settling ponds shall be collected in a settling pond outfall sump and may be again used for dust suppression. Excess water in case of rainfall shall be routed to storm water drain. The effluents gathered due to dust suppression in wagon tipplers from the existing sump and pumps shall be collected in a new local sump and subsequently shall be pumped to CHP garland drains for auxiliary settling in settling ponds.

(11) The ash silo area of Stage I and Stage II are located in the near by vicinity. Two pits already exist in Stage-I with individual jet pumps to forward ash slurry by washing to ash handling plant. Effluents from stage -2 shall also be routed to these pits for disposal in similar manner as of Stage –I.

(12) The wash water from remote ash silo area shall be drained to a new local sump and there from it will be pumped to the sludge pump of lamella clarifier for further disposal in ash handling plant.

(13) Suitable TSS removal facility such as Lamella clarifier or tube settlers (150 m^3/hr) shall be provided. Clear water from lamella clarifier/ tube settlers shall be led to CMB gravity. Alum/lime dosing system is also endowed as applicable for proper settling and PH correction. The sludge from the Lamella Clarifier will be pumped to the ash slurry pump house.

(14) The basin will be in two compartments. Each compartment will be sized for atleast 90 minutes continuous inflow. 2 x 100 percent capacity pumps will be provided for dewatering the CMB. CMB discharge will be used for horticulture/ coal dust suppression/ash handling plant make up within plant boundary. Excess water shall be drained to the nearest drain channel for final disposition to Kallamalla Vagu. Acid dosing system shall be provided for PH correction and a PH meter is installed at discharge line to monitor it.

Performance Assessment of Kinnersani Dam due to climate Variability (Monsoon Fluctuations): During Prospective and Lean months of a year

Capacity at FRL – 8400 MCFT; Full Reservoir Level: 407
For the year 2005-06: Rainy and winter season: (Storage capacity varying between 6695 MCFT to 7910 MCFT) .Reservoir levels were maintained at 405.

Month	Storage Capacity (MCFT)	Reservoir Level	Production of Electricity (MU)
July	6695	407	413.49
August	6695	407	435.35
September	6695	407	458.37
October	6695	407	429.33
November	6695	407	433.7
December	6695	407	234.26
January	6695	407	231.73
February	7910 MCFT	407	308.93

March	**5537 to 4290 MCFT**	**407**	**89.2**
April	**5537 to 4290 MCFT**	**407**	**92.07**
May	**5537 to 4290 MCFT**	**407**	**71.02**

The water shortage problem can be tackled through the following counteracting measures:

- Water supply to M/s Navabharath Ferro Alloys and silk is to be disconnected as per the notices issued to them.
- Annual Evaporation losses: 0.829 to 1.61 TMC during the period (1970-71 to 2007-08). The Leakages through Construction sluices in TMC: 0.584 to 2.2 TMC. In lieu of this, the precious natural resource water is to be judiciously utilized besides minimizing all leakages and wastages.
- Water is to be pumped from the Godavari river basin near Bhadrachalam.

Therefore the available water in the Godavari river basin i.e. through discharge, depths etc are to be obtained from CWC to study the feasibilities of pumping of water. It is also stated that the minimum flow of 300 cusecs discharge and 2 feet depth of water is always available during all months during the year of 2009. It is therefore under review whether the discharge and depths of flow in Godavari river basin at Bhadrachalam enables to study the feasibility of pumping.

Case Study 5: Water Management in Rayalaseema Thermal Power Station: Role of Mylavaram Reservoir

For the Rayalaseema Thermal Power Project, the Government decided to supply 40 cusecs of water from Mylavaram reservoir through out the year totaling to 1.3 TMC at Muddanur on priority basis for the betterment of backward areas Rayalaseema.

The Mylavaram reservoir is intended to supply water to an extent of 75000 acres of irrigation dry crops. The reservoir apart from this is also catering to the drinking water needs across the river. With respect to RTPP, nearly 1.30 TMC of water has been allocated for power generation. The reservoir has received surplus water mostly in the month of June and September 2007 to the level of 9.2 TMC. The State Government authorities have prioritized to deplete the reservoir in order to start the construction of Gandikota dam that was under submersion of Mylavaram back waters. As per the instructions of Government the water is depleted and nearly 1.30 TMC of water has been exclusively kept for RTPP power generation and evaporation losses. A meager quantity of 9.00 MCFT of water has been released towards irrigation purpose for the month of March 2008.

For instance the RTPP consumption on 8/7/2008 is 0.945 TMC (that includes evaporation losses) that is from 1/2008 to 8/7/2008 and still there is 0.492 TMC (1888.510) water is available in the reservoir as on today. These including evaporation losses, the RTPP water consumption is lowest at 60.29 MCFT in January 2008 and the highest evaporation losses were recorded to the level of 98 MCFT in the month of 5/2008. It can also be notified that the withdrawals also raised from 24 cusecs to 40 cusecs in the month of May/2008 and now it has come down to 33 cusecs. Due to sudden increase in the water drawals by 13 cusecs in the month of May/2008, it was informed to the RTPP authorities for the installation of lifting arrangement in order to with draw required water of 33 cusecs.

Due to sudden increase in the water withdrawals by 13 cusecs in the month of May/2008, it was informed to the RTPP authorities for the installation of lifting arrangement in order to withdraw required water of 33 cusecs. In addition to this, at the rate of 20 cusecs/day water supply would be ensured up to 20/7/2008 by gravity flow. On August 2008, there was lifting of water. This kind of lift arrangement enabled to lift about 18 to 20 cusecs only. Additional lift arrangements are considered prerequisite to lift 33 cusecs of water.

Apart from the self-yield from the catchment's area, there has been a share of 4 TMC from the Tungabhadra Board. At the end it can be said that in the last 10 years period water released from MPR Dam for the year 2006-07. Against this, 3280 TMC water released at MPR only 0.40 TMC water was able to be recovered at Mylavaram Reservoir Dam.

The hydraulic particulars of the dam are seen in appendix table 8.2. In case of Mylavaram reservoir the total catchment of the river is 19197 square miles with its width of 365.70 meters. The maximum height of the earth dam is 24.30 meters. The gross storage at FRL is 283.00 Mcum or 9.965 TMC, but this is not commensurate with its live storage that is 254.00 Mcum. The entire water spread at FRL is 41 sq miles. The minimum drawn down level is 190.50 M and its dead storage level is 189.00 M. There are nearly 13 no's spill gates with a size of 12.2 M x8.65 M and the length of spill way is 195.10 M. The crest level of the dam is 194 M and the dam is bifurcated in to north and south canal. The length of north canal is 34.34 km, with its discharge capacity of 25.65 cumecs and at sill level the water is maintained at 186 M. Nearly 50,000 acres of land can be brought under irrigation by utilizing the water of North Canal. The South Canal water is mainly to cater the electricity needs of the power station RTPP and at times irrigation. . The length of south canal is 44.44 km, with its discharge capacity of 10.19 cumecs. The sill level of the south canal is +187.15 M. By this nearly 25,000 acres of land can come under prospective vegetation coverage. The size of North canal gate is 2.25 M x 50 M and size of south canal gate is 1.80 x2.50 M, along with the sill level of river that stood at 185.00 M. The entire cost of the project is 2384.58 lakhs. The project has been commenced in the year 1968-

1969 and its date of completion was 1983. Totally 76 villages were benefited with the onset of this reservoir.

Performance Assessment of Mylavaram Reservoir in Rayalaseema Thermal Power Plant

Scenario of Water Shortage

Water Level in dam	< 190-194
Water Storage Capacity	< 1 TMC and ≥ 2 TMC
RTPP water withdrawals	≤ 20 cusec and > 25-30 cusec

Scenario of Medium level Water

Water Level in dam	>194
Water Storage Capacity	>2 TMC
RTPP	≥30 cusec

Scenario of Adequate water

Water level in dam	≥200
Water Storage Capacity	> (3-9 TMC)
RTPP Water Withdrawals	≥30-200 cusec

The appendix table 8.3 portrays the trends of number of days (in percentage terms) the Rayalaseema Thermal power plant scenario of water excess and water shortage level's at south canal of Mylavaram reservoir for the time period (1995-2009)

For the year 1995---- 143 days there was water shortage

(a) The dam level was < 190 storage
(b) Capacity was between 1 and 2 TMC
(c) RTPP water withdrawals from Myalavaram was between 20-30 cusec

For the year 2003--- 243 day there was water shortage

(a) As the dam level was ≥ 190
(b) Capacity was in the range of 1 &2 TMC
(c) RTPP water withdrawals from Myalavaram was between ≤ 15-20 cusec

For the year 2004--- 165 days there was water shortage

(a) ≥ 190 dam level
(b) > 1 TMC capacity
(c) RTPP water withdrawals from Myalavaram was ≤ 20 cusec

For the year 2005 ---- 200 days there was water shortage

(a) ≥ 190-194 dam level
(b) ≥ 1 TMC capacity
(c) RTPP water withdrawals from Myalavaram was ≤ 20 cusec

For the year 2006---- 100 days there was water shortage

(a) ≥ 194 & < 190 dam level
(b) < 1TMC & > 2 TMC storage capacity
(c) RTPP water withdrawals from Myalavaram was ≤ 20 cusec

For the year 2007--- 49 days there was water shortage

(a) < 190 dam level
(b) < 1 TMC Capacity
(c) RTPP water withdrawals from Myalavaram was ≤ 20 cusec

For the year 2008 --- 66 days there was water shortage

(a) < 190 dam level
(b) < 1 TMC Capacity
(c) RTPP water withdrawals from Myalavaram was ≤ 20 cusec

There fore during the period of 1995- 2009 the number of days in percentage terms RTPP encountered water shortages were 966 days and remaining days to the level of 750 days there was excess water.

One of the other reason for aggravating situation of water shortage in RTPP was diversion of water to the level of 1.5 TMC to Bramhani Steel plant as per G.O. number 84 Taking advantage of this Government order the Bramhani steel plant have made a mechanism of 6 meters width and 2 meters depth pump house near Mylavaram back water. This mechanism was facilitated by an approach canal up to the level of 1.041 Km. This was supported by 550 HP Motors. The Bramhani steel plant started building structures in the Mylavaram reservoir up to the level of 1.80 KM. But with out having, any agreement with the irrigation department started taking 0.59 TMC water illegally. Due to this the RTPP has landed in a very precarious situation. It was not able to cater to the needs of its power plant due to diversion of water.

Counteracting measure followed is by spending crores of rupees RTPP is now planning to get water from pipeline laid 70 Kms at Bramhasagar. Hydraulic particulars of Veera Brahmendra Swamy to RTPP. (Appendix table 8.4)

9.0 Policy Recommendations

For Judicious Utilization of Water and its conservation with Special Emphasis on Power Sector the ***general suggestions*** include

- Afforestration measures can avert the adverse repercussions of climate variability w.r.t to water availability, by onset promotion of abundant water supplies.
- Usage of Reversible generating sets in Hydel. Water used from dam used for the purpose of generation of electricity can be again reutilized by pumping in to reservoir. Unlike in thermal power stations it is not possible to use this mechanism, as water is used for cooling purposes and the discharge water is warm water.
- Cement lining of water canals can avoid shrinkage of water (evaporation losses), there by sustaining the appropriate levels of monsoon water.
- Construction of new dams or artificial ponds timely during rainy season, by not allowing water to get absorbed in to sea. This curbs the wastage of precious water.

Specific Suggestions include the following

- Desalination water technology can be adopted by the selected thermal power plants especially in KTPS O &M, KTPS Stage V and RTPP where in the brackish water from the effluents can be treated for fresh water extraction.

  Moreover the cost of production of water from desalination plants is as low as 15 paisa per liter. But still in comparison with water availability from surface water and ground water this is considered high and can inflate the over all production cost for any power plant. But taking in view of generation losses due to water shortage that are ending up with power cuts and its aftermath effects on forward and backward linkages of agriculture, industry and domestic sectors are getting drastically affected. In lieu of this, it is imperative for power industry units to take up desalination plants on a priority basis.
- Judicious and good water efficiency practices adopted at the regional level helps to mitigate the water shortages at maximum extent. For example in KTPS leakages are more. The power plant has to take up leakage reduction programme on a wider scale based on economic principles.
- Setting up of water banks and quota system, where in government should strictly adhere to the allocation of water for the confined sector by not diverting it other sectors (which are considered as more important on a priority basis) depending upon the suitability of the socio-economic conditions. In addition to this, penalty charges should be levied

exorbitantly to those sectors that resort to over consumption of water depending upon their requirements.

- The water supply authorities to VTPS, KTPS, RTPP and other selected hydel power stations should set up pricing policies based on the extent of water withdrawals. Incase of more water withdrawals, a higher water fee need to be charged and vice versa. Suppose if a cluster of thermal power plants are located in same region a discount water fee should be agreed upon when water withdrawals are carried out through collective power management body. This kind of measure aims at encouraging a collective encompassment of the resources. In case of thermal plants, environmental costs should also be included in water tariff by means of pollution charges.
- Awareness campaigns should be evoked in the surroundings areas of power plant location to make the public realize the importance of scarce precious resource "Water". Further, safeguarding the existing natural catchments and aquifers with thorough stream lining measures and day to day monitoring.
- The respective power stations should be allotted maximum funds by the respective State Power Ministry for taking up mini rural development programmes in rural areas, especially in sensitive areas as regards water scarcity, vulnerability of droughts and floods. This enables to sustain rural electrification on a continuous basis for remote areas.
- A full fledged mechanism should be in progress to eliminate customer discrimination (for industries on a priority basis) and elimination of phenomenon of cross subsidies, equalizing water prices for all water users
- Transport of surface water to power plants to regions where in there is no source of river. However a cautious approach needs to be followed for its feasibility and adaptability on a sustained basis.
- In dry regions like KTPS and RTPP where there is bountiful availability of natural "sun", electric energy accessibility can be tapped to the maximum extent. To compensate for the loss of generation due to water shortage, these thermal power plants should set up medium capacity solar thermal power integrated with combined system of steam plant as ancillary power industrial units in future. For example in KTPS and RTPP huge pipe lines were laid to pump water from distant place where there is river source, that is not at all cost effective. In regard it is advisable to adapt solar thermal technology that helps to conserve surface water resources.
- Emphasis should be on taking up of renewable energy sources like solar power, wind power and biomass power plants by APGENCO with large installed capacities, instead of relying solely on thermal and hydel stations (that need requisite quantities of water). (See Appendix table 8.5)

- Though our knowledge continues to lay emphasis about climate variability on water availability and vulnerability, we are still far from able to exactly identify the hot spot areas of vulnerability in various power plants of India. In this regard a consistent frame work for vulnerability assessment should be developed. This could serve to identify hot spot areas in power plants on priority basis, where in society, respective power plants and researchers try to either suggest or avert to mitigate climate related risks.

- As clearly evident from this paper that as climate change in terms of especially optimum availability of water to power stations due to monsoonal fluctuations are ultimately ending up in significant shifts in power production. The other varied reasons such as low precipitation, high temperature, high evaporation losses, droughts, floods are also having similar impact. Therefore technological advances in improving electricity production yields and tolerances to aridity coupled with well planned day to day climate and weather forecasting helps to bring significant pay offs for a “No Regrets Approach” in the field of water management of Electricity Industry.
- For enhancement of water resource sustainability in future, a common plat form of multi stake holder that includes stakeholders, civil society, in house power plants, NGOs, Government’s, researchers, scientists etc should be set in for a effective dialogue and discussion on climate variability and necessary steps to be adapted for increasing avenues of water sources.

Appendix Tables

Table A 5.1

Season Wise water foot prints –NTTPs for 2005-06

Seasons	Total Water Consumption at various stages in cubic meters: Steam Generation and DM make up water in boiler	DM plant Back Wash	Process (a+b)	Ash slurry	Condenser Cooling	Domestic Purpose	Total water Consumption	Generation (Million Units)	Water Footprint[1] = Total water Consumption / Generation (m^3/MWhr)
April	56119	6552	62671	1789861	68028750	157500	70038782	939.19	78.72
May	66671	7595	74266	1843056	71161200	162750	73241272	889.7	80.2
June	63946	6793	70739	1840942	67460561	157500	69529742	912.79	77.4
July	73961	8366	82327	1891733	74268539	162750	76405349	898.38	88.8
August	68799	7556	76355	1653435	92820998	162750	94713538	860.4	153
September	44084	5252	49336	1740933	88324455	157500	90272224	620.63	152
October	57443	6541	63984	1984773	96075716	167150	98291623	593.05	143
November	64232	7307	71539	1813758	93428648	157500	95471445	689.49	133
December	57372	6465	63837	1889681	110445630	162750	112561898	717.55	129
January	55453	6050	61503	1984001	110560005	162750	112768259	872.33	123
February	51553	5771	57324	1626865	99737700	151171	101573060	915.34	120
March	54800	6424	61224	1837025	104650695	157500	106706444	846.38	113.6

[1] Calculated Figures to determine the typical water consumption to produce 1 MWH of electricity by NTTPs

Table A 5.2

SEASON WISE WATER FOOT PRINTS IN KTPS O & M: 2005-06

Total Water Consumption at various stages in cubic meters

Seasons	Steam Generation and DM make up water in boiler	DM plant Back Wash & Plantation Beds	Condenser Cooling	Ash slurry	Fire fighting	Domestic Purpose, Drinking and Sanitation	Total water Consumption	Generation (Million Units)	Water Footprint[7] = Total water Consumption / Generation (m^3/MWhr)
April	60608	5250	1872338.42	1128945.26	30	35850	3103021.68	456.1	6.8
May	66399	5250	1906105.79	1067279.66	31	36910	3081975.45	463.6	6.6
June	71318	5250	1777491.02	989918.86	30	35850	2879857.88	471.8	6.5
July	51352	5250	1392288.75	795309.01	31	36910	2281140.76	439.9	5.2
August	58903	5250	1288911.54	788394.98	31	36910	2178400.52	343.3	6.3
September	66814	5250	1448751.18	884212.68	30	35850	2440907.86	319.5	7.6
October	56031	5250	1596243.61	999648.50	31	36910	2694114.11	358.4	7.5
November	53858	5250	1694051.91	1065330.22	30	35850	2854370.13	396.1	7.2
December	58321	5250	1894777.28	1192530.70	31	36910	3187819.98	419.9	7.6
January	55695	5250	1923890.84	1214568.16	31	36910	3236345.00	468.4	6.9
February	52444	5250	1687404.78	1047456.13	29	34790	2827373.91	475.5	5.9
March	62894	5250	1842931.63	1200196.57	31	36910	3148213.20	417.8	7.5

[1] Calculated Figures to determine the typical water consumption to produce 1 MWH of electricity by KTPS O & M

Table A 5.3

Season Wise water foot prints –KTPS Stage V- for 2005-06

Seasons	Total Water Consumption at various stages in cubic meters: Steam Generation and DM make up water in boiler	DM plant Back Wash & Plantation Beds	Condenser Cooling	Ash slurry	Fire fighting	Domestic Purpose, Drinking and Sanitation	Total water Consumption	Generation (Million Units)	Water Footprint[1] = Total water Consumption / Generation (m^3/MWhr)
April	18333	6000	1050002	485178	30	11670	1656500	354	4.6
May	27352	6000	645392	416202	31	11670	1110851	217.6	5.1
June	25821	6000	6359919	537224	30	11670	798734	214.4	3.7
July	26521	6000	1046900	570465	31	11670	1277408	352.9	3.6
August	18736	6000	883262	420406	31	11670	1507766	297.8	5.1
September	19021	6000	682820	119294	30	11670	1198458	230.2	5.2
October	20532	6000	832330	186286	31	11670	1390535	280.6	5.1
November	21031	6000	627279	588067	30	11670	1090091	211.5	4.9
December	20111	6000	1018803	478917	31	11670	1691980	343.5	4.9
January	21062	6000	865769	519972	31	11670	1346838	291.9	4.6
February	22635	6000	950917	424081	28	11670	1518075.74	320.6	4.7
March	22501	6000	1088513	635365	31	11670	1799117	366.9	4.9

[1] Calculated Figures to determine the typical water consumption to produce 1 MWH of electricity by KTPS V

Table A 5.4

Season Wise water foot prints –RTPP for 2005-06

Seasons	Total Water Consumption at various stages in cubic meters							
	Steam Generation and DM make up water in boiler	DM plant Back Wash & Plantation Beds	Condenser Cooling	Ash slurry	Domestic Purpose, Drinking and Sanitation	Total water Consumption	Generation (Million Units)	Water Footprint[1] = Total water Consumption / Generation (m^3/MWhr)
April	178	6	5958	1144	2826	10112	1638	6.2
May	130	6	5686	1088	558	7468	1071	6.9
June	196	14	5836	920	4198	11168	1414	7.8
July	6204	20	6204	1332	4792	12550	840	14.9
August	210	12	7322	782	1418	9744	847	11.5
September	196	8	7202	1284	2138	10828	1008	10.7
October	130	4	6618	1676	2556	10984	1813	6.1
November	234	6	6448	1054	8086	15828	924	17.1
December	218	4	6102	996	7664	14984	1008	14.9
January	130	2	5886	1106	2394	9518	1776	5.3
February	130	4	5650	1590	2100	9474	1904	4.9
March	132	2	5694	1744	2186	9758	2044	4.7

[1] Calculated Figures to determine the typical water consumption to produce 1 MWH of electricity by RTPP

Table A 5.5

Season Wise Water Foot prints in Srisailam Left Bank Power House: 2005-06

Month	Water Withdrawals Seasonal (Generation mode)- Cubic meters	Pump Mode Cubic Meters	Generation in MU	Pump Mode in MU	Water Foot prints Seasonal (Generation Mode) m^3/MWh	Water Foot Prints at Pump Mode m^3/MWh
June	965520000	0	5.2	0	185676.9	0
July	2171188800	0	11.7	0	185571.7	0
August	92591968320	0	570.8	0	162214.4	0
September	82648667520	0	510.1	0	162024.4	0
October	52795566720	0	332.4	0	158831.4	0
November	17224187328	0	109.9	0	156725.9	0
December	17899589952	5642784000	121.9	55	146838.3	1025960.7
January	26681866560	10552032000	178.8	102	149227.4	1034512.9
February	22072927680	5010336000	148.8	61	148339.6	821366.6
March	23413937760	9196416000	165.2	88	141730.9	1045047.3
April	32152127040	12978144000	212.6	123	151232.9	1055133.7
May	5663157120	12682656000	34.2	107	165589.4	529267.0

Table A 5.5 Calculation of Water Foot prints after Evaporation losses in Srisailam Left Bank Power House for the year 2005-06

Month	Evaporation losses	Water Withdrawals due to seasonal monsoons-Evaporation losses = Water withdrawals after Evaporation losses	Water Foot prints after Evaporation losses
June	9770400	955749600	183798
July	19002720	2152186080	183947.5
August	84025440	92507942880	162067.2
September	79069440	82583928000	161897.5
October	64739520	52730827200	158636.7
November	77993280	17146194048	156016.3
December	76010880	12256805952	100548.0
January	66750240	16129834560	90211.6
February	47974080	22024953600	148017.2
March	48342240	23365595520	141438.2
April	18351360	32133775680	151146.6
May	10903200	5652253920	165270.6

Table A 5.6

Season Wise Water Foot prints in Srisailam Right Bank Power House: 2005-06

Month	Water Withdrawals Seasonal Cubic meters	Evaporation losses (Cubic Meters)	Generation at Busbar (MU)	Water Withdrawals after Evaporation losses (cubic meters)	Water Foot prints Seasonal $m^3/MWhr$	Water Foot Prints after Evaporation losses m^3/MWh
June	0	0	0	0	0	0
July	901445760	9770400	6.5	901445753.48	13825.86	138683.9
August	65747116800	19002720	435.8	65728114080	150899.9	150821.7
September	57652896960	84025440	381.6	57568871520	151082.0	150861.8
October	34744826880	64739520	233.7	34680087360	148672.7	148395.8
November	9752685120	77993280	65.2	9674691840	149581.1	148384.8
December	9752685120	76010880	68.6	9683465280	142266.4	141158.4
January	19288704960	66750240	133.5	19221954720	144484.7	143984.7
February	13817226240	47974080	96.5	13769279160	143183.7	142686.8
March	8113789440	48342240	56.9	8065447200	142597.4	141747.8
April	12543647040	18351360	82.3	12525295680	152413.7	152190.7
May	2568957120	10903200	16.3	2558053920	157604.7	156935.8

Table A 5.7

Season Wise Water Foot prints in Nagarjuna Sagar Main Power House:

2005-06			
Month	Water Withdrawals Seasonal Cubic meters	Generation at Busbar (MU)	Water Foot prints m^3/ MWhr
June	1627257600	10.1	161114.6
July	2300400000	14.3	160867.1
August	183772800	1.2	153144
September	9660124800	60.1	160734.18
October	58345401600	464.5	125609.04
November	48328876800	392.3	123193.7
December	37103702400	301.2	123186.3
January	15963091200	129.5	123267.1
February	4568140800	35.4	129043.5
March	10942387200	83.1	131677.3
April	6357398400	46.8	135841.8
May	2970691200	21.6	137532

Table A 5.8

Season Wise Water Foot prints in Nagarjuna Sagar Left Canal Power House: 2005-06

Month	Water Withdrawals Seasonal Cubic meters	Evaporation losses (Cubic Meters)	Generation at Busbar (MU)	Water Withdrawals after Evaporation losses (cubic meters)	Water Foot prints Seasonal m^3/MWhr	Water Foot Prints after Evaporation losses m^3/MWh
June	0	35116800	0	35116800	0	0
July	0	16992000	0	16992000	0	0
August	14380416000	17275200	19.6	14363140800	733694.7	732813.3
September	14487310080	15009600	21.5	14472300480	673828.4	673130.3
October	13485787200	11611200	20.4	13474176000	661068	660498.8
November	15985641600	12460800	23.6	15973180800	677357.7	676829.7
December	9065416320	16992000	11.9	9048424320	761799.1	760371.8
January	17126380800	24355200	14.4	17102025600	11893332	79032228.9
February	13237862400	31435200	7.7	13206427200	1719202.9	1187640.67
March	4423688640	32851200	1.83	4390837440	241731.6	1715120.4
April	4831902720	43612800	2.9	4788289920	1666173.4	1651134.5
May	0	46728000	0	46728000	0	0

Table A 5.9

Season Wise Water Foot prints in Nagarjuna Sagar Right Canal Power House: 2005-06

Month	Water Withdrawals Seasonal Cubic meters	Evaporation losses (Cubic Meters)	Generation at Busbar (MU)	Water Withdrawals after Evaporation losses (cubic meters)	Water Foot prints Seasonal m^3/MWhr	Water Foot Prints after Evaporation losses m^3/MWh
June	0	35116800	0	35116800	0	0
July	0	16992000	0	16992000	0	0
August	10428497280	17275200	24.4	10411222080	427397.4	426689.4
September	22214606400	15009600	45.9	22199596800	483978.4	483651.3
October	24253162560	11611200	49.3	24253162560	491950.6	491715.0
November	24121903680	12460800	42.3	24121903680	570257.8	569963.2
December	23771180160	1699200	38.3	23769480960	620657.4	620613.1
January	20956527360	24355200	32.1	20932172160	652851.3	652092.6
February	20660448960	31435200	24.5	20660448960	844566.7	843283.6
March	19563145920	32851200	16.9	19530294720	1157582.6	1155638.7
April	11779369920	43612800	12.1	11735757120	973501.6	969897.3
May	0	46728000	0	46728000	0	0

Table A 5.10

Season Wise Water Foot prints in Vijjeswaram Gas Based Power Plant: 2006-07

Month	Water Consumption (Cubic Meters)	Generation	Water Consumption (Cubic Meters)	Generation	Water Foot prints	Water Foot Prints
	Stage -I		Stage-II		Stage-I	Stage-II
April	443	31.2	3210	113.7	0.014	0.028
May	856	31.6	3149	103.4	0.027	0.0304
June	794	30.7	2110	95.1	0.026	0.0221
July	792	33.6	3107	102.3	0.024	0.0304
August	1467	35.7	3424	101.3	0.041	0.0338
September	568	31.1	864	99.4	0.018	0.0086
October	377	12.1	1732	107.7	0.031	0.0161
November	0	0	1562	109.9	0	0.0142
December	132	0	1235	113.7	0	0.01086
January	31	0	835	112.4	0	0.00742
February	1240	24.3	933	84.8	0.051	0.01100
March	400	33.2	1132	106.1	0.012	0.01067

Table A 5.11

Water Foot prints for Biomass Power Plant- My Home Power Limited

Month	Raw Water Consumption (m^3)	DM Water Consumption (m^3)	Domestic Consumption (m^3)	Cooling Tower Consumption (m^3)	Total Water Consumption (m^3)	Generation (MU)	Water Footprints (m^3)
Jan 09	22080	414	25	21641	44160	5410355.7	8.2
Feb 09	22715	423	25	22267	45430	4893279	0.01
Mar 09	24792	541	25	24226	49584	5530625	8.9
Apr 09	24957	489	25	24443	49914	4877051.7	1.02
May 09	23708	449	25	23234	47416	4546515.1	1.04
Jun 09	23690	382	25	23283	47380	5410219.4	8.7
Jul 09	23194	374	25	22795	46388	5308903.8	8.7
Aug 09	23754	382	25	23347	47508	5110636.4	9.3
Sep 09	20376	325	25	20026	40752	4820871.4	8.5
Oct 09	18942	437	25	18480	37884	4131844.9	9.2
Nov 09	21113	517	25	20571	4226	5406810.4	7.8
Dec 09	21113	517	25	20571	4226	5406810.4	7.8

Table A 5.12

Water Foot prints for Sri Satyakala Power Projects Private limited Biomass Power Plant- My Home Power Limited

Month	Process Boiler	Cooling	Domestic	Total Water Consumption (m^3)	Generation (MU)	Water Footprints (m^3)
April	3432	10192	120	13744	2398100	0.006
May	3300	9800	120	13220	2062800	0.006
June	3696	10976	120	14792	2590200	0.006
July	3696	10976	120	14792	2353900	0.006
August	4092	12152	124	16368	2807200	0.006
September	2640	7840	124	10604	2187600	0.005
October	0	0	124	124	2523000	4.91
November	0	0	124	124	1625000	7.6
December	2640	7840	124	10604	2839100	0.004
January	6600	19600	236	26436	3085400	0.008
February	3960	11760	124	15844	2806900	0.006
March	0	0	124	124	2529200	4.9

Table A 5.13

Sri Rayalaseema Green Energy Limited 2003-04

Month	Process	Cooling Purpose	Domestic	Total water Consumption	Generation	Water Foot Prints
April	1022.8	14211.6	45.6	15280	3663700	0.0042
May	1116	14298.7	179.8	15594.5	3690000	0.0042
June	1185.44	15188.5	186.1	16560.04	3880200	0.0043
July	1121.52	14369.5	179.8	15670.82	3678300	0.0043
August	1117.1	14313.1	186.25	15666.4	3358000	0.0047
September	1008	13905.2	186	15099.2	3278600	0.0046
October	1085.3	13905.2	1131.2	16121.7	3580000	0.0045
November	1156.96	14823.6	188.7	16169.26	3803800	0.0043
December	1035.2	13263.5	185.9	14484.6	3414700	0.0042
January	1187.44	15214.1	185.9	16587.44	3905600	0.0042
February	1109.2	14206.5	186.3	15502	3682300	0.0042
March	1077.4	13796.5	176.8	15050.7	3553700	0.0042

Table A 5.14

Comparative Analysis of Water Foot Prints by Energy Type for Power Plants in Andhra Pradesh: Name of Power Plant by Feedstock Type

Month	**NTTPs (Thermal)**	**KTPS O & M (Thermal)**	**KTPS Stage V**	**RTPP Thermal**	**Vijjeswaram Natural Gas: Stage I**	**Vijjeswaram Natural Gas: Stage II**
April	78.72	6.8	4.6	6.2	0.014	0.028
May	80.82	6.6	5.1	6.9	0.027	0.0304
June	77.4	6.5	3.7	7.8	0.026	0.0221
July	88.8	5.2	3.6	14.9	0.024	0.0304
August	153	6.3	5.1	11.5	0.041	0.0338
September	152	7.6	5.2	10.7	0.018	0.0086
October	143	7.5	5.1	6.1	0.031	0.0161
November	133	7.2	4.9	17.1	0	0.0142
December	129	7.6	4.9	14.9	0	0.0108
January	123	6.9	4.6	5.3	0	0.0074
February	120	5.9	4.7	4.9	0.051	0.011
March	113.6	7.5	4.9	4.7	0.012	0.0106

Contd…Water Foot Prints in Hydel (Feed Stock) for power generation m^3/ MWH

Power plant Name	**Srisailam Left Bank Power House**			**Srisailam Right Bank**		**Nagarjuna Sagar**
Month	Seasonal	Pump mode	After Evaporation Losses	Seasonal	After Evaporation losses	Seasonal
June	185676.9	0	183798	0	0	161114.6
July	185571.7	0	183947.5	13825.86	138683.9	1608671
August	162214.4	0	162067.2	150899.9	150821.7	153144
September	162024.4	0	161897.5	151082.0	150861.8	160734.18
October	158831.4	0	158636.7	148672.7	148395.8	125609.04
November	156725.9	0	156016.3	149581.1	148384.8	123193.7
December	146838.3	1025960.7	100548.0	142266.4	141158.4	123186.3
January	149227.4	1034512.9	90211.6	144484.7	143984.7	123267.1
February	148339.6	821366.6	148017.2	143183.7	142686.8	129043.5
March	141730.9	1045047.3	141438.2	142597.4	141747.8	131677.3
April	151232.9	1055133.7	151146.6	152413.7	152190.7	135841.8
May	165589.4	529267.0	165270.6	157604.7	156935.8	137532

Contd…Water Foot Prints in Biomass (Feed Stock) for power generation m3/ MWH

Month	My Home Power Limited (2008-2009)	Sri Satyakala Power Project Limited (2005-06)	Sri Rayalaseema Green Energy Limited (2003-04)
April	1.02	0.006	0.0042
May	1.04	0.006	0.0042
June	8.7	0.006	0.0043
July	8.7	0.006	0.0043
August	9.3	0.006	0.0047
September	8.5	0.005	0.0046
October	9.2	4.91	0.0045
November	7.8	7.6	0.0043
December	7.8	0.004	0.0042
January	8.2	0.008	0.0042
February	0.01	0.006	0.0042
March	8.9	4.9	0.0042

Table A 6.1

NAGARJUNA SAGAR MAIN POWER HOUSE

SCENARIO OF WATER WITHDRAWALS:

Year		Actual Water With Drawals (in Hundred million cubic meters)	X-code	4-q-m-a	Centered Moving Average	Specific Seasonal = WD/Centered	Deseasonalized WD= Actual WD/SI
2001-02	Summer1	3.67	1				11.22
	Rainy 2	5.01	2				3.74
	Winter 3	4.78	3	4.0	3.8	1.25	2.75
	Spring 4	2.55	4	3.6	3.6	0.71	4.49
2002-03	1	2.02	5	3.5	3.7	0.55	6.17
	2	4.77	6	3.9	3.7	1.29	3.56
	3	6.33	7	3.5	3.4	1.9	3.65
	4	1.00	8	3.3	2.7	0.37	1.76
2003-04	1	1.10	9	2.1	1.8	0.61	3.36
	2	0.13	10	1.4	1.5	0.87	0.096
	3	3.47	11	1.5	1.4	2.48	2.002
	4	1.48	12	1.3	1.5	0.99	2.61
2004-05	1	0.31	13	1.6	1.7	0.18	0.94
	2	1.23	14	1.9	1.8	0.68	0.92
	3	4.49	15	1.8	1.8	2.49	2.6
	4	1.10	16	1.9	2.6	0.42	1.9
2005-06	1	0.69	17	3.3	4.0	0.17	2.11
	2	6.82	18	4.7	4.8	1.42	5.1
	3	10.14	19	5.0	5.0	2.03	5.9
	4	2.19	20	5.1	5.4	0.41	3.9
2006-07	1	1.12	21	5.7	5.7	0.19	3.4
	2	9.54	22	5.7	5.7	1.67	7.11
	3	9.76	23	5.8	5.7	1.71	5.6
	4	2.69	24	5.7	6.1	0.44	4.7
2007-08	1	0.72	25	6.6	6.8	0.11	2.2
	2	13.05	26	7.0	6.8	1.92	9.7
	3	11.46	27	6.7	6.6	1.74	6.6
	4	1.57	28	6.5	5.2	0.30	2.8
2008-09	1	0.00	29	3.9	3.6	0	0
	2	2.55	30	3.2	3.2	0.79	1.9
	3	8.73	31	3.1			5.04
	4	1.31	32				2.3

Calculation of Seasonal index

Year	Summer (Dry Season)	Rainy (wet Season)	Winter (Cold season)	Post Monsoon
2001-02			1.25	0.71
2002-03	0.55	1.29	1.9	0.37
2003-04	0.61	0.87	2.48	0.99
2004-05	0.18	0.68	2.49	0.42
2005-06	0.17	1.42	2.03	0.41
2006-07	0.19	1.67	1.71	0.44
2007-08	0.11	1.92	1.74	0.30
2008-09	0	0.79		
Total	1.81	8.64	11.12	3.64
Unadjusted Seasonal Mean	0.30	1.23	1.59	0.52
Adjusted Seasonal	0.327	1.3407	1.7331	0.5668
Seasonal Index	32.7	134.07	173.31	56.68

As per the Indian monsoon conditions, the Seasonal index values calculated are as follows:

Final SVI	32.7 +57.77 =90.47	134.07 +18.89 =152.96	173.31-57.77 = 115.54	56.68-18.89 =37.79

Correction Factor for adjusting Quarterly Means

Determine the factor needed to adjust the index numbers to typical index numbers.

Typical quarterly index = 100 x 4 = 400.

Correction Factor = 4/ 3.64 = 1.09

Trend equation: y = 2.59+ 0.080 x

Seasonalized Forecast of Water Withdrawals

Year	X-code	Trend Unadjusted Forecast	Seasonal Index	Forecast Seasonal Adjusted (in hundred million cubic meters)
2009-10				
Summer	33	5.23	0.327	1.71
Rainy	34	5.31	1.3407	7.1
Winter	35	5.39	1.7331	9.3
Post Monsoon	36	5.47	0.5668	3.1

2010-2011				
Summer	37	5.47	0.327	1.78
Rainy	38	5.55	1.3407	7.44
Winter	39	5.71	1.7331	9.8
Post Monsoon	40	5.79	0.5668	3.28
2011-2012				
Summer	41	5.87	0.327	1.91
Rainy	42	5.95	1.3407	7.97
Winter	43	6.03	1.7331	10.45
Post Monsoon	44	6.11	0.5668	3.46
2012-2013				
Summer	45	6.19	0.327	2.02
Rainy	46	6.27	1.3407	8.41
Winter	47	6.35	1.7331	11.01
Post Monsoon	48	6.43	0.5668	3.64
2013-2014				
Summer	49	6.51	0.327	2.13
Rainy	50	6.59	1.3407	8.83
Winter	51	6.67	1.7331	11.56
Post Monsoon	52	6.75	0.5668	3.83

SCENARIO OF LOSS OF GENERATION:

Year		Loss Generation due to WS (Thousand million units)	X-code	4-q-m-a	centered	Specific Seasonal	Deseasonalised Loss of Generation
2001-02	1	1.53	1				1.40
	2	1.45	2				1.60
	3	1.42	3	1.5	1.5	0.95	1.61
	4	1.59	4	1.5	1.5	1.06	1.43
2002-03	1	1.64	5	1.5	1.6	1.025	1.50
	2	1.47	6	1.6	1.6	0.92	1.63
	3	1.37	7	1.6	1.7	0.81	1.55
	4	1.71	8	1.7	1.7	1.01	1.54
2003-04	1	1.70	9	1.7	1.7	1	1.55
	2	1.76	10	1.7	1.7	1.01	1.95
	3	1.56	11	1.7	1.6	0.96	1.77

	4	1.67	12	1.6	1.6	1.04	1.50
2004-05	1	1.74	13	1.6	1.6	1.08	1.59
	2	1.68	14	1.6	1.6	1.05	1.86
	3	1.44	15	1.5	1.5	0.96	1.64
	4	1.69	16	1.4	1.4	1.2	1.52
2005-06	1	1.72	17	1.4	1.4	1.2	1.57
	2	1.24	18	1.4	1.3	0.95	1.37
	3	0.94	19	1.3	1.3	0.72	1.07
	4	1.60	20	1.3	1.3	1.2	1.44
2006-07	1	1.69	21	1.3	1.3	1	1.55
	2	1.02	22	1.3	1.3	0.78	1.13
	3	0.97	23	1.2	1.2	0.81	1.102
	4	1.56	24	1.2	1.2	1.3	1.40
2007-08	1	1.71	25	1.2	1.2	1.4	1.57
	2	0.71	26	1.2	1.3	0.55	0.79
	3	0.84	27	1.5	1.5	1.1	0.95
	4	1.65	28	1.5	1.5	1.17	1.48
2008-09	1	1.76	29	1.5	1.5	1.05	1.61
	2	1.58	30			1.19	1.75
	3	1.06	31				1.20
	4	1.67	32				1.50

Calculation of Seasonal Index

Years	Summer	Rainy	Winter	Post Monsoon Season
2001-02			0.95	1.06
2002-03	1.025	0.92	0.81	1.01
2003-04	1	1.01	0.96	1.04
2004-05	1.08	1.05	0.96	1.2
2005-06	1.2	0.95	0.72	1.2
2006-07	1	0.78	0.81	1.3
2007-08	1.4	0.55	1.1	1.17
2008-09	1.05	1.19		

Total	7.76	6.45	6.31	7.98
Unadjusted Mean	1.12	0.92	0.901	1.14
Adjusted Seasonal Index	1.0978	0.90178	0.8832	1.1174
Seasonal Variation Index	109.78	90.17	88.32	111.7

Correction Factor = 4/4.081 = 0.9802

Trend equation: y = 1.55 - 0.03 x

Seasonalized Forecast of Loss of Generation

Year	X-code	Trend	Seasonal Index	Seasonally Adjusted Forecast (in thousand million units)
2009-10				
Summer	33	0.56	1.0978	0.65
Rainy	34	0.53	0.90178	0.48
Winter	35	0.5	0.8832	0.44
Post monsoon	36	0.47	1.1174	0.53
2010-2011	37	0.44	1.0978	0.48
	38	0.41	0.90178	0.37
	39	0.38	0.8832	0.34
	40	0.35	1.1174	0.39
2011-2012				
	41	0.32	1.0978	0.35
	42	0.29	0.90178	0.26
	43	0.26	0.8832	0.23
	44	0.23	1.1174	0.26
2012-2013				
	45	0.2	1.0978	0.22
	46	0.17	0.90178	0.15

	47	0.14	0.8832	0.12
	48	0.11	1.1174	0.12
2013-2014				
	46	0.08	1.0978	0.087
	47	0.05	0.90178	0.045
	48	0.02	0.8832	0.017
	49	-0.01	1.1174	-0.011

Forecast of Water Withdrawals (in Hundred million cubic meters) versus Loss of Generation (in thousand million units)*[8]

Quarter	Summer	Rainy	Winter	Post Monsoon Season
2009-10 WD (hundred million cubic meters) LG (thousand million units)	4.8 0.8	8.13 0.66	6.24 0.29	2.06 0.35
2010-2011 WD LG	5.1 0.59	8.53 0.5	6.69 0.23	2.18 0.26
2011-2012 WD LG	5.39 0.43	9.2 0.35	6.97 0.15	2.31 0.17
2012-2013 WD LG	5.69 0.26	9.62 0.15	7.34 0.08	2.42 0.12
2013-2014 WD LG	5.98 0.093	10.1 0.0413	7.71 0.011	2.6 -0.0073

[8] Calculated figures of Final Seasonal Forecast figures as per Indian Monsoon Conditions

Season Wise Varying Levels of Plant Load Factor (Percentage)

Year	Quarters	Water Withdrawals (Hundred Million Cubic Meters)	Loss of Generation due to water shortage (thousand Million Units)	Plant Load Factor (PLF) percentage
2001-02	Summer 1	3.67	1.53	28.96
	Rainy 2	5.01	1.45	38.36
	Winter3	4.78	1.42	42.29
	Post Monsoon 4	2.55	1.59	21.31
2002-03	1	2.02	1.64	15.35
	2	4.77	1.47	36.22
	3	6.33	1.37	48.50
	4	1.00	1.71	6.50
2003-04	1	1.10	1.70	8.19
	2	0.13	1.76	0.92
	3	3.47	1.56	25.28
	4	1.48	1.67	11.23
2004-05	1	0.31	1.74	2.24
	2	1.23	1.68	10.23
	3	4.49	1.44	39.93
	4	1.10	1.69	9.16
2005-06	1	0.69	1.72	5.64
	2	6.82	1.24	64.47
	3	10.14	0.94	100.91
	4	2.19	1.60	20.27
2006-07	1	1.12	1.69	9.36
	2	9.54	1.02	91.71
	3	9.76	0.97	97.07
	4	2.69	1.56	24.60
2007-08	1	0.72	1.71	5.90
	2	13.05	0.71	128.79
	3	11.46	0.84	113.85
	4	1.57	1.65	13.77
2008-09	1	0.00	1.76	0.00
	2	2.55	1.58	22.74
	3	8.73	1.06	86.46
	4	1.31	1.67	11.21

Table A 6.2

NAGARJUNA SAGAR LEFT CANAL POWER HOUSE

SCENARIO OF WATER WITHDRAWALS:

Year		Water with drawals (in hundred million cubic meters)	X-code	4-q-m-a	centred	Specific Seasonal	Deseasonalised
2001-02	1Summer	0.00	1				0.00
	2 Rainy	0.00	2				0.00
	3 Winter	22.24	3	6.6	6.6	3.39	11.09
	4 Post Monsoon	4.12	4	6.6	6.6	0.62	4.62
2002-03	Summer	0.00	5	6.6	3.8	0	0.00
	Rainy	0.00	6	1.0	0.5	0	0.00
	Winter	0.00	7	0.0	0.0	0	0.00
	Post Monsoon	0.00	8	0.0	0.0	0	0.00
2003-04	Summer	0.00	9	0.0	0.0	0	0.00
	Rainy	0.00	10	0.0	0.0	0	0.00
	Winter	0.00	11	0.0	0.0	0	0.00
	Post Monsoon	0.00	12	0.0	0.0	0	0.00
2004-05	Summer	0.00	13	0.0	1.3	0	0.00
	Rainy	0.00	14	2.5	2.5	0	0.00
	Winter	10.16	15	2.5	3.7	2.75	5.03
	Post Monsoon	0.00	16	4.9	6.7	0	0.00
2005-06	Summer	9.26	17	8.4	12.7	0.73	15.2
	Rainy	14.38	18	16.9	21.8	0.66	29.3
	Winter	43.96	19	26.8	25.6	1.72	21.76
	Post Monsoon	39.43	20	24.4	25.5	1.55	44.30
2006-07	Summer	0.00	21	26.5	28.7	0	0
	Rainy	22.70	22	30.8	39.1	0.58	37.21
	Winter	61.24	23	47.4	47.4	1.29	30.32
	Post Monsoon	105.66	24	47.4	50.1	2.11	118.72
2007-08	Summer	0.00	25	52.9	63.1	0	0
	Rainy	44.68	26	73.4	60.3	0.74	91.18
	Winter	143.12	27	47.3	47.3	3.02	70.85
	Post Monsoon	1.41	28	47.3	43.1	0.03	1.58

2008-09	Summer	0.00	29	38.9	34.9	0	0
	Rainy	11.04	30	30.9	35.0	0.32	22.53
	Winter	111.14	31	39.0		0	55.02
	Post Monsoon	33.97	32			0	38.17

Calculation of Seasonal Index

Year	Summer	Rainy	Winter	Post Monsoon
2001-02	0	0	3.39	0.62
2002-03	0.0	0	0	0
2003-04	0	0	0	0
2004-05	0	0	2.75	0
2005-06	0.73	0.66	1.72	1.55
2006-07	0	0.58	1.29	2.11
2007-08	0	0.74	3.03	0.03
2008-09	0	0.32		
Total	0.73	2.3	12.17	4.31
Unadjusted Mean	0.73	0.58	2.4	1.07
Adjusted Seasonal Mean	0.61	0.49	2.02	0.89
Index	61	49	202	89

Correction Factor = 4/4.78 = 0.84

Multiply with the correction factor 0.84 with unadjusted mean to get the adjusted seasonal mean.

As per the Indian monsoon conditions, the Seasonal index values calculated are as follows:

Final SVI	61+67 =61	49 + 29 =49	202-67 = 135	89-29 =60

Trend equation: y = -11.8+ 2.0

Seasonalized Forecast of Water Withdrawals

Year	X-code	Trend Unadjusted Forecast	Seasonal Index	Forecast
2009-10				
Summer	33	54.2	0.61	33.06
Rainy	34	56.2	0.49	27.54
Winter	35	58.2	2.02	117.56
Post Monsoon	36	60.2	0.89	53.58
2010-2011				
Summer	37	62.2	0.61	37.94
Rainy	38	64.2	0.49	31.46
Winter	39	66.2	2.02	133.72
Post Monsoon	40	68.2	0.89	60.69
2011-2012				
Summer	41	70.2	0.61	42.82

Rainy	42	72.2	0.49	35.38
Winter	43	74.2	2.02	149.88
Post Monsoon	44	76.2	0.89	67.82
2012-2013				
Summer	45	78.2	0.61	47.70
Rainy	46	80.2	0.49	39.29
Winter	47	82.2	2.02	166.04
Post Monsoon	48	84.2	0.89	74.94
2013-2014				
Summer	49	86.2	0.61	52.58
Rainy	50	88.2	0.49	43.22
Winter	51	90.2	2.02	182.20
Post Monsoon	52	92.2	0.89	82.06

SCENARIO OF LOSS OF GENERATION:

Year		Loss Generation due to WS (in hundred million units)	X-code	4-q-m-a	centred	Specific seasonal	Deseasonalised
2001-02	1Summer	1.98	1				2.13
	2 Rainy	1.98	2				2.04
	3 Winter	1.77	3	1.9	1.9	0.93	1.45
	4 Post Monsoon	1.96	4	1.9	1.9	1.03	2.01
2002-03	1Summer	1.98	5	1.9	2.0	0.99	2.13
	2 Rainy	1.98	6	2.0	2.0	0.99	2.04
	3 Winter	1.98	7	2.0	2.0	0.99	1.63
	4 Post Monsoon	1.98	8	2.0	2.0	0.99	2.03
2003-04	1Summer	1.98	9	2.0	2.0	0.99	2.13
	2 Rainy	1.98	10	2.0	2.0	0.99	2.04
	3 Winter	1.98	11	2.0	2.0	0.99	1.63
	4 Post Monsoon	1.98	12	2.0	2.0	0.99	2.03
2004-05	1Summer	1.98	13	2.0	2.0	0.99	2.13
	2 Rainy	1.98	14	2.0	2.0	0.99	2.04
	3 Winter	1.94	15	2.0	2.0	0.97	1.59
	4 Post Monsoon	1.98	16	2.0	1.9	1.04	2.03
2005-06	1Summer	1.93	17	1.9	1.8	1.07	2.08
	2 Rainy	1.79	18	1.8	1.7	1.05	1.84
	3 Winter	1.33	19	1.7	1.7	0.78	1.09
	4 Post Monsoon	1.64	20	1.7	1.7	0.96	1.68
2006-07	1Summer	1.98	21	1.7	1.6	1.24	2.13
	2 Rainy	1.67	22	1.6	1.6	1.043	1.72
	3 Winter	1.11	23	1.6	1.6	0.69	0.91
	4 Post	1.65	24	1.6	1.6	1.031	1.69

	Monsoon						
2007-08	1Summer	1.98	25	1.6	1.6	1.24	2.13
	2 Rainy	1.75	26	1.7	1.7	1.03	1.80
	3 Winter	1.29	27	1.7	1.7	0.76	1.06
	4 Post Monsoon	1.91	28	1.7	1.8	1.06	1.95
2008-09	1Summer	1.98	29	1.8	1.8	1.1	2.13
	2 Rainy	1.93	30	1.8	1.8	1.07	1.99
	3 Winter	1.25	31	1.8			1.03
	4 Post Monsoon	1.90	32				1.94

Calculation of Seasonal Index

Year	Summer	Rainy	Winter	Post Monsoon
2001-02	0	0	0.93	1.03
2002-03	0.99	0.99	0.99	0.99
2003-04	0.99	0.99	0.99	0.99
2004-05	0.99	0.99	0.97	1.04
2005-06	1.07	1.05	0.78	0.96
2006-07	1.24	1.04	0.69	1.03
2007-08	1.24	1.03	0.76	1.06
2008-09	1.1	1.07		
Total	7.62	7.16	6.11	7.1
Unadjusted Mean	1.09	1.02	0.87	1.01
Adjusted Seasonal Mean	1.09	1.02	0.87	1.01
Index	109	102	87	101

As per the Indian monsoon conditions, the Seasonal index values calculated are as follows:

Final SVI	109+29 =138	102+34 =136	87-29 = 58	101-34 =67s

Trend equation: y = 20.2 – 0.012 x

Seasonalized Forecast of Loss of Generation

Year	X-code	Trend	Seasonal Index	Forecast
2009-10				
Summer	33	19.80	1.09	21.58
Rainy	34	19.79	1.02	20.19
Winter	35	19.78	0.87	17.21
Post Monsoon Season	36	19.77	1.01	19.97
2010-2011				

Summer	37	19.76	1.09	21.53
Rainy	38	19.74	1.02	20.14
Winter	39	19.73	0.87	17.17
Post Monsoon Season	40	19.72	1.01	19.92
2011-2012				
Summer	41	19.71	1.09	21.5
Rainy	42	19.69	1.02	20.1
Winter	43	19.68	0.87	17.1
Post Monsoon Season	44	19.67	1.01	19.86
2012-2013				
Summer	45	19.66	1.09	21.42
Rainy	46	19.65	1.02	20.09
Winter	47	19.64	0.87	17.08
Post Monsoon season	48	19.62	1.01	19.8
2013-2014				
Summer	49	19.61	1.09	21.38
Rainy	50	19.6	1.02	19.99
Winter	51	19.59	0.87	17.04
Post Monsoon season	52	19.57	1.01	19.77

Forecast of Water Withdrawals (in Hundred million cubic meters) versus Loss of Generation (in hundred million units)*[9]

Quarter	Summer	Rainy	Winter	Post Monsoon Season
2009-10 WD (in hundred million cubic meters) LG (in million units)	72.24 27.32	45.4 26.85	78.38 11.47	35.72 13.31
2010-2011 WD LG	82.51 27.25	51.69 26.78	89.15 11.45	40.46 13.28
2011-2012 WD LG	92.78 27.2	57.99 26.72	99.92 11.4	45.21 13.24
2012-2013 WD LG	103.05 27.11	64.27 26.69	110.69 11.39	49.96 13.2
2013-2014 WD LG	113.31 27.06	70.57 26.58	121.47 11.36	54.71 13.18

[1] Calculated figures of Final Seasonal Forecast figures as per Indian Monsoon Conditions

Season Wise Varying levels of Plant Load Factor (Percentage)

Year	Quarters	Water Withdrawals (Hundred Million Cubic Meters)	Loss of Generation due to water shortage (hundred Million Units)	Plant Load Factor (PLF) percentage
2001-02	Summer 1	0.00	1.98	0.00
	Rainy 2	0.00	1.98	0.00
	Winter3	22.24	1.77	32.39
	Post Monsoon Season 4	4.12	1.96	2.95
2002-03	1	0.00	1.98	0.00
	2	0.00	1.98	0.00
	3	0.00	1.98	0.00
	4	0.00	1.98	0.00
2003-04	1	0.00	1.98	0.00
	2	0.00	1.98	0.00
	3	0.00	1.98	0.00
	4	0.00	1.98	0.00
2004-05	1	0.00	1.98	0.00
	2	0.00	1.98	0.00
	3	10.16	1.94	7.14
	4	0.00	1.98	0.00
2005-06	1	9.26	1.93	7.24
	2	14.38	1.79	29.67
	3	43.96	1.33	99.15
	4	39.43	1.64	51.53
2006-07	1	0.00	1.98	0.00
	2	22.70	1.67	46.84
	3	61.24	1.11	132.76
	4	105.66	1.65	49.94
2007-08	1	0.00	1.98	0.00
	2	44.68	1.75	35.67
	3	143.12	1.29	105.04
	4	1.41	1.91	11.02
2008-09	1	0.00	1.98	0.00
	2	11.04	1.93	8.01

	3	111.14	1.25	110.42
	4	33.97	1.90	12.72

Table A 6.3

NAGARJUNA SAGAR RIGHT CANAL POWER HOUSE

SCENARIO OF WATER WITHDRAWALS:

Year		Water with drawals (in hundred million cubic meters)	X-code	4-q-m-a	centered	Specific seasonal	Deseasonalised
2001-02	1Summer	0.00	1				0.00
	2 Rainy	0.00	2				0.00
	3 Winter	37.02	3	15.0	15.0	2.5	21.3
	4 Post Monsoon	22.90	4	15.0	15.0	1.53	21.6
2002-03	1Summer	0.00	5	15.0	10.4	0	0.00
	2 Rainy	0.00	6	5.7	2.9	0	0.00
	3 Winter	0.00	7	0.0	0.0	0	0.00
	4 Post Monsoon	0.00	8	0.0	0.0	0	0.00
2003-04	1Summer	0.00	9	0.0	0.0	0	0.00
	2 Rainy	0.00	10	0.0	0.0	0	0.00
	3 Winter	0.00	11	0.0	0.0	0	0.00
	4 Post Monsoon	0.00	12	0.0	0.2	0	0.00
2004-05	1Summer	0.00	13	0.4	6.8	0	0.00
	2 Rainy	1.51	14	13.2	13.8	0.11	6.7
	3 Winter	51.48	15	14.4	18.3	2.8	29.6
	4 Post Monsoon	4.49	16	22.2	23.3	0.19	4.2
2005-06	1Summer	31.34	17	24.4	26.8	1.17	31.9
	2 Rainy	10.43	18	29.2	36.8	0.28	46.11
	3 Winter	70.59	19	44.4	42.2	1.67	40.6
	4 Post Monsoon	65.42	20	39.9	41.5	1.57	62.6
2006-07	1Summer	13.25	21	43.1	50.0	0.27	13.5
	2 Rainy	23.06	22	57.0	74.3	0.31	101.9
	3 Winter	126.12	23	91.6	90.0	1.4	72.5
	4 Post Monsoon	204.17	24	88.3	92.7	2.20	192.36
2007-08	1Summer	0.00	25	97.0	110.9	0	0.00
	2 Rainy	57.62	26	124.8	113.5	0.51	58.6
	3 Winter	237.49	27	102.2	146.0	1.63	136.5
	4 Post	113.70	28	189.7	184.4	0.62	107.12

	Monsoon						
2008-09	1Summer	350.15	29	179.1	178.2	1.96	356.2
	2 Rainy	15.16	30	177.3	176.2	0.09	67.02
	3 Winter	230.27	31	175.1			132.3
	4 Post Monsoon	104.73	32				98.7

Calculation of Seasonal Index

Year	Summer	Rainy	Winter	Post Monsoon
2001-02			2.5	1.53
2002-03	0	0	0	0
2003-04	0	0	0	0
2004-05	0	0.11	2.8	0.19
2005-06	1.17	0.28	1.67	1.57
2006-07	0.27	0.31	1.4	2.20
2007-08	0	0.51	1.63	0.62
2008-09	1.96	0.09		
Total	3.4	1.3	10	6.11
Unadjusted Mean	1.13	0.26	2	1.22
Adjusted Seasonal Mean	0.9831	0.2262	1.74	1.0614
Index	98.31	22.62	174	106.14

As per the Indian monsoon conditions, the Seasonal index values calculated are as follows:

Final SVI	98.31+58 =156	22.62+35 =58	174-58 = 116	106.14-35 =106.14

Correction Factor = 4/4.61 = 0.87
Trend equation: y = -4.14+ 0.59 x

Seasonalized Forecast of Water Withdrawals

Year	X-code	Trend Unadjusted Forecast	Seasonal Index	Forecast (in hundred million cubic meters)
2009-10				
Summer	33	15.33	0.9831	15.07
Rainy	34	15.92	0.2262	3.6
Winter	35	16.51	1.74	28.72
Post Monsoon	36	17.1	1.0614	18.1
2010-2011				

Summer	37	17.32	0.9831	17.03
Rainy	38	18.28	0.2262	4.13
Winter	39	18.87	1.74	32.83
Post Monsoon	40	19.46	1.0614	20.6
2011-2012				
Summer	41	20.05	0.9831	19.71
Rainy	42	20.64	0.2262	4.7
Winter	43	21.23	1.74	36.94
Post Monsoon	44	21.82	1.0614	23.16
2012-2013				
Summer	45	22.41	0.9831	22.03
Rainy	46	23	0.2262	5.2
Winter	47	23.59	1.74	41.05
Post Monsoon	48	24.18	1.0614	25.66
2013-2014				
Summer	49	24.5	0.9831	24.09
Rainy	50	25.36	0.2262	5.74
Winter	51	25.95	1.74	45.15
Post Monsoon	52	26.54	1.0614	28.17

SCENARIO OF LOSS OF GENERATION:

Year		Loss Generation due to WS (in million units)	X-code	4-q-m-a	centred	Specific Seasonal	Deseasonalised
2001-02	1Summer	132.18	1				197.28
	2Rainy	132.18	2				133.51
	3 Winter	86.90	3	117.4	117.4	0.74	66.34
	4 Post Monsoon	118.44	4	117.4	117.4	1.01	114.9
2002-03	1Summer	132.18	5	117.4	123.1	0	197.28
	2Rainy	132.18	6	128.7	130.5	0	133.51
	3 Winter	132.18	7	132.2	132.2	0	100.90
	4 Post Monsoon	132.18	8	132.2	132.2	0	128.33
2003-04	1Summer	132.18	9	132.2	132.2	0	197.28
	2Rainy	132.18	10	132.2	132.2	0	133.51
	3 Winter	132.18	11	132.2	132.2	0	100.90
	4 Post Monsoon	132.18	12	132.2	132.0	0	128.33
2004-05	1Summer	132.18	13	131.8	126.4	0	197.28
	2Rainy	130.81	14	121.0	120.4	0.11	132.13
	3 Winter	88.74	15	119.9	116.9	2.8	67.74
	4 Post Monsoon	127.75	16	113.8	111.3	0.19	124.03
2005-06	1Summer	108.10	17	108.7	98.4	1.17	161.34
	2Rainy	110.06	18	88.2	78.6	0.28	111.17
	3 Winter	6.89	19	68.9	71.7	1.67	-5.26

	4 Post Monsoon	50.74	20	74.5	72.0	1.57	49.26
2006-07	1Summer	130.44	21	69.4	67.3	0.265	194.69
	2Rainy	89.43	22	65.1	68.6	0.31	90.33
	3 Winter	-10.03	23	72.1	72.3	1.40	-7.7
	4 Post Monsoon	78.54	24	72.5	72.9	2.20	76.25
2007-08	1Summer	132.24	25	73.3	74.4	0	197.37
	2Rainy	92.61	26	75.5	78.3	0.51	93.54
	3 Winter	-1.33	27	81.1	70.1	1.63	-1.02
	4 Post Monsoon	100.88	28	59.1	62.9	0.62	97.94
2008-09	1Summer	44.08	29	66.8	67.0	1.96	65.79
	2Rainy	123.67	30	67.2	67.6	0.09	124.92
	3 Winter	0.33	31	67.9			0.25
	4 Post Monsoon	103.61	32				100.59

Calculation of Seasonal Index

Year	Summer	Rainy	Winter	Post Monsoon
2001-02			0.74	1.01
2002-03	0	0	0	0
2003-04	0	0	0	0
2004-05	0	0.11	2.8	0.19
2005-06	1.17	0.28	1.67	1.57
2006-07	0.265	0.31	1.40	2.20
2007-08	0	0.51	1.63	0.62
2008-09	1.96	0.09		
Total	3.51	6.51	8.63	5.59
Unadjusted Mean	0.88	1.3	1.73	1.35
Adjusted Seasonal Mean	0.67	0.99	1.31	1.03
Index	67	99	131	102.6

As per the Indian monsoon conditions, the Seasonal index values calculated are as follows:

Final SVI	67+44 =111	99+34 =133	131-44 = 87	103-34 =69

Correction Factor = 4/5.26 = 0.76

Trend equation: y = 14.2 – 0.26 x

Seasonalized Forecast of Loss of Generation

Year	X-code	Trend Unadjusted Forecast	Seasonal Index	Forecast (in million units)
2009-10				
Summer	33	5.62	0.67	3.8
Rainy	34	5.36	0.99	5.3
Winter	35	5.1	1.31	6.7
Post Monsoon	36	4.84	1.03	4.99
2010-2011				
Summer	37	4.58	0.67	3.07
Rainy	38	4.58	0.99	4.5
Winter	39	4.04	1.31	5.3
Post Monsoon	40	3.8	1.03	3.9
2011-2012				
Summer	41	3.54	0.67	2.4
Rainy	42	3.28	0.99	3.2
Winter	43	3.02	1.31	3.9
Post Monsoon	44	2.76	1.03	2.8
2012-2013				
Summer	45	2.5	0.67	1.7
Rainy	46	2.5	0.99	2.2
Winter	47	1.98	1.31	2.6
Post Monsoon	48	0.68	1.03	0.70
2013-2014				
Summer	49	1.46	0.67	0.98
Rainy	50	1.2	0.99	1.19
Winter	51	0.94	1.31	1.23
Post Monsoon	52	0.68	1.03	0.70

Forecast of Water Withdrawals (in Hundred million cubic meters) versus Loss of Generation (in million units)*[10]

Quarter	Summer	Rainy	Winter	Post Monsoon Season
2009-10				
WD	24.64	9.63	19.15	12.07
LG	6.03	6.96	4.47	3.33
2010-2011				
WD	29.28	7.9	23.93	13.94
LG	4.84	5.62	3.53	2.13
2011-2012				
WD	32.01	12.39	24.63	15.44
LG	3.7	4.13	2.6	1.87
2012-2013				
WD	35.71	13.70	27.37	17.1
LG	2.57	2.43	1.73	0.49
2013-2014				
WD	39.14	15.13	30.1	18.78
LG	1.39	1.42	0.82	0.97

[10] Calculated figures of Final Seasonal Forecast figures as per Indian Monsoon Conditions

Season Wise Varying levels of Plant Load Factor (Percentage)

Year	Quarters	Water Withdrawals (In Hundred Million Cubic Meters)	Loss of Generation due to water shortage (Million Units)	Plant Load Factor (PLF) percentage
2001-02	Summer 1	0.00	132.18	0.00
	Rainy 2	0.00	132.18	0.00
	Winter3	37.02	86.90	2.52
	Post Monsoon Season 4	22.90	118.44	0.76
2002-03	1	0.00	132.18	0.00
	2	0.00	132.18	0.00
	3	0.00	132.18	0.00
	4	0.00	132.18	0.00
2003-04	1	0.00	132.18	0.00
	2	0.00	132.18	0.00
	3	0.00	132.18	0.00
	4	0.00	132.18	0.00
2004-05	1	0.00	132.18	0.00
	2	1.51	130.81	0.06
	3	51.48	88.74	1.74
	4	4.49	127.75	0.17
2005-06	1	31.34	108.10	8.16
	2	10.43	110.06	3.64
	3	70.59	6.89	20.14
	4	65.42	50.74	22.07
2006-07	1	13.25	130.44	0.23
	2	23.06	89.43	0.68
	3	126.12	-10.03	2.19
	4	204.17	78.54	2.19
2007-08	1	0.00	132.24	0.09
	2	57.62	92.61	0.62
	3	237.49	-1.33	2.16
	4	113.70	100.88	1.21
2008-09	1	350.15	44.08	0.03
	2	15.16	123.67	0.26

	3	230.27	0.33	2.14
	4	104.73	103.61	1.21

Table A6.4

SRISAILAM LEFT CANAL POWER HOUSE

SCENARIO OF WATER WITHDRAWALS:

Year		Water with drawals (in hundred million cubic meters)	X-code	4-q-m-a	centered	Specific Seasonal	Deseasonalised
2001-02	1	19.78	1				22.63
	2	6.95	2				20.11
	3	20.07	3	13.9	13.4	1.49	12.9
	4	8.69	4	12.9	12.5	0.69	6.2
2002-03	1	15.72	5	12.0	14.8	1.06	17.98
	2	3.69	6	17.6	20.3	0.18	10.68
	3	42.46	7	23.0	22.3	1.90	27.30
	4	29.93	8	21.7	21.2	1.41	21.38
2003-04	1	10.56	9	20.7	16.8	0.63	12.08
	2	0.00	10	12.9	12.6	0	0
	3	11.24	11	12.2	16.9	0.67	7.23
	4	26.96	12	21.6	23.3	1.29	19.26
2004-05	1	48.23	13	25.0	33.0	1.46	55.18
	2	13.54	14	41.1	47.0	0.28	39.18
	3	75.50	15	52.9	55.9	1.35	48.55
	4	74.49	16	58.9	62.1	1.19	53.21
2005-06	1	72.17	17	65.2	78.0	0.93	82.57
	2	38.78	18	90.7	92.4	0.42	112.07
	3	177.41	19	94.1	87.0	2.04	114.07
	4	87.92	20	80.0	76.7	1.15	62.8
2006-07	1	15.85	21	73.3	52.8	0.30	18.13
	2	12.12	22	32.2	22.3	0.54	35.07

	3	12.93	23	12.4	10.8	1.19	8.52
	4	8.56	24	9.2	7.9	1.08	15.86
2007-08	1	3.33	25	6.6	6.6	0.50	3.81
	2	1.54	26	6.7	8.4	0.18	4.46
	3	13.25	27	10.1			8.52
	4	22.21	28				15.86

Calculation of Seasonal Index

Year	Summer	Rainy	Winter	Post Monsoon
2001-02			1.49	0.69
2002-03	1.06	0.18	1.90	1.41
2003-04	0.63	0	0.67	1.29
2004-05	1.46	0.28	1.35	1.19
2005-06	0.93	0.42	2.04	1.15
2006-07	0.30	0.54	1.19	1.08
2007-08	0.50	0.18		
Total	4.88	1.6	8.64	6.81
Unadjusted Mean	0.81	0.32	1.44	1.13
Adjusted Seasonal Mean	0.874	0.3456	1.5552	1.4
Index	87.4	34.56	155.5	140.4

As per the Indian monsoon conditions, the Seasonal index values calculated are as follows:

Final SVI	87.4 +51.83 =139.23	34.56+46.8 =81.36	155-51.83 = 103.67	140.4-46.8 =93.6

Correction Factor = 4 /3.7 = 1.08

Trend equation: $y = 23.0 + 0.57\ x$

Seasonalized Forecast of Water Withdrawals:

Year	X-code	Trend Unadjusted Forecast	Seasonal Index	Forecast (in hundred million cubic meters)
2008-09				
Summer	29	39.53	0.874	34.55
Rainy	30	40.1	0.3456	13.9
Winter	31	40.67	1.5552	63.25
Post Monsoon	32	41.2	1.4	57.68
2009-2010				
Summer	33	41.81	0.874	6.54
Rainy	34	42.38	0.3456	14.65
Winter	35	42.95	1.5552	66.79
Post Monsoon	36	43.52	1.4	60.93
2010-2011				
Summer	37	49.09	0.874	42.90

Rainy	38	44.66	0.3456	15.43
Winter	39	45.23	1.5552	70.34
Post Monsoon	40	45.8	1.4	64.14
2011-2012				
Summer	41	46.37	0.874	40.53
Rainy	42	46.94	0.3456	16.22
Winter	43	47.51	1.5552	73.89
Post Monsoon	44	48.09	1.4	67.33
2012-2013				
Summer	45	48.65	0.874	42.52
Rainy	46	49.22	0.3456	17.01
Winter	47	49.79	1.5552	77.43
Post Monsoon	48	50.36	1.4	70.50
2013-2014				
Summer	49	50.93	0.874	44.51
Rainy	50	51.5	0.3456	45.01
Winter	51	52.07	1.5552	80.9
Post Monsoon Season	52	52.64	1.4	73.69

SCENARIO OF LOSS OF GENERATION:

Year		Loss Generation due to WS (in thousand million units)	X-code	4-q-m-a	centered	Specific Seasonal	Deseasonalised
2001-02	1	1.81	1				1.71
	2	0.60	2				0.55
	3	1.80	3	1.5	1.5	1	2.14
	4	1.88	4	1.5	1.7	1.04	1.92
2002-03	1	1.85	5	1.9	1.8	1.1	1.75
	2	1.92	6	1.8	1.8	1.03	1.75
	3	1.68	7	1.8	1.8	0.93	1.99
	4	1.76	8	1.8	1.8	0.97	1.79
2003-04	1	1.88	9	1.8	1.8	1.04	1.77
	2	1.94	10	1.9	1.9	1.02	1.76
	3	1.87	11	1.9	1.8	1.04	2.2
	4	1.77	12	1.8	1.8	0.98	1.8
2004-05	1	1.63	13	1.8	1.7	0.96	1.54
	2	1.87	14	1.7	1.6	1.17	1.70
	3	1.40	15	1.6	1.6	0.87	1.66
	4	1.40	16	1.5	1.5	0.93	1.43
2005-	1	1.45	17	1.5	1.4	1.04	1.37

06							
	2	1.69	18	1.4	1.3	1	1.54
	3	0.85	19	1.3	1.4	0.61	1.01
	4	1.38	20	1.4	1.4	0.99	1.41
2006-07	1	1.74	21	1.4	1.5	1.16	1.64
	2	1.82	22	1.5	1.5	1.21	1.66
	3	1.01	23	1.5	1.5	.67	1.20
	4	1.54	24	1.5	1.5	1.03	1.57
2007-08	1	1.56	25	1.4	1.4	1.02	1.47
	2	1.60	26	1.3	1.3	1.11	1.46
	3	0.66	27	1.4	1.2	1.23	0.78
	4	1.59	28	1.0			1.62

Calculation of Seasonal Index

Year	Summer	Rainy	Winter	Post Monsoon
2001-02			1	1.04
2002-03	1.1	1.03	0.93	0.97
2003-04	1.04	1.02	1.04	0.98
2004-05	0.96	1.17	0.87	0.93
2005-06	1.04	1	0.61	0.99
2006-07	1.16	1.21	0.67	1.03
2007-08	1.11	1.23		
Total	6.41	6.66	5.12	5.94
Unadjusted Mean	1.07	1.11	0.85	0.99
Adjusted Seasonal Mean	1.0593	1.099	0.8415	0.9801
Index	105.93	109.9	84.15	98.01

As per the Indian monsoon conditions, the Seasonal index values calculated are as follows:

Final SVI	105.93+28.05 =133.98	109.9+32.67 =142.57	84.15-28.05 =56.1	98.01-32.67 =65.34

Correction Factor = 4/4.02 = 0.99

Trend equation: y = 1.79 - 0.015 x

Seasonalized Forecast of Loss of Generation:

Year	X-code	Trend Unadjusted Forecast	Seasonal Index	Forecast (in thousand million units)
2008-09				
Summer	29	1.355	1.0593	1.44
Rainy	30	1.34	1.099	1.47
Winter	31	1.325	0.8415	1.11

Post Monsoon	32	1.31	0.9801	1.28
2009-2010				
Summer	33	1.295	1.0593	1.37
Rainy	34	1.28	1.099	1.41
Winter	35	1.265	0.8415	1.06
Post Monsoon	36	1.25	0.9801	1.23
2010-2011				
Summer	37	1.35	1.0593	1.43
Rainy	38	1.22	1.099	1.34
Winter	39	1.205	0.8415	1.01
Post Monsoon	40	1.19	0.9801	1.16
2011-2012				
Summer	41	1.18	1.0593	1.25
Rainy	42	1.16	1.099	1.27
Winter	43	1.15	0.8415	0.97
Post Monsoon	44	1.13	0.9801	1.11
2012-2013				
Summer	45	1.11	1.0593	1.17
Rainy	46	1.1	1.099	1.21
Winter	47	1.085	0.8415	0.91
Post Monsoon	48	1.07	0.9801	1.05
2013-2014				
Summer	49	1.055	1.0593	1.12
Rainy	50	1.04	1.099	1.14
Winter	51	1.02	0.8415	0.859
Post Monsoon Season	52	1.01	0.9801	0.99

Forecast of Water Withdrawals (in Hundred million cubic meters) versus Loss of Generation (in thousand million units)*[11]

Quarter	Summer	Rainy	Winter	Post Monsoon Season
2008-09 WD LG	55.63 1.81	33.13 1.9	42.17 0.74	38.45 0.85
2009-10 WD LG	28.8 1.72	34.9 1.82	44.53 0.71	40.62 0.82
2010-2011 WD LG	66.35 1.77	36.81 1.73	46.89 0.67	42.76 0.77
2011-2012 WD LG	65.16 1.57	38.66 1.64	49.26 0.65	44.89 0.74
2012-2013 WD LG	68.33 1.47	40.51 1.56	51.62 0.61	46.98 0.7
2013-2014 WD LG	71.48 1.41	69.57 1.47	53.93 0.57	4s9.13 0.66

[11] Calculated figures of Final Seasonal Forecast figures as per Indian Monsoon Conditions

Season Wise Varying Levels of Plant Load Factor (Percentage)

Year	Quarters	Water Withdrawals (In Hundred Million Cubic Meters)	Loss of Generation due to water shortage (in thousand Million Units)	Plant Load Factor (PLF) percentage
2001-02	Summer 1	19.78	1.81	20.76
	Rainy 2	6.95	0.60	6.96
	Winter3	20.07	1.80	21.65
	Spring 4	8.69	1.88	10.15
2002-03	1	15.72	1.85	15.31
	2	3.69	1.92	3.58
	3	42.46	1.68	40.94
	4	29.93	1.76	28.23
2003-04	1	10.56	1.88	9.44
	2	0.00	1.94	0.00
	3	11.24	1.87	11.73
	4	26.96	1.77	27.89
2004-05	1	48.23	1.63	48.81
	2	13.54	1.87	11.94
	3	75.50	1.40	83.97
	4	74.49	1.40	84.04
2005-06	1	72.17	1.45	76.04
	2	38.78	1.69	38.90
	3	177.41	0.85	168.61
	4	87.92	1.38	87.07
2006-07	1	15.85	1.74	31.85
	2	12.12	1.82	20.02
	3	12.93	1.01	144.12
	4	8.56	1.54	62.82
2007-08	1	3.33	1.56	58.88
	2	1.54	1.60	53.60
	3	13.25	0.66	198.27
	4	22.21	1.59	55.09

Table A 6.5

SRISAILAM RIGHT CANAL POWER HOUSE

SCENARIO OF WATER WITHDRAWALS:

Year		Water with drawals (in hundred million cubic meters)	X-code	4-q-m-a	centered	Specific Seasonal	Deseasonalised
2000-01	1	4.77	1				12.9
	2	9.33	2				10.72
	3	17.76	3	10.3	10.5	1.69	5.12
	4	9.21	4	10.7	10.4	0.88	9.7
2001-02	1	6.32	5	10.2	9.0	0.70	17.1
	2	7.40	6	7.9	7.6	0.97	8.5
	3	8.63	7	7.2	6.5	1.33	4.8
	4	6.59	8	5.7	4.9	1.34	6.9
2002-03	1	0.07	9	4.2	3.7	0.02	0.19
	2	1.40	10	3.2	2.5	0.56	1.7
	3	4.77	11	1.8	1.8	2.65	2.65
	4	0.87	12	1.8	1.6	0.54	0.92
2003-04	1	0.00	13	1.4	1.1	0	0
	2	0.00	14	0.8	1.0	0	0
	3	2.50	15	1.2	1.3	1.9	1.39
	4	2.13	16	1.4	1.8	1.18	2.24
2004-05	1	0.77	17	2.3	2.9	0.27	2.08
	2	3.63	18	3.5	3.3	1.1	4.2
	3	7.31	19	3.2	3.4	2.15	4.06
	4	1.14	20	3.6	4.0	0.29	1.2
2005-06	1	2.49	21	4.4	4.8	0.52	6.7
	2	6.66	22	5.1	5.5	1.21	7.7
	3	10.22	23	5.9	5.8	1.76	5.7
	4	4.29	24	5.7	5.0	0.86	4.5
2006-07	1	1.73	25	4.3	3.2	0.54	4.7
	2	1.07	26	2.0	1.6	0.67	1.23

	3	0.90	27	1.2	1.0	0.9	0.5
	4	1.24	28	0.8	0.8	1.55	1.3
2007-08	1	0.17	29	0.7	0.9	0.19	0.45
	2	0.68	30	1.0	1.0	0.68	0.78
	3	2.06	31	1.0			1.14
	4	1.13	32				1.19

Calculation of Seasonal Index

Year	Summer	Rainy	Winter	Post Monsoon
2000-01			1.69	0.88
2001-02	0.70	0.97	1.33	1.34
2002-03	0.02	0.56	2.65	0.54
2003-04	0	0	1.9	1.18
2004-05	0.27	1.1	2.15	0.29
2005-06	0.52	1.21	1.76	0.86
2006-07	0.54	0.67	0.9	1.55
2007-08	0.19	0.68		
Total	2.24	5.19	12.38	6.64
Unadjusted Mean	0.37	0.87	1.8	0.95
Adjusted Seasonal Mean	0.37	0.87	1.8	0.95
Index	37	87	180	95

As per the Indian monsoon conditions, the Seasonal index values calculated are as follows:

Final SVI	37 +60= 97	87 +31.67 =118.67	180-60 =120	95-31.67 =63.33

Correction factor = 4/3.99 =1

Trend equation: y = 7.70 - 0.23 x

Seasonalized Forecast of Water Withdrawals:

Year	X-code	Trend Unadjusted Forecast	Seasonal Index	Forecast
2008-09				
Summer	29	1.03	0.37	0.38
Rainy	30	0.8	0.87	0.69
Winter	31	0.57	1.8	1.03
Post Monsoon	32	0.34	0.95	0.32
2009-2010				
Summer	33	0.11	0.37	0.41
Rainy	34	-0.12	0.87	-1.04
Winter	35	-0.35	1.8	-0.63
Post Monsoon	36	-0.58	0.95	-0.55
2010-2011				
Summer	37	-0.81	0.37	-0.29

Rainy	38	-1.04	0.87	-0.90
Winter	39	-1.27	1.8	-2.3
Post Monsoon	40	-1.5	0.95	-1.4
2011-2012				
Summer	41	-1.73	0.37	-0.64
Rainy	42	-1.96	0.87	-3.9
Winter	43	-2.19	1.8	-2.3
Post Monsoon	44	-2.42	0.95	-2.29
2012-2013				
Summer	45	-2.65	0.37	-0.98
Rainy	46	-2.88	0.87	-2.51
Winter	47	-3.11	1.8	-5.6
Post Monsoon	48	-3.34	0.95	-3.2
2013-2014				
Summer	49	-3.57	0.37	-1.32
Rainy	50	-3.8	0.87	-3.31
Winter	51	-4.03	1.8	-7.3
Post Monsoon Season	52	-4.26	0.95	-4.05

SCENARIO OF LOSS OF GENERATION:

Year		Loss of Generation due to WS(in thousand million units)	X-code	4-q-m-a	centered	Specific Seasonal	Deseasonalised
2000-01	1	1.35	1				1.4
	2	1.03	2				0.95
	3	0.34	3	0.9	0.9	0.38	0.37
	4	0.99	4	0.9	0.9	1.1	0.92
2001-02	1	1.28	5	1.0	1.0	1.28	1.35
	2	1.21	6	1.1	1.2	1.01	1.12
	3	1.06	7	1.2	1.2	0.88	1.16
	4	1.18	8	1.3	1.3	0.91	1.09
2002-03	1	1.66	9	1.4	1.4	1.18	1.75
	2	1.57	10	1.4	1.5	1.05	1.45
	3	1.36	11	1.6	1.6	0.85	1.49
	4	1.61	12	1.6	1.6	1.01	1.49
2003-04	1	1.66	13	1.6	1.6	1.07	1.75
	2	1.66	14	1.6	1.6	1.04	1.54
	3	1.49	15	1.6	1.6	0.93	1.63
	4	1.53	16	1.6	1.5	1.02	1.42
2004-	1	1.61	17	1.5	1.5	1.07	1.69

05							
	2	1.39	18	1.4	1.4	0.99	1.28
	3	1.11	19	1.4	1.4	0.79	1.23
	4	1.58	20	1.4	1.4	1.13	1.46
2005-06	1	1.50	21	1.4	1.3	1.15	1.58
	2	1.22	22	1.3	1.3	0.94	1.13
	3	0.98	23	1.3	1.3	0.75	1.07
	4	1.36	24	1.3	1.2	1.13	1.26
2006-07	1	1.45	25	1.2	1.2	1.21	1.33
	2	0.95	26	1.2	1.2	0.79	0.65
	3	1.06	27	1.2	1.2	0.88	1.04
	4	1.51	28	1.2	1.2	1.26	1.26
2007-08	1	1.26	29	1.1	1.1	1.14	
	2	0.71	30	1.1	1.1	0.65	
	3	0.95	31	1.1			
	4	1.36	32				

Calculation of Seasonal Index

Year	Summer	Rainy	Winter	Post Monsoon
2000-01			0.38	1.1
2001-02	1.28	1.01	0.88	0.91
2002-03	1.18	1.05	0.85	1.01
2003-04	1.07	1.04	0.93	1.02
2004-05	1.07	0.99	0.79	1.13
2005-06	1.15	0.94	0.75	1.13
2006-07	1.21	0.79	0.88	1.26
2007-08	1.14	0.65		
Total	5.64	6.47	5.46	6.43
Unadjusted Mean	0.81	0.92	0.78	0.92
Adjusted Seasonal Mean	0.948	1.08	0.91	1.08
Index	94.8	108	91	108

As per the Indian monsoon conditions, the Seasonal index values calculated are as follows:

Final SVI	94.8+30.33 =125.13	108+36 =144	91-30.33 =60.67	108-36 =72

Correction Factor = 4/3.43 = 1.17

Trend equation: y = 12.7 - 0.10 x

Seasonalized Forecast of Water Withdrawals

Year	X-code	Trend Unadjusted Forecast	Seasonal Index	Forecast
2008-09				
Summer	29	10	0.948	9.48
Rainy	30	9.9	1.08	10.69
Winter	31	9.8	0.91	0.92
Post Monsoon	32	9.5	1.08	10.26
2009-2010				
Summer	33	9.4	0.948	8.9
Rainy	34	9.3	1.08	10.04
Winter	35	9.2	0.91	8.4
Post Monsoon	36	9.1	1.08	9.8
2010-2011				
Summer	37	9	0.948	8.5
Rainy	38	8.9	1.08	9.6
Winter	39	8.8	0.91	8.01
Post Monsoon	40	8.7	1.08	9.4
2011-2012				
Summer	41	8.6	0.948	8.15
Rainy	42	8.5	1.08	8.6
Winter	43	8.4	0.91	7.6
Post Monsoon	44	8.3	1.08	8.9
2012-2013				
Summer	45	8.2	0.948	7.8
Rainy	46	8.1	1.08	8.7
Winter	47	8	0.91	7.3
Post Monsoon	48	7.9	1.08	8.5
2013-2014				
Summer	49	7.8	0.948	7.4
Rainy	50	7.7	1.08	8.32
Winter	51	7.6	0.91	6.9
Post Monsoon Season	52	7.5	1.08	8.1

Forecast of Water Withdrawals (in Hundred million cubic meters) versus Loss of Generation (in thousand million units)*[12]

Quarter	Summer	Rainy	Winter	Post Monsoon Season
2008-09 WD LG	 0.72 9.79	 0.79 14.11	 0.78 0.61	 0.21 6.84
2009-10 WD LG	 0.62 11.7	 -1.22 13.24	 -0.42 5.6	 -0.37 6.6
2010-2011 WD LG	 0.47 11.17	 -0.44 12.7	 -1.54 5.34	 -0.94 6.3
2011-2012 WD LG	 0.12 10.65	 -3.14 11.57	 -1.54 5.1	 -1.53 5.93
2012-2013 WD LG	 0.89 10.2	 -1.45 11.5	 -3.73 4.9	 0 5.7
2013-2014 WD LG	 1.08 9.7	 -1.96 11.02	 -4.9 4.6	 -2.7 5.4

[1] Calculated figures of Final Seasonal Forecast figures as per Indian Monsoon Conditions

Season Wise Varying Levels of Plant Load Factor (Percentage)

Year	Quarters	Water Withdrawals (in Hundred Million Cubic Meters)	Loss of Generation due to water shortage (in thousand Million Units)	Plant Load Factor (PLF) percentage
2000-01	Summer 1	4.77	1.35	56.37
	Rainy 2	9.33	1.03	113.74
	Winter3	17.76	0.34	238.76
	Spring 4	9.21	0.99	121.11
2001-02	1	6.32	1.28	68.73
	2	7.40	1.21	81.99
	3	8.63	1.06	108.23
	4	6.59	1.18	87.20
2002-03	1	0.07	1.66	0.69

	2	1.40	1.57	16.60
	3	4.77	1.36	54.76
	4	0.87	1.61	9.26
2003-04	1	0.00	1.66	0.00
	2	0.00	1.66	0.00
	3	2.50	1.49	31.53
	4	2.13	1.53	23.78
2004-05	1	0.77	1.61	8.90
	2	3.63	1.39	48.42
	3	7.31	1.11	99.49
	4	1.14	1.58	14.13
2005-06	1	2.49	1.50	30.15
	2	6.66	1.22	79.77
	3	10.22	0.98	122.75
	4	4.29	1.36	53.85
2006-07	1	1.73	1.45	37.98
	2	1.07	0.95	128.12
	3	0.90	1.06	108.27
	4	1.24	1.51	28.14
2007-08	1	0.17	1.26	73.01
	2	0.68	0.71	171.48
	3	2.06	0.95	128.67
	4	1.13	1.36	54.44

Table A 6.6

LOWER SILERU HYDEL POWER HOUSE

SCENARIO OF WATER WITHDRAWALS:

Year		Water with drawals (in hundred million cubic meters)	X-code	4-q-m-a	centered	Specific Seasonal	Deseasonalised
2001-02	1	21.55	**1**				19.24
	2	25.93	**2**				29.80
	3	27.61	**3**	2.8	2.8	9.8	31.37
	4	36.11	**4**	2.9	2.7	13.3	31.95
2002-03	1	26.89	5	2.5	2.4	11.20	24
	2	10.53	6	2.2	1.9	0.55	12.10
	3	13.85	7	1.6	1.5	0.91	15.24
	4	13.33	8	1.4	1.5	0.89	33.65
2003-04	1	19.98	9	1.6	1.8	1.14	17.8
	2	15.46	10	1.9	2.3	0.69	17.8
	3	28.99	11	2.6	2.7	1.07	32.94
	4	38.02	12	2.9	3.1	1.23	33.65
2004-05	1	32.29	13	3.3	3.3	0.97	28.83
	2	32.78	14	3.4	3.2	1.02	37.68
	3	31.23	15	3.1	3.1	1.01	35.49
	4	27.00	16	3.1	3.0	0.89	23.89
2005-06	1	33.40	17	2.9	2.7	1.25	29.82
	2	25.86	18	2.4	2.6	1.01	29.72
	3	9.56	19	2.7	2.8	0.34	10.86
	4	40.34	20	2.8	2.9	1.39	35.69
2006-07	1	37.53	21	3.0	3.2	1.18	33.51
	2	30.62	22	3.4	3.3	0.93	35.19
	3	27.47	23	3.2	3.1	0.90	31.21
	4	30.84	24	3.0	2.9	1.06	27.29
2007-08	1	29.89	25	2.9	2.9	1.05	26.69
	2	26.21	26	2.8	2.8	0.92	30.61
	3	26.63	27	2.8	2.8	0.94	30.26
	4	30.95	28	2.8	2.8	1.09	27.39

2008-09	1	29.65	29	2.8	2.8	1.05	26.47
	2	25.88	30	2.8	2.8	0.91	29.75
	3	26.28	31	2.8			29.86
	4	32.17	32				28.47

Calculation of seasonal Index

Year	1	2	3	4		
2001-02			9.7	13.3		
2002-03	11.4	5.5	9.1	8.9		
2003-04	11.4	6.9	10.7	12.3		
2004-05	9.7	10.2	10.1	8.9		
2005-06	12.5	10.1	3.4	13.9		
2006-07	11.8	9.3	9	10.6		
2007-08	10.5	9.2	9.4	10.9		
2008-09	10.5	9.1				
Total	77.8	60.3	61.4	78.8		
Unadjusted Mean	11.11	8.61	8.77	11.26	39.75	0.1006
Adjusted Seasonal Mean	1.12	0.87	0.88	1.13		
Seasonal Index	112	87	88	113		

Correction Factor =4/39.75=0.1006

As per the Indian monsoon conditions, the Seasonal index values calculated are as follows:

Final SVI	112+29.33 =141.33	87+37.67 =124.67	88-29.33 =58.67	113-37.67 =75.33

Trend equation: y = 2.30 + 0.025 x

Seasonalized Forecast

Year	X-code	Trend Unadjusted Forecast	Seasonal Index	Forecast Seasonal Adjusted (in hundred million cubic meters)
2009-10				
Summer	33	3.1	0.12	0.37
Rainy	34	3.2	0.87	2.8
Winter	35	3.2	0.88	2.8
Post Monsoon	36	3.2	0.13	0.42
2010-2011				
Summer	37	3.2	0.12	0.38
Rainy	38	3.25	0.87	2.8
Winter	39	3.3	0.88	2.9
Post Monsoon	40	3.3	0.13	0.43
2011-2012				
Summer	41	3.3	0.12	0.39
Rainy	42	3.4	0.87	2.9
Winter	43	3.4	0.88	2.99
Post Monsoon	44	3.4	0.13	0.44
2012-2013				
Summer	45	3.4	0.12	0.41
Rainy	46	3.5	0.87	3.04
Winter	47	3.5	0.88	3.08
Post Monsoon	48	3.5	0.13	0.455
2013-2014				
Summer	49	3.5	0.12	0.42
Rainy	50	3.6	0.87	3.13
Winter	51	3.5	0.88	3.08
Post Monsoon	52	3.6	0.13	0.468

SCENARIO OF LOSS OF GENERATION

Year		LFWA (in hundred million Units)	X-code	4-q-m-a	Centered	Specific Seasonal	Deseasonalised
2001-02	1	6.59	**1**				6.7
	2	6.18	**2**				1.20
	3	6.02	**3**	6.0	5.9	1.01	5.57
	4	5.21	**4**	5.9	6.1	0.86	6.3
2002-03	1	6.09	5	6.2	6.4	0.95	6.3
	2	7.64	6	6.6	6.8	1.12	7.07
	3	7.32	7	7.1	7.2	1.02	6.7
	4	7.37	8	7.3	7.2	1.02	8.9
2003-04	1	6.74	9	7.2	7.0	0.97	6.9
	2	7.17	10	6.8	6.5	1.10	6.6
	3	5.89	11	6.2	6.1	0.97	5.45
	4	5.03	12	5.9	5.7	0.88	6.06
2004-05	1	5.57	13	5.5	5.5	1.02	5.74
	2	5.53	14	5.5	5.6	0.99	5.12
	3	5.67	15	5.7	5.7	1.00	5.25
	4	6.08	16	5.7	5.8	1.05	7.32
2005-06	1	5.47	17	5.8	6.1	0.90	5.6
	2	6.18	18	6.4	6.2	1.00	5.7
	3	7.73	19	6.0	6.0	1.29	7.16
	4	4.81	20	5.9	5.9	0.82	5.8
2006-07	1	5.07	21	5.8	5.6	0.90	5.2
	2	5.73	22	5.4	5.5	1.04	5.3
	3	6.03	23	5.6	5.7	1.05	5.58
	4	5.71	24	5.8	5.9	0.97	6.87
2007-08	1	5.80	25	5.9	5.9	0.98	5.9
	2	6.15	26	5.9	5.9	1.04	5.7
	3	6.11	27	5.9	5.9	1.03	5.65
	4	5.70	28	5.9	5.9	0.96	6.86
2008-09	1	5.82	29	6.0	6.0	0.98	6
	2	6.18	30	6.0	5.9	1.04	5.7
	3	6.14	31	5.9			5.7
	4	5.58	32				6.7

Calculation of Seasonal Index

	Year	1	2	3	4		
1	2001-02			1.01	0.86		
2	2002-03	0.95	1.12	1.02	1.02		
3	2003-04	0.97	1.1	0.97	0.88		
4	2004-05	1.02	0.99	1	1.05		
5	2005-06	0.9	1	1.29	0.82		
6	2006-07	0.9	1.04	1.05	0.97		
7	2007-08	0.98	1.04	1.03	0.96		
8	2008-09	0.98	1.04				
	Total	6.7	7.33	7.37	5.68		
	Unadjusted Seasonal	0.95	1.05	1.05	0.81	3.86	1.03
	Adjusted Seasonal	0.97	1.08	1.08	0.83		
		97	108	108	83		

Correction factor = 4/3.86= 1.03

As per the Indian monsoon conditions, the Seasonal index values calculated are as follows:

Final SVI	97+36 =133	108+27.67 =135.67	108-36 =72	83-27.67 =55.33

Trend equation: $y = 6.46 - 0.023\ x$

Seasonalized Forecast

Year	X-code	Trend Unadjusted Forecast	Seasonal Index	Forecast Seasonal Adjusted (in million hundred cubic meters)
2009-10				
Summer	33	7.22	0.97	7.003
Rainy	34	7.24	1.08	7.8
Winter	35	7.27	1.08	7.85
Post Monsoon	36	7.29	0.83	6.05
2010-2011				

Summer	37	5.6	0.97	5.4
Rainy	38	5.6	1.08	6.05
Winter	39	5.6	1.08	6.05
Post Monsoon	40	5.5	0.83	4.6
2011-2012				
Summer	41	5.5	0.97	5.3
Rainy	42	5.5	1.08	5.94
Winter	43	5.5	1.08	5.94
Post Monsoon	44	5.4	0.83	4.5
2012-2013				
Summer	45	5.4	0.97	5.1
Rainy	46	5.4	1.08	5.7
Winter	47	5.4	1.08	5.7
Post Monsoon	48	5.4	0.83	4.4
2013-2014				
Summer	49	5.3	0.97	5.1
Rainy	50	5.31	1.08	5.7
Winter	51	5.3	1.08	5.7
Post Monsoon	52	5.3	0.83	4.4

Forecast of Water Withdrawals versus Loss of Generation

Quarter	Summer	Rainy	Winter	Post Monsoon Season
2009-10 WD (in hundred million cubic meters) LG (in hundred million units)	1.3 9.6	2.94 9.82	1.87 5.23	0.28 4.03
2010-2011 WD LG	1.35 8.43	2.94 7.58	1.93 3.02	0.29 3.07
2011-2012 WD LG	1.38 7.28	3.04 7.44	2 3.96	0.3 3
2012-2013 WD LG	1.44 7	3.56 7.17	2.05 3.8	-0.065 2.93
2013-2014 WD LG	1.45 7	3.29 7.17	2 3.8	0.31 2.93

Season Wise Varying Levels of Plant Load Factor (Percentage)

Year	Quarters	Water Withdrawals (Hundred Million Cubic Meters)	Loss of Generation due to water shortage (hundred Million Units)	Plant Load Factor (PLF) percentage
2001-02	Summer 1	21.55	6.59	51.19
	Rainy 2	25.93	6.18	61.58
	Winter3	27.61	6.02	65.58
	Spring 4	36.11	5.21	85.77
2002-03	1	26.89	6.09	63.87
	2	10.53	7.64	25.01
	3	13.85	7.32	32.90
	4	13.33	7.37	31.66
2003-04	1	19.98	6.74	47.46
	2	15.46	7.17	36.73
	3	28.99	5.89	68.86
	4	38.02	5.03	90.31
2004-05	1	32.29	5.57	76.68
	2	32.78	5.53	77.85
	3	31.23	5.67	74.16
	4	27.00	6.08	64.13
2005-06	1	33.40	5.47	79.33
	2	25.86	6.18	61.42
	3	9.56	7.73	22.70
	4	40.34	4.81	95.80
2006-07	1	37.53	5.07	89.14
	2	30.62	5.73	72.73
	3	27.47	6.03	65.25
	4	30.84	5.71	73.25
2007-08	1	29.89	5.80	71.00
	2	26.21	6.15	62.25
	3	26.63	6.11	63.25
	4	30.95	5.70	73.50
2008-09	1	29.65	5.82	70.42
	2	25.88	6.18	61.47
	3	26.28	6.14	62.41
	4	32.17	5.58	76.40

Table A 6.7

UPPER SILERU HYDEL POWER HOUSE

SCENARIO OF WATER WITHDRAWALS:

Year		Water with drawals (in hundred million cubic meters)	X-code	4-q-m-a	centered	Specific Seasonal	Deseasonalised
2001-02	1	9.46	**1**				19.24
	2	13.20	**2**				29.80
	3	9.41	**3**	0.1	0.1	94.1	31.37
	4	15.02	**4**	0.1	0.1	150.2	31.95
2002-03	1	6.14	5	0.1	0.1	61.4	24
	2	4.88	6	0.1	0.1	48.8	12.10
	3	6.07	7	0.1	0.1	60.7	15.74
	4	8.75	8	0.1	0.1	87.5	33.65
2003-04	1	9.31	9	0.1	0.1	93.1	17.8
	2	4.79	10	0.1	0.1	47.9	17.8
	3	9.57	11	0.1	0.1	95.7	32.94
	4	18.43	12	0.1	0.1	184.3	33.65
2004-05	1	15.92	13	0.2	0.2	79.6	33.65
	2	16.83	14	0.2	0.1	168.3	28.83
	3	10.90	15	0.1	0.1	109	37.68
	4	13.60	16	0.1	0.1	136	35.49
2005-06	1	16.07	17	0.1	0.1	160.7	23.89
	2	10.11	18	0.1	0.1	101.1	29.82
	3	6.35	19	0.1	0.1	63.5	29.72
	4	17.03	20	0.1	0.1	170.3	10.86
2006-07	1	13.40	21	0.1	0.1	134	35.69
	2	12.54	22	0.1	0.1	125.4	33.51
	3	10.21	23	0.1	0.1	102.1	35.19
	4	12.74	24	0.1	0.1	127.4	31.21

2007-08	1	11.73	25	0.1	0.1	117.3	27.29
	2	10.93	26	0.1	0.1	109.3	26.69
	3	9.98	27	0.1	0.1	99.8	30.6
	4	13.54	28	0.1	0.1	135.4	30.26
2008-09	1	11.73	29	0.1	0.1	117.3	27.39
	2	10.93	30	0.1	0.1	109.3	26.47
	3	9.98	31	0.1			29.75
	4	13.54	32				29.86
							28.47

Calculation of Seasonal Index

Year	1Summer	2Rainy	3Winter	4 Post Monsoon
2001-02			94.1	150.2
2002-03	61.4	48.8	60.7	87.5
2003-04	93.1	47.9	95.7	184.3
2004-05	79.6	168.3	109	136
2005-06	160.7	101.1	63.5	170.3
2006-07	134	125.4	102.1	127.4
2007-08	117.3	109.3	99.8	135.4
2008-09	117.3	109.3		
Total	763.4	710.11	624.9	991.1
Unadjusted Mean	109.06	101.4	88.27	141.58
Adjusted Seasonal Mean	1.09	1.01	0.88	1.42
Index	109	101	88	142

Correction Factor = 4/440.31=0.01

As per the Indian monsoon conditions, the Seasonal index values calculated are as follows:

Final SVI	109+29.3 =138.3	101+47.3 =148.3	88-29.3 =58.7	142-47.3 =94.7

Trend equation: y = 9.90 + 0.087 x

Seasonalized Forecast of Water withdrawals

Year	X-code	Trend Unadjusted Forecast	Seasonal Index	Forecast Seasonal Adjusted (in hundred millioncubic meters)
2009-10				
Summer	33	12.8	1.09	13.9
Rainy	34	12.9	1.01	13.03
Winter	35	12.9	0.88	11.35
Post Monsoon	36	13.0	1.42	18.46
2010-2011				
Summer	37	13.12	1.09	14.3
Rainy	38	13.12	1.01	13.34
Winter	39	13.3	0.88	11.70
Post Monsoon	40	13.38	1.42	18.99
2011-2012				
Summer	41	13.47	1.09	14.68
Rainy	42	13.55	1.01	13.69
Winter	43	13.64	0.88	12
Post Monsoon	44	13.73	1.42	19.49
2012-2013				
Summer	45	13.82	1.09	15.06
Rainy	46	13.90	1.01	14.04
Winter	47	13.99	0.88	12.31
Post Monsoon	48	14.08	1.42	19.99
2013-2014				
Summer	49	14.16	1.09	15.43
Rainy	50	14.25	1.01	14.39
Winter	51	14.33	0.88	12.6
Post Monsoon	52	14.42	1.42	20.48

: SCENARIO OF LOSS OF GENERATION

Year		LFWA (in hundred million Units)	X-code	4-q-m-a	centered	Specific Seasonal	Deseasonalised
2001-02	1	4.29	**1**				6.7
	2	3.93	**2**				1.20
	3	4.29	**3**	4.1	4.1	1.05	5.57

	4	3.76	**4**	4.1	4.2	0.89	6.3
2002-03	1	4.60	5	4.3	4.4	1.05	6.3
	2	4.72	6	4.4	4.5	1.05	7.07
	3	4.61	7	4.6	4.5	1.02	6.7
	4	4.35	8	4.5	4.5	0.97	8.9
2003-04	1	4.30	9	4.5	4.5	0.97	6.9
	2	4.73	10	4.4	4.3	1.10	6.6
	3	4.28	11	4.2	4.1	1.04	5.45
	4	3.43	12	4.0	3.9	0.88	6.06
2004-05	1	3.67	13	3.7	3.7	0.99	5.74
	2	3.58	14	3.7	3.8	0.95	5.12
	3	4.15	15	3.8	3.8	1.09	5.25
	4	3.89	16	3.8	3.9	1.00	7.32
2005-06	1	3.66	17	4.0	4.0	0.91	5.6
	2	4.22	18	4.1	4.0	1.04	5.7
	3	4.58	19	4.0	4.0	1.13	7.16
	4	3.57	20	4.1	4.0	0.88	5.8
2006-07	1	3.91	21	4.0	4.0	0.99	5.2
	2	3.99	22	3.9	4.0	1.01	5.3
	3	4.21	23	4.0	4.0	1.04	5.58
	4	3.97	24	4.1	4.1	0.97	6.87
2007-08	1	4.07	25	4.1	4.1	0.99	5.9
	2	4.15	26	4.1	4.1	1.01	5.7
	3	4.24	27	4.1	4.1	1.04	5.65
	4	3.90	28	4.1	4.1	0.95	6.86
2008-09	1	4.07	29	4.1	4.1	1.00	6
	2	4.15	30	4.1	4.1	1.01	5.7
	3	4.24	31	4.1			5.7
	4	3.90	32				6.7

Calculation of Seasonal Index

	Year	1	2	3	4
1	2001-02			1.05	0.89
2	2002-03	1.05	1.05	1.02	0.97
3	2003-04	0.97	1.1	1.04	0.88
4	2004-05	0.99	0.95	1.09	1
5	2005-06	0.91	1.04	1.13	0.88
6	2006-07	0.99	1.01	1.04	0.97
7	2007-08	0.99	1.01	1.04	0.95
8	2008-09	1	1.01		
	Total	6.9	7.17	7.41	6.54
	Unadjusted Seasonal Mean	0.98	1.02	1.06	0.82
	Adjusted Seasonal	1.01	1.05	1.09	0.84
	Index	101	105	109	84

Correction Factor =4/3.88=1.03

As per the Indian monsoon conditions, the Seasonal index values calculated are as follows:

Final SVI	101+36.33 =137.33	105+28 =133	109-36.33 =72.67	84-28 =56

Trend equation: $y = 4.24 - 0.083\ x$

Seasonalized Forecast of Loss of Generation

Year	X-code	Trend Unadjusted Forecast	Seasonal Index	Forecast Seasonal Adjusted (in hundred million cubic meters)
2009-10				
Summer	33	6.98	1.01	7.05
Rainy	34	7.06	1.05	7.4
Winter	35	7.15	1.09	7.8
Post Monsoon	36	7.23	0.84	6.07
2010-2011				
Summer	37	1.17	1.01	1.18
Rainy	38	1.09	1.05	1.14
Winter	39	1.003	1.09	1.09

Post Monsoon	40	0.92	0.84	0.77
2011-2012				
Summer	41	0.84	1.01	0.85
Rainy	42	0.75	1.05	0.79
Winter	43	0.671	1.09	0.73
Post Monsoon	44	0.59	0.84	0.49
2012-2013				
Summer	45	0.51	1.01	0.52
Rainy	46	0.34	1.05	0.36
Winter	47	0.34	1.09	0.37
Post Monsoon	48	0.26	0.84	0.22
2013-2014				
Summer	49	0.17	1.01	0.17
Rainy	50	0.09	1.05	0.09
Winter	51	0.007	1.09	0.008
Post Monsoon	52	-0.08	0.84	-0.067

Forecast of Water Withdrawals (in Hundred million cubic meters) versus Loss of Generation (in hundred million units)*[13]

Quarter	Summer	Rainy	Winter	Post Monsoon Season
2009-10 WD LG	17.68 9.65	19.18 9.42	7.57 5.2	12.31 4.05
2010-2011 WD LG	18.2 1.54	19.64 1.4	7.8 0.73	12.69 0.51
2011-2012 WD LG	18.68 1.09	20.18 2.39	8 0.49	13 0.33
2012-2013 WD LG	19.16 0.643	20.7 0.433	8.21 0.247	13.33 0.147
2013-2014 WD LG	19.63 0.173	21.22 0.0677	8.4 0.0054	13.65 -0.0447

[13] Calculated figures of Final Seasonal Forecast figures as per Indian Monsoon Conditions

Season Wise Varying Levels of Plant Load Factor (Percentage)

Year	Quarters	Water Withdrawals Hundred Million Cubic Meters	Loss of Generation due to water shortage (hundred Million Units)	Plant Load Factor (PLF) percentage
2001-02	1	9.46	4.29	37.45
	2	13.20	3.93	52.25
	3	9.41	4.29	37.25
	4	15.02	3.76	59.45
2002-03	1	6.14	4.60	24.32
	2	4.88	4.72	19.33
	3	6.07	4.61	24.02
	4	8.75	4.35	34.65
2003-04	1	9.31	4.30	36.84
	2	4.79	4.73	18.95
	3	9.57	4.28	37.87
	4	18.43	3.43	72.95
2004-05	1	15.92	3.67	63.03
	2	16.83	3.58	66.63
	3	10.90	4.15	43.16
	4	13.60	3.89	53.85
2005-06	1	16.07	3.66	63.60
	2	10.11	4.22	40.02
	3	6.35	4.58	25.13
	4	17.03	3.57	67.41
2006-07	1	13.40	3.91	53.04
	2	12.54	3.99	49.62
	3	10.21	4.21	40.42
	4	12.74	3.97	50.42
2007-08	1	11.73	4.07	46.42
	2	10.93	4.15	43.25
	3	9.98	4.24	39.49
	4	13.54	3.90	53.60
2008-09	1	11.73	4.07	46.42
	2	10.93	4.15	43.25
	3	9.98	4.24	39.49
	4	13.54	3.90	53.60

Table A 6.8

KOTHAGUDAEM O &M THERMAL POWER STATION

SCENARIO OF WATER WITHDRAWALS:

Year		Water with drawals (hundred million cubic meters)	X-code	4-q-m-a	centered	Specific Seasonal	Deseasonalised
2003-04	1 Summer	2.09	1				1.9
	2 Rainy	2.32	2				1.92
	3 Winter	1.58	3	1.8	1.8	0.88	1.61
	4 Post Monsoon	1.21	4	1.7	1.7	0.71	1.29
2004-05	1	1.77	5	1.7	1.7	1.04	1.67
	2	2.08	6	1.8	1.8	1.16	1.71
	3	1.97	7	1.9	1.9	1.04	2.01
	4	1.92	8	1.9	1.8	1.07	2.04
2005-06	1	1.67	9	1.8	1.7	0.98	1.6
	2	1.50	10	1.7	1.6	0.94	1.2
	3	1.53	11	1.6	1.6	0.96	1.6
	4	1.70	12	1.7	1.7	1	1.8
2006-07	1	2.04	13	1.8	1.8	1.13	1.94
	2	1.76	14	1.8	1.8	0.98	1.46
	3	1.84	15	1.8	1.8	1.02	1.88
	4	1.62	16	1.8	1.8	0.96	1.72
2007-08	1	1.90	17	1.8	1.8	1.05	1.81
	2	1.82	18	1.8	1.8	1.01	1.5
	3	1.77	19	1.8	1.8	0.98	1.81
	4	1.66	20	1.7	1.7	0.98	1.76
2008-09	1	1.68	21	1.7	1.7	0.99	1.6
	2	1.58	22	1.7	1.6	0.99	1.3
	3	1.69	23	1.6			1.72
	4	1.56	24				1.66

Calculation of Seasonal index

Year	Summer (Dry Season)	Rainy (wet Season)	Winter (Cold season)	Post Monsoon
2003-04			0.88	0.71
2004-05	1.04	1.16	1.04	1.07
2005-06	0.98	0.94	0.96	1
2006-07	1.13	0.98	1.02	0.9
2007-08	1.05	1.01	0.98	0.98
2008-09	0.99	0.99		
Total	5.19	5.08	4.88	4.66
Unadjusted Seasonal Mean	1.04	1.02	0.97	0.93
Adjusted Seasonal	1.05	1.21	0.98	0.941
Seasonal Index	105	121	98	94.1

As per the Indian monsoon conditions, the Seasonal index values calculated are as follows:

Final SVI	105 +32.67 =137.67	121+31.37 =152.37	98-32.67 =65.33	94.1-31.37 =62.73

Correction factor = 4/3.97 = 1.01

Trend equation: y = 1.97 - 0.09 x

Seasonalized Forecast of Water withdrawals

Year	X-code	Trend Unadjusted Forecast	Seasonal Index	Forecast Seasonal Adjusted (in hundred million cubic meters)
2009-10				
Summer	25	-0.28	1.05	-0.29
Rainy	26	-0.4	1.21	-0.48
Winter	27	-0.46	0.98	-0.45
Post Monsoon	28	-0.55	0.94	-0.52
2010-2011				
Summer	29	-0.64	1.05	-0.67
Rainy	30	-0.73	1.21	-0.89
Winter	31	-0.82	0.98	-0.80

Post Monsoon	32	-0.91	0.94	-0.86
2011-2012				
Summer	33	-1	1.05	-1.05
Rainy	34	-1.09	1.21	-1.32
Winter	35	-1.18	0.98	-1.16
Post Monsoon	36	-1.27	0.94	-1.19
2012-2013				
Summer	37	-1.36	1.05	-1.43
Rainy	38	-1.45	1.21	-1.75
Winter	39	-1.54	0.98	-1.51
Post Monsoon	40	-1.63	0.94	-1.5
2013-2014				
Summer	41	-1.72	1.05	-1.8
Rainy	42	-1.81	1.21	-2.2
Winter	43	-1.9	0.98	-1.8
Post Monsoon	44	-1.99	0.94	-1.9

SCENARIO OF LOSS OF GENERATION:

Year		Loss of Generation due to WS (in thousand million units)	X-code	4-q-m-a	Centered	Specific Seasonal	Deseasonalised
2003-04	1	9.64	1				14.6
	2	18.83	2				15.18
	3	19.39	3	13.6	14.1	1.37	16.29
	4	6.74	4	14.6	13.8	0.49	7.57
2004-05	1	13.63	5	13.0	12.3	1.11	20.65
	2	12.19	6	11.6	12.6	0.99	9.8
	3	13.96	7	13.5	12.6	1.11	11.7
	4	14.38	8	11.7	12.6	1.14	16.16
2005-06	1	6.45	9	13.5	14.2	0.45	9.77
	2	19.02	10	15.0	15.2	1.25	15.3
	3	20.23	11	15.4	15.4	0.08	17
	4	15.78	12	15.4	14.7	1.07	17.73
2006-07	1	6.47	13	14.0	16.1	0.40	9.80
	2	13.45	14	18.3	19.5	0.69	10.84
	3	37.45	15	20.8	20.6	1.82	16.58
	4	25.69	16	20.4	21.8	1.18	6.72
2007-08	1	4.81	17	23.2	21.0	0.23	21.57

	2	24.75	18	18.7	16.3	1.52	17.62
	3	19.74	19	13.8	15.0	1.32	12.36
	4	5.98	20	16.2	15.8	0.38	12.96
2008-09	1	14.24	21	15.5	14.8	0.96	
	2	21.86	22	14.2	14.9	1.47	
	3	14.71	23	15.6			
	4	11.53	24				

Calculation of Seasonal index

Year	Summer (Dry Season)	Rainy (wet Season)	Winter (Cold season)	Post Monsoon
2003-04			1.37	0.49
2004-05	1.11	0.99	1.11	1.14
2005-06	0.45	1.25	0.08	1.07
2006-07	0.40	0.69	1.82	1.18
2007-08	0.23	1.52	1.32	0.38
2008-09	0.96	1.47		
Total	3.15	5.92	5.7	4.26
Unadjusted Seasonal Mean	0.63	1.18	1.14	0.85
Adjusted Seasonal	0.66	1.24	1.19	0.89
Seasonal Index	66	124	119	89.25

As per the Indian monsoon conditions, the Seasonal index values calculated are as follows:

Final SVI	66 + 39.67 =105.67	124 + 29.75 =153.75	119-39.67 =79.33	89.25-29.75 =59.5

Correction factor = 4/3.8 = 1.05

Trend equation: y = 1.7 +0.15 x

Seasonalized Forecast of Loss of Generation

Year	X-code	Trend Unadjusted Forecast	Seasonal Index	Forecast Seasonal Adjusted (in hundred million cubic meters)
2009-10				
Summer	25	5.45	0.66	3.59
Rainy	26	5.6	1.24	6.94

Winter	27	5.75	1.19	6.84
Post Monsoon	28	5.9	0.89	5.25
2010-2011				
Summer	29	6.05	0.66	3.99
Rainy	30	6.2	1.24	7.69
Winter	31	6.35	1.19	7.56
Post Monsoon	32	6.5	0.89	5.78
2011-2012				
Summer	33	6.65	0.66	4.39
Rainy	34	6.8	1.24	8.4
Winter	35	6.95	1.19	8.27
Post Monsoon	36	7.1	0.89	6.32
2012-2013				
Summer	37	3.55	0.66	2.34
Rainy	38	7.4	1.24	9.17
Winter	39	7.55	1.19	8.98
Post Monsoon	40	7.7	0.89	6.8
2013-2014				
Summer	41	7.85	0.66	5.18
Rainy	42	8	1.24	9.92
Winter	43	8.15	1.19	9.69
Post Monsoon	44	8.3	0.89	7.38

Forecast of Water Withdrawals (in Hundred million cubic meters) versus Loss of Generation (in thousand million units)*[14]

Quarter	Summer	Rainy	Winter	Post Monsoon Season
2009-10				
WD	-0.14	-0.31	-0.3	-0.69
LG	5.87	8.69	4.56	3.5
2010-2011				
WD	-0.4	-0.6	-0.53	-0.57
LG	6.51	9.8	5.04	3.88
2011-2012				
WD	-0.66	-0.93	-0.77	-0.8
LG	7.19	10.51	5.47	4.21
2012-2013				
WD	-0.93	-1.25	-1.01	1
LG	5.24	11.47	6.08	4.5
2013-2014				
WD	-1.2	-1.57	-1.2	-1.27
LG	8.41	12.38	6.46	4.92

[14] Calculated figures of Final Seasonal Forecast figures as per Indian Monsoon Conditions

Season Wise Varying Levels of Plant Load Factor (Percentage)

Year	Quarters	Water Withdrawals Hundred Million Cubic Meters	Loss of Generation due to water shortage (thousand Million Units)	Plant Load Factor (PLF) percentage
2003-04	1	2.09	9.64	25.1
	2	2.32	18.83	22.3
	3	1.58	19.39	19.2
	4	1.21	6.74	19.7
2004-05	1	1.77	13.63	27.0
	2	2.08	12.19	26.8
	3	1.97	13.96	28.0
	4	1.92	14.38	27.8
2005-06	1	1.67	6.45	27.4
	2	1.50	19.02	22.8
	3	1.53	20.23	19.5
	4	1.70	15.78	27.0
2006-07	1	2.04	6.47	28.5
	2	1.76	13.45	24.5
	3	1.84	37.45	21.6
	4	1.62	25.69	23.1
2007-08	1	1.90	4.81	28.4
	2	1.82	24.75	22.5
	3	1.77	19.74	24.0
	4	1.66	5.98	27.8
2008-09	1	1.68	14.24	23.9
	2	1.58	21.86	20.1
	3	1.69	14.71	22.9
	4	1.56	11.53	24.2

Table A 6.9

KOTHAGUDAEM Stage V THERMAL POWER STATION

SCENARIO OF WATER WITHDRAWALS:

Year		Water with drawals	X-code	4-q-m-a	centered	Specific Seasonal	Deseasonalised
2001-02	1	5.76	1				5.9
	2	6.02	2				6.2
	3	5.46	3	5.9	5.9	0.92	5.6
	4	6.38	4	5.9	5.8	1.09	5.5
2002-03	1	5.76	5	5.8	5.7	1.01	5.9
	2	5.40	6	5.7	5.6	0.97	5.57
	3	5.06	7	5.5	5.5	0.92	5.2
	4	5.66	8	5.5	5.6	1.01	4.9
2003-04	1	5.83	9	5.8	5.8	1.00	6.01
	2	6.49	10	5.9	5.8	1.12	6.7
	3	5.49	11	5.8	5.8	0.95	5.66
	4	5.25	12	5.8	5.8	0.91	4.5
2004-05	1	6.12	13	5.7	5.8	1.05	6.3
	2	6.01	14	6.0	6.1	0.99	6.2
	3	6.48	15	6.1	6.2	1.04	6.7
	4	5.98	16	6.3	6.5	0.93	5.2
2005-06	1	6.82	17	6.6	6.5	1.04	7.03
	2	7.11	18	6.5	6.5	1.09	7.3
	3	6.06	19	6.6	6.5	0.94	6.2
	4	6.40	20	6.3	6.2	1.03	5.5
2006-07	1	5.80	21	6.1	6.1	0.96	5.9
	2	6.31	22	6.0	6.0	1.04	6.5
	3	5.52	23	6.1	6.1	0.90	5.7
	4	6.66	24	6.2	6.2	1.07	5.74
2007-08	1	6.24	25	6.2	6.3	1.00	6.4
	2	6.49	26	6.3	6.2	1.05	6.6
	3	5.75	27	6.1	5.9	0.97	5.9
	4	6.07	28	5.7	5.7	1.06	5.2
2008-09	1	4.50	29	5.7	5.7	0.79	4.6
	2	6.53	30	5.6	5.4	1.20	6.7
	3	5.44	31	5.2			3.6
	4	4.38	32				3.8

Calculation of Seasonal Index

Year	Summer	Rainy	Winter	Post Monsoon		
2001-02			0.92	1.09		
2002-03	1.01	0.97	0.92	1.01		
2003-04	1	1.12	0.95	0.91		
2004-05	1.05	0.99	1.04	0.93		
2005-06	1.04	1.09	0.94	1.03		
2006-07	0.96	1.04	0.9	1.07		
2007-08	1	1.05	0.97	1.06		
2008-09	0.79	1.2				
Unadjusted Seasonal Mean	0.9	0.9	0.9	1.0	3.7	1.08
Adjusted Seasonal	0.97	0.97	0.97	1.16		
Index	97	97	97	116		

Correction factor = 4/3.7 = 1.08

As per the Indian monsoon conditions, the Seasonal index values calculated are as follows:

Final SVI	97 +32.33 =129.33	97+38.67 =135.67	97-32.33 =64.67	116-38.67 =77.33

Trend equation: y = 5.94-0.01 x

Seasonalized Forecast of Water Withdrawals

Year	X-code	Trend Unadjusted Forecast	Seasonal Index	Forecast Seasonal Adjusted (in million hundred cubic meters)
2009-10				
Summer	33	5.6	0.97	5.4
Rainy	34	5.6	0.97	5.4
Winter	35	5.6	0.97	5.4
Post Monsoon	36	5.6	1.16	6.5
2010-2011				

Summer	37	5.57	0.97	5.4
Rainy	38	5.56	0.97	5.4
Winter	39	5.55	0.97	5.4
Post Monsoon	40	5.54	1.16	6.4
2011-2012				
Summer	41	5.53	0.97	5.4
Rainy	42	5.52	0.97	5.4
Winter	43	5.51	0.97	5.3
Post Monsoon	44	5.5	1.16	6.38
2012-2013				
Summer	45	5.49	0.97	5.3
Rainy	46	5.48	0.97	5.3
Winter	47	5.47	0.97	5.3
Post Monsoon	48	5.46	1.16	6.3
2013-2014				
Summer	49	5.45	0.97	5.3
Rainy	50	5.44	0.97	5.3
Winter	51	5.43	0.97	5.3
Post Monsoon	52	5.42	1.16	6.3

SCENARIO OF LOSS OF GENERATION:

Year		Loss of Generation(in million units)	X-code	4-q-m-a	centered	Specific Seasonal	Deseasonalised
2001-02	1	17.16	1				24.51
	2	11.98	2				10.79
	3	21.75	3	20.9	20.1	1.08	17.26
	4	32.69	4	19.3	20.4	1.60	35.92
2002-03	1	10.65	5	21.6	21.0	0.51	15.21
	2	21.35	6	20.5	18.0	1.19	19.23
	3	17.19	7	15.4	15.0	1.14	13.64
	4	12.59	8	14.6	15.5	0.81	13.83
2003-04	1	7.42	9	16.4	16.9	0.44	10.6
	2	28.28	10	17.5	17.0	1.66	25.48
	3	21.71	11	16.5	16.6	1.31	17.23
	4	8.59	12	16.6	14.6	0.59	19.88
2004-05	1	7.96	13	12.5	12.0	0.66	11.37
	2	11.84	14	11.6	12.8	0.93	10.67
	3	17.92	15	14.0	15.9	1.13	14.22

	4	18.09	16	17.9	20.2	0.89	19.88
2005-06	1	23.60	17	22.6	26.0	0.91	33.71
	2	30.94	18	29.5	29.9	1.03	27.87
	3	45.22	19	30.4	28.4	1.59	35.89
	4	21.86	20	26.3	24.9	0.88	24.02
2006-07	1	7.36	21	23.4	23.3	0.32	10.51
	2	19.10	22	23.2	24.3	0.79	17.21
	3	44.53	23	25.4	25.9	1.72	35.34
	4	30.77	24	26.3	27.4	1.12	33.81
2007-08	1	10.85	25	28.6	25.4	0.43	15.5
	2	28.13	26	22.3	20.2	1.39	25.34
	3	19.45	27	18.2	22.6	0.86	15.44
	4	14.30	28	26.9	26.6	0.54	15.71
2008-09	1	45.90	29	26.3	27.5	1.67	65.57
	2	25.44	30	28.8	31.0	0.82	22.91
	3	29.65	31	33.2			23.53
	4	31.99	32				35.15

Calculation of Seasonal Index

	Year	1	2	3	4
1	2001-02			1.08	1.6
2	2002-03	0.51	1.19	1.14	0.81
3	2003-04	0.44	1.66	1.31	0.59
4	2004-05	0.66	0.93	1.13	0.89
5	2005-06	0.91	1.03	1.59	0.88
6	2006-07	0.32	0.79	1.72	1.12
7	2007-08	0.43	1.39	0.86	0.54
8	2008-09	1.67	0.82		
	Total	4.94	7.81	8.83	6.43
	Unadjusted Seasonal Mean	0.71	1.12	1.27	0.92
	Adjusted Seasonal	0.70	1.11	1.26	0.91
	Seasonal Index	70	111	126	91

Correction Factor = 4/4.02 = 0.99

As per the Indian monsoon conditions, the Seasonal index values calculated are as follows:

Final SVI	70+42 =112	111+30.33 =141.33	126-42 =84	91-30.33 =60.67

Trend equation: y = 14.33 + 0.45 x

Seasonalized Forecast of Loss of Generation

Year	X-code	Trend Unadjusted Forecast	Seasonal Index	Forecast Seasonal Adjusted (in hundred million cubic meters)
2009-10				
Summer	33	29.18	0.70	20.42
Rainy	34	29.63	1.11	32.89
Winter	35	30.08	1.26	37.9
Post Monsoon	36	30.53	0.91	27.78
2010-2011				
Summer	37	30.98	0.70	21.69
Rainy	38	31.43	1.11	34.89
Winter	39	31.88	1.26	40.17
Post Monsoon	40	32.33	0.91	29.42
2011-2012				
Summer	41	18.45	0.70	12.92
Rainy	42	33.23	1.11	36.88
Winter	43	33.68	1.26	42.43
Post Monsoon	44	34.13	0.91	31.05
2012-2013				
Summer	45	34.58	0.70	24.21
Rainy	46	35.03	1.11	38.88
Winter	47	35.48	1.26	44.7
Post Monsoon	48	35.93	0.91	32.69
2013-2014				
Summer	49	36.38	0.70	25.47
Rainy	50	36.83	1.11	40.88
Winter	51	37.28	1.26	6.97
Post Monsoon	52	37.73	0.91	34.33

Forecast of Water Withdrawals (in Hundred million cubic meters) versus Loss of Generation (in million units)*[15]

Quarter	Summer	Rainy	Winter	Post Monsoon Season
2009-10 WD LG	 7.2 33.05	 7.57 42.15	 3.6 25.27	 4.33 18.52
2010-2011 WD LG	 7.2 35.08	 7.53 44.7	 3.6 26.78	 4.27 19.61
2011-2012 WD LG	 7.53 27.06	 7.53 47.23	 3.17 28.29	 4.25 20.7
2012-2013 WD LG	 7.53 39.11	 7.4 49.77	 3.17 29.8	 4.2 21.8
2013-2014 WD LG	 7.53 27.79	 7.4 52.32	 3.17 4.65	 4.2 22.89

[1] Calculated figures of Final Seasonal Forecast figures as per Indian Monsoon Conditions

Season Wise Varying Levels of Plant Load Factor (Percentage)

Year	Quarters	Water Withdrawals Hundred Million Cubic Meters	Loss of Generation due to water shortage (Million Units)	Plant Load Factor (PLF) percentage
2003-04	1	5.76	17.16	27.9
	2	6.02	11.98	29.3
	3	5.46	21.75	26.6
	4	6.38	32.69	23.5
2004-05	1	5.76	10.65	29.7
	2	5.40	21.35	26.7
	3	5.06	17.19	27.9
	4	5.66	12.59	29.1
2005-06	1	5.83	7.42	30.6
	2	6.49	28.28	24.8
	3	5.49	21.71	26.6
	4	5.25	8.59	30.2
2006-07	1	6.12	7.96	30.4
	2	6.01	11.84	29.3
	3	6.48	17.92	27.6
	4	5.98	18.09	27.6
2007-08	1	6.82	23.60	26.1
	2	7.11	30.94	24.0
	3	6.06	45.22	20.1
	4	6.40	21.86	26.6
2008-09	1	5.80	7.36	30.6
	2	6.31	19.10	27.3
	3	5.52	44.53	20.3
	4	6.66	30.77	24.1

Table : A 6.10

NARLA TATA RAO THERMAL POWER STATION

Year		Water with drawals	X-code	4-q-m-a	centred	Specific Seasonal	Deseasonalised
2003-04	1	2.29	1				2.6
	2	2.44	2				2.7
	3	2.27	3	2.3	2.3	0.98	2.5
	4	2.17	4	2.3	2.2	0.99	2.4
2004-05	1	2.17	5	2.1	2.1	1.03	2.4
	2	1.99	6	2.1	2.1	0.95	2.7
	3	2.20	7	2.1	2.1	1.05	2.4
	4	2.13	8	2.1	2.1	1.03	2.3
2005-06	1	2.14	9	2.2	2.1	1.02	2.4
	2	2.26	10	2.1	2.1	1.08	2.5
	3	1.91	11	2.0	2.0	0.96	2.09
	4	1.83	12	2.0	2.0	1.005	2.01
2006-07	1	2.01	13	2.0	2.0	1.04	2.3
	2	2.18	14	2.0	2.1	1.03	2.45
	3	2.17	15	2.1	2.1	1.06	2.38
	4	2.12	16	2.1	2.0	1.03	2.32
2007-08	1	1.83	17	2.0	1.9	0.96	2.06
	2	1.76	18	1.9	1.9	0.93	1.98
	3	1.85	19	1.8	1.8	1.03	1.03
	4	1.85	20	1.8	1.8	1.03	2.03
2008-09	1	1.59	21	1.7	1.7	0.94	0.94
	2	1.69	22	1.6	1.6	1.05	1.89
	3	1.39	23	1.5			
	4	1.47	24				

Calculation of Seasonal index

Year	Summer (Dry Season)	Rainy (wet Season)	Winter (Cold season)	Post Monsoon
2003-04			0.98	0.99
2004-05	1.03	0.95	1.05	1.03
2005-06	1.02	1.08	0.96	1.005
2006-07	1.04	1.03	1.06	1.03
2007-08	0.96	0.93	1.03	1.03
2008-09	0.94	1.05		
Total	4.99	5.04	5.08	5.09

Unadjusted Seasonal Mean	0.998	1.01	1.02	1.02
Adjusted Seasonal	0.89	0.89	0.91	0.91
Seasonal Index	89	89	91	91

As per the Indian monsoon conditions, the Seasonal index values calculated are as follows:

Final SVI	89+30.33 =119.33	89+30.33 =119.33	91-30.33 =60.67	91-30.33 =60.67

Correction factor = 4/4.5 = 0.89
Trend equation: y = 24 - 0.33 x

Seasonalized Forecast of Water Withdrawals

Year	X-code	Trend Unadjusted Forecast	Seasonal Index	Forecast Seasonal Adjusted (in million hundred cubic meters)
2009-10				
Summer	25	15.75	0.89	14.01
Rainy	26	15.42	0.89	13.72
Winter	27	15.09	0.91	13.7
Post Monsoon	28	14.76	0.91	13.43
2010-2011				
Summer	29	14.43	0.89	12.84
Rainy	30	14.1	0.89	12.55
Winter	31	13.77	0.91	12.53
Post Monsoon	32	13.44	0.91	12.23
2011-2012				
Summer	33	13.11	0.89	11.67
Rainy	34	12.78	0.89	11.37
Winter	35	12.45	0.91	11.33
Post Monsoon	36	12.12	0.91	11.03
2012-2013				
Summer	37	11.79	0.89	10.49
Rainy	38	11.46	0.89	10.19
Winter	39	11.13	0.91	10.12
Post Monsoon	40	10.8	0.91	9.8
2013-2014				
Summer	41	10.47	0.89	9.3

Rainy	42	10.14	0.89	9.02
Winter	43	9.81	0.91	8.9
Post Monsoon	44	9.48	0.91	8.6

SCENARIO OF LOSS OF GENERATION

Year		Loss Generation due to WS (in hundred million units)	X-code	4-q-m-a	Centered	Specific Seasonal	Deseasonalised
2003-04	1	3.54	1				6.1
	2	6.62	2				5.02
	3	7.84	3	5.9	5.9	1.32	5.3
	4	5.71	4	5.8	6.0	0.95	9.4
2004-05	1	3.08	5	6.2	6.3	0.49	5.3
	2	8.10	6	6.5	6.5	1.25	6.1
	3	9.12	7	6.5	6.5	1.40	6.2
	4	5.80	8	6.4	6.3	0.91	9.5
2005-06	1	2.58	9	6.3	6.8	0.38	4.4
	2	7.70	10	7.3	7.0	1.1	5.8
	3	13.03	11	6.7	7.0	1.86	8.9
	4	3.30	12	7.3	7.5	0.44	5.4
2006-07	1	5.33	13	7.7	7.2	0.74	9.2
	2	9.20	14	6.7	6.6	1.39	6.9
	3	8.93	15	6.6	6.2	1.44	6.07
	4	2.92	16	5.8	6.4	0.46	4.8
2007-08	1	2.29	17	7.0	7.3	0.31	3.9
	2	13.74	18	7.7	7.7	1.78	10.41
	3	11.85	19	7.6	8.0	1.48	8.06
	4	2.56	20	8.4	7.5	0.34	4.2
2008-09	1	5.64	21	6.5	5.5	1.03	9.7
	2	5.77	22	4.6	4.7	1.23	4.4
	3	4.26	23	4.9			2.89
	4	3.77	24				6.2

Calculation of Seasonal index

Year	Summer (Dry Season)	Rainy (wet Season)	Winter (Cold season)	Post Monsoon
2003-04			1.32	0.95
2004-05	0.49	1.25	1.40	0.91
2005-06	0.38	1.1	1.86	0.44
2006-07	0.74	1.39	1.44	0.46
2007-08	0.31	1.78	1.48	0.34
2008-09	1.03	1.23		
Total	2.95	6.75	7.5	3.1
Unadjusted Seasonal Mean	0.59	1.35	1.5	0.62
Adjusted Seasonal	0.58	1.32	1.47	0.61
Seasonal Index	58	132	147	61

As per the Indian monsoon conditions, the Seasonal index values calculated are as follows:

Final SVI	58+49 =107	132+20.33 =152.33	147-49 =98	61-20.33 =40.67

Correction factor = 4/4.06 =0.98

Trend equation: y = 65.0 – 0.12 x

Seasonalized Forecast of Loss of Generation

Year	X-code	Trend Unadjusted Forecast	Seasonal Index	Forecast Seasonal Adjusted (in hundred million cubic meters)
2009-10				
Summer	25	62	0.58	35.9
Rainy	26	61.88	1.32	81.68
Winter	27	61.76	1.47	90.8
Post Monsoon	28	61.64	0.61	37.6
2010-2011				
Summer	29	61.52	0.58	35.7
Rainy	30	61.4	1.32	81.05
Winter	31	61.28	1.47	9.08
Post Monsoon	32	61.16	0.61	37.3
2011-2012				

Summer	33	61.04	0.58	35.4
Rainy	34	60.92	1.32	80.4
Winter	35	60.8	1.47	89.4
Post Monsoon	36	60.68	0.61	37.01
2012-2013				
Summer	37	60.56	0.58	35.12
Rainy	38	60.44	1.32	79.8
Winter	39	60.32	1.47	88.7
Post Monsoon	40	60.2	0.61	36.72
2013-2014				
Summer	41	60.08	0.58	34.84
Rainy	42	59.96	1.32	79.14
Winter	43	59.84	1.47	87.96
Post Monsoon	44	59.72	0.61	36.42

Forecast of Water Withdrawals (in Hundred million cubic meters) versus Loss of Generation (in hundred million units)*[16]

Quarter	Summer	Rainy	Winter	Post Monsoon Season
2009-10				
WD	18.58	18.2	9.13	8.95
LG	66.17	94.21	60.53	25.07
2010-2011				
WD	17.01	16.59	8.36	8.19
LG	39	93.45	6.05	24.9
2011-2012				
WD	15.45	15.05	7.55	7.35
LG	65.2	92.7	59.6	24.71
2012-2013				
WD	13.86	13.46	6.75	6.53
LG	64.69	92.04	59.13	24.48
2013-2014				
WD	12.27	11.89	5.93	5.73
LG	64.16	91.28	57.94	24.28

[16] Calculated figures of Final Seasonal Forecast figures as per Indian Monsoon Conditions

Season Wise Varying Levels of Plant Load Factor (Percentage)

Year	Quarters	Water Withdrawals Hundred Million Cubic Meters	Loss of Generation due to water shortage (Million Units)	Plant Load Factor (PLF) percentage
2003-04	1	2.29	3.54	29.6
	2	2.44	6.62	27.5
	3	2.27	7.84	26.8
	4	2.17	5.71	28.1
2004-05	1	2.17	3.08	29.8
	2	1.99	8.10	25.8
	3	2.20	9.12	25.2
	4	2.13	5.80	27.8
2005-06	1	2.14	2.58	30.2
	2	2.26	7.70	26.2
	3	1.91	13.03	22.0
	4	1.83	3.30	29.0
2006-07	1	2.01	5.33	28.5
	2	2.18	9.20	25.7
	3	2.17	8.93	25.8
	4	2.12	2.92	29.8
2007-08	1	1.83	2.29	30.4
	2	1.76	13.74	23.1
	3	1.85	11.85	24.0
	4	1.85	2.56	30.2
2008-09	1	1.59	5.64	28.5
	2	1.69	5.77	27.7
	3	1.39	4.26	28.7
	4	1.47	3.77	29.1

Table A 6.11

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SCENARIO OF WATER WITHDRAWALS:

Year		Water with drawals(in hundred million cubic meters)	X-code	4-q-m-a	centered	Specific Seasonal	Deseasonalised
2005-06	1	2.73	**1**				3.3
	2	3.35	**2**				4.08
	3	3.76	**3**	3.3	3.3	1.13	3.03
	4	3.40	**4**	3.4	3.4	1.01	3.03
2006-07	1	2.98	5	3.3	3.3	0.92	3.6
	2	3.22	6	3.2	3.1	1.04	3.9
	3	3.05	7	3.0	3.2	0.96	2.3
	4	2.80	8	3.3	3.5	0.81	2.5
2007-08	1	4.18	9	3.6	3.9	1.08	5.09
	2	4.45	10	4.2	4.5	0.99	5.4
	3	5.19	11	4.8	5.1	1.01	4.18
	4	5.41	12	5.4	5.7	0.95	4.8
2008-09	1	6.64	13	5.9	6.0	1.10	8.09
	2	6.46	14	6.1	6.3	1.03	7.9
	3	5.99	15	6.4	5.6	1.07	4.8
	4	6.56	16	4.8			5.8

Calculation of seasonal Index

	Year	1	2	3	4	
1	2005-06			1.13	1.01	
2	2006-07	0.92	1.04	0.96	0.81	
3	2007-08	1.08	0.99	1.01	0.95	
4	2008-09	1.1	1.03	3.1	2.77	
	Total	3.1	3.06	6.2	5.54	
	Unadjusted Seasonal Mean	1.03	1.02	1.55	1.4	5
	Adjusted Seasonal	0.82	0.82	1.24	1.12	
	Index	82	82	124	112	

Correction Factor = 4/5=0.8
As per the Indian monsoon conditions, the Seasonal index values calculated are as follows:

Final SVI	82 +41.33 =123.33	82+37.33 =119.33	124-41.33 =82.67	112-37.33 =74.67

Trend equation: y = 2.1 + 0.27 x

Seasonalized Forecast of Water Withdrawals:

Year	X-code	Trend Unadjusted Forecast	Seasonal Index	Forecast Seasonal Adjusted (in million hundred cubic meters)
2009-10				
Summer	17	6.69	0.82	5.5
Rainy	18	6.96	0.82	5.7
Winter	19	7.23	1.24	8.9
Post Monsoon	20	7.50	1.12	8.4
2010-2011				
Summer	21	7.7	0.82	6.3
Rainy	22	8.04	0.82	6.6
Winter	23	8.31	1.24	10.30
Post Monsoon	24	8.58	1.12	9.6
2011-2012				
Summer	25	8.85	0.82	7.3
Rainy	26	9.12	0.82	7.5
Winter	27	9.39	1.24	11.6
Post Monsoon	28	9.66	1.12	12.03
2012-2013				
Summer	29	9.93	0.82	9.02
Rainy	30	10.2	0.82	9.2
Winter	31	10.47	1.24	14.3
Post Monsoon	32	10.74	1.12	13.23
2013-				

2014				
Summer	33	11.01	0.82	12.1
Rainy	34	11.28	0.82	13.76
Winter	35	11.55	1.24	9.31
Post Monsoon	36	11.82	1.12	10.55

SCENARIO OF LOSS OF GENERATION:

Year		Loss of Generation	X-code	4-q-m-a	centered	Specific Seasonal	Deseasonalised
2005-06	1	3.39	**1**				5.06
	2	5.75	**2**				4.08
	3	4.83	**3**	4.3	4.1	1.18	3.77
	4	3.06	**4**	3.9	3.5	0.87	2.84
2006-07	1	1.79	5	3.0	2.7	0.66	2.67
	2	2.50	6	2.3	2.1	1.19	1.77
	3	1.96	7	1.8	1.8	1.09	1.53
	4	0.91	8	1.7	2.0	0.46	2.5
2007-08	1	1.57	9	2.2	2.2	0.71	2.3
	2	4.37	10	2.2	2.2	1.99	3.09
	3	1.82	11	2.2	2.1	0.87	1.42
	4	0.83	12	2.0	1.6	0.52	1.31
2008-09	1	0.85	13	1.3	1.4	0.61	1.27
	2	1.65	14	1.6	1.6	1.03	1.17
	3	2.92	15	1.6	1.5	1.95	2.28
	4	1.08	16	1.4			1.71

Calculation of Seasonal Index

	Year	1	2	3	4
1	2005-06			1.18	0.87
2	2006-07	0.66	1.19	1.09	0.46
3	2007-08	0.71	1.99	0.87	0.52
4	2008-09	0.61	1.03	1.95	
	Total	1.98	4.21	5.09	1.85
	Unadjusted Seasonal Mean	0.66	1.40	1.27	0.62
	Adjusted Seasonal	0.67	1.41	1.28	0.63
	Index	67	141	128	63

Correction Factor = 4/3.95 =1.01

As per the Indian monsoon conditions, the Seasonal index values calculated are as follows:

Final SVI	67 +42.67 =109.67	141+21 =162	128-42.67 =85.33	63-21 =42

Trend equation: y = 4.09 - 0.19 x

Seasonalized Forecast of Loss of Generation

Year	X-code	Trend Unadjusted Forecast	Seasonal Index	Forecast Seasonal Adjusted (in million hundred cubic meters)
2009-10				
Summer	17	0.83	0.67	0.56
Rainy	18	0.64	1.41	0.90
Winter	19	0.45	1.28	0.57
Post Monsoon	20	0.26	0.63	0.16
2010-2011				
Summer	21	0.1	0.67	0.067
Rainy	22	0.09	1.41	0.127
Winter	23	-0.28	1.28	-0.36
Post Monsoon	24	-0.47	0.63	-0.29
2011-2012				
Summer	25	-0.66	0.67	-0.44
Rainy	26	-0.85	1.41	-1.19
Winter	27	-1.04	1.28	-1.33
Post Monsoon	28	-1.23	0.63	-0.77
2012-2013				
Summer	29	-1.42	0.67	-0.95
Rainy	30	-1.61	1.41	-2.27
Winter	31	-1.8	1.28	-2.3
Post Monsoon	32	-1.99	0.63	-1.25
2013-2014				
Summer	33	-2.18	0.67	-1.46
Rainy	34	-2.37	1.41	-3.3
Winter	35	-2.56	1.28	-3.2
Post Monsoon	36	-2.75	0.63	-1.7

Forecast of Water Withdrawals (in Hundred million cubic meters) versus Loss of Generation (in million units)*[17]

Quarter	Summer	Rainy	Winter	Post Monsoon Season
2009-10 WD LG	8.46 0.75	8.5 0.95	5.94 0.38	5.6 0.107
2010-2011 WD LG	9.73 -0.053	9.8 -0.03	6.87 -0.24	6.4 -0.19
2011-2012 WD LG	11.1 -0.88	11.51 -0.93	7.8 -0.89	8.02 -0.51
2012-2013 WD LG	13.72 -1.72	13.61 -1.35	9.6 -1.53	8.82 -0.83
2013-2014 WD LG	15.2 -2.53	32.48 -2.73	6.21 -2.13	7.03 -1.13

[17] Calculated figures of Final Seasonal Forecast figures as per Indian Monsoon Conditions

Season Wise Varying Levels of Plant Load Factor (Percentage)

Year	Quarters	Water Withdrawals Hundred Million Cubic Meters	Loss of Generation due to water shortage (Million Units)	Plant Load Factor (PLF) percentage
2005-06	1	2.73	3.39	22.5
	2	3.35	5.75	14.6
	3	3.76	4.83	17.7
	4	3.40	3.06	23.5
2006-07	1	2.98	1.79	27.2
	2	3.22	2.50	24.9
	3	3.05	1.96	26.7
	4	2.80	0.91	30.1
2007-08	1	4.18	1.57	27.9
	2	4.45	4.37	18.7
	3	5.19	1.82	27.1
	4	5.41	0.83	30.4
2008-09	1	6.64	0.85	30.3
	2	6.46	1.65	27.7
	3	5.99	2.92	23.5
	4	6.56	1.08	29.5

Table A 8.1

Hydraulic Particulars of Kinnersani Dam

KSP DAM

Location of Dam :		
Latitude	-	17^0- 41'-00
Longitude	-	18^0 -40'-00
Catchment Area	-	511.16 Sqm
Intercepted	-	3.64 Sqm
Dependable Monsoon Rainfall	-	45''
Yield Per square mile	-	19.16 MCFT or 0.5426 M.CUM
Total Monsoon dependable Yield	-	9863.00 MCFT or 279.32 M.CUM
Total Annual Dependable yield	-	10.060 or 284.90 M.CUM
Maximum Flood Discharge	-	168400 Cusecs

(i) By 10 % precipitation in 12 hrs – 200000 Cusecs

TBL (Tank Bund Level)	- 415.00'
FRL (Full Reservoir Level)	- 407.00
Crest of Spill way	- 383.00'
Head of Discharge	- 24'
Length of Earthen Dam	- 6874'-00''
Max. Height of Gravity dam	- 126'-0
Length of Spill way	- 590'
Max. Height of Gravity dam	- 80'
Flood Disposal works way 590'	- 11 Nos radial Gates 40'x 24' size (each spill weight 40 MT) - 2 Nos radial Gates 20 ' x 24 'size
(each weight 20 M)	
Sill of water supply sluice	- +360.00
Sill of construction sluice	- +365.00
Capacity at MDDL (Minimum Drawn Down level)	- 1450 MCFT
Capacity at Crest level of weir	- +383.00 or 3375 MCFT
Capacity at FRL	- 8400 MCFT
Life of Reservoir	- 100 years

KSP CANAL

Discharge in water supply channel	- 110 cusecs
Bed Width	- 3'
Full supply Depth	- 4'-6''
Bed Fall	- 1 in 3520
Velocity	- 2411 ft/sec
Length of the channel	- 6 miles 113'feet
Cost of the project	- Rs.549.17 lakhs
Year of starting	- 1961-62
Year of Completion	- 1971-72

Table A 8.2

MYLAVARAM RESERVOIR

Location	**-** On Pennar River near Mylavaram, Mylavaram Mandal, Kadapa (Dist)
Latitude	- 14^0-15^1
Longitude	**-** 78^0-20^1-40^{11}
Total Catchments of the river at dam site	- 19197 square miles
Deep River Bed Level	- 181.470 M
Width of the river at dam site	- 365.70 M
Maximum Flood Discharge	- 8180 Cumecs
Maximum water level	- 202.65 M
Dead Storage Level	- 189.00 M
Minimum Drawn Down Level	- 190.50 M
Gross Storage at FRL	- 283.00 M.Cum (9.965 TMCft)
Live Storage at FRL	- 254.00 M.Cum
Water Spread at FRL	- 41 sq.Miles
No. and size of vents of spill way	- 13 Nos (12.2 M x 8.65 M)
Length of spillway	- 195.10 M
Crest Level of Dam	- 194 M (Spill way crest level)
L/s of Earth dam from 0/0 to 740.84 M	- 740.84 M
Top Width of earth dam	- 6 M
Maximum Height of Earth Dam	- 24.30 M

Sill Level of North Canal	- + 186 M
Discharge of the North Canal	- 25.65 Cumecs
Length of the North Canal	- 34.34 KM
Ayacut under the North Canal	- 50,000 Acres
Sill level of the South Canal	- + 187.15 M
Discharge of the South Canal	- 10.19 Cumecs
Length of the South Canal	- 44.44 KM
Ayacut under the South canal	- 25,000 Acres
Cost of the Project	- 23.84.58 Lakhs
Year of Commencement	- 1968-1969
Year of Completion	- 1983
No: of Villages Benefited	- 76
Size of the North Canal Gate	- 2.25 M X2.50 M
Size of South Canal Gate	- 1.80 M X2.50M
Sill level of River	- 185.00 M

Table A8.3

SCENARIO OF WATER EXCESS AND SHORTAGE LEVELS AT SOUTH CANAL MYLAVARAM RESERVIOR

Year & Month	Number of days (in percentage)	Water level in dam	Water storage capacity	RTPP with drawal
1995				
Jan.-August	61-WS	< 190	< 1 TMC	< 20 Cusec
Sept-Dec.	30-WS	> 194	> 2 TMC	≥ 30 Cusec
1996				
Jan. – Feb	28-WS	> 190	> 1 TMC	> 20 Cusec
Mar.- Mid June	24- WS	< 190	< 1 TMC	< 20 Cusec
Mid June – Dec.	50- WE	> 196 (196 to > 200)	> 3 TMC (3-7)	> 25- 30 Cusec > 80-100 Cusec
1997				
Jan. – Dec.	100-EW	≥ 200	> 8 TMC (4 -8)	> 30 Cusec. (30-180)
1998				
Jan. – Dec.	100-EW	> 200	> 7 TMC (2-9)	> 25 Cusec (25-200 Cusec)
1999				
Jan. – Dec.	100-EW	> 200 (196-200)	> 6 TMC (3 – 7 TMc)	> 25 Cusec (25-200)
2000				
Jan. – Dec.	100-EW	> 194 (190-194)	> 2 TMC (1 -5 TMC)	> 25 Cusec (25-200)
2001				
Jan. – Dec.	100-EW	> 196	> 3 TMC (2-9 TMC)	> 25 Cusec(25-200)
2002				
Jan. – Dec.	100-EW	> 200 (190-200)	> 6 TMC (2-6)	> 25 Cusec(25-200)
2003				
Jan. – June	51-WS	≥ 193	> 1 TMC	≤20 Cusec
July – Mid Oct	25-WS	190	< 1 TMC	≤15 Cusec
Oct. – Dec.	24-WS	> 190	> 1 TMC (1-2 TMC)	≤20 Cusec
2004				
Jan. – Mid June	45-WS	≥ 192	> 1 TMC	≤20 Cusec
Mid. June – Mid July	7.3-WS	< 190	< 1 TMC	< 20 Cusec
July – Sept.	21-WS	> 191	> 1 TMC	≤20
Oct. – Dec.	26-WS	< 190	< 1 TMC	< 20 Cusec
2005				
Jan. - Sept	68-WS	< 190	< 1 TMC	< 20 Cusec (7- 10 Cusec)
Oct. – Dec.	32-WS	> 194	> 1 TMC	≤20 Cusec
2006				
Jan. - April	26-WS	> 194	> 2 TMC	≤20 Cusec
May – Dec.	74-WS	< 190	< 1 TMC	< 20 Cusec
2007				
Jan. - June	49-WS	< 190	< 1 TMC	≤ 20 Cusec
July – Dec.	50-EW		2-9 TMC	≥ 30 Cusec
2008				
Jan - April	27-WS	> 190	> 1 TMC	≤ 20 Cusec
April - Aug	39-WS	< 190	< 1 TMC	< 20 Cusec
Sep. - Dec		> 190	> 1 TMC (1-3 TMC)	> 20 Cusec (20-30 Cusec)
2009				
	100	> 195	> 3 TMC	> 30 Cusec

Table A 8.4

Sri Pothuluri Veera Brahmendra swamy Reservoir

Full Reservoir Level	: +216.50M
Middle Water Level	: +217.50 M
Tank Bund Level	: +220.50 M
Minimum Drawn Down Level	: +186.00
Free Board	: 3.00 M
Live Storage @FRL	: 16.17 TMC
Reservoir Capacity @FRL	: 17.735 TMC
Dead Storage	: 1.565 TMC
Maximum Height of Dam	: 50.50 M
Deepest bed Level	: +170.00 M

Right Canal

Vent Size	: 2.50x2.50 M
Sill Level	: 186.00 M
Ayacut	: 30,000 acres
Design Discharge	: +186.00 M
Lengthy of Canal	: 436 cusecs

Left Canal

Vent size	: 2x2.50x3.50M
Sill level	: +192.50M
Ayacut	: 1,27,000
Design Discharge	: 1.825 Cusecs
Length of Canal	: 109.50 Km

Table A 8.5

List of On-going and Future Power Projects of APGENCO

Taking in to purview the precarious position of existing hydel and thermal power plants w.r.t to its water availability vis-à-vis loss of generation, it is necessary to gauge the water requirements of future hydel and thermal power plants. However APGENCO is likely to take up few more thermal and hydel power projects. But judicious management of precious resource “WATER” in power plants is a matter of great concern.

Year	Name of the Project	Capacity Addition (MW)	Commissioning by
2009-2010 (from Dec, 2009)	Pochampad HEP Unit 4	9	Dec,2009
	Kakatiya TPP Stage I	500	Mar,2010
	Priyadarshini Jurala HEP	6X39 = 78	Unit 4 by Jan,2010; Unit 5 by Mar, 2010
	Total	587	
2010-2011	Priyadarshini Jurala HEP	39	Unit 6 by July,2010
	Rayalaseema TPP unit	210	Aug,2010
	Kothagudem TPS Stage VI	500	Oct, 2010
	Nagarjuna Sagar Tail Pond Dam	25	Unit 1 by Mar,2011
	Pulichintala HEP	30	Unit 1 by Mar,2011
	Total	804	
2011-2012	Nagarjuna Sagar Tail Pond Dam	25	Unit 2 by June,2011
	Pulichintala HEP	90	Unit 2 by Jun,2011; unit 3 by Sept, 2011 and unit 4 by Dec, 2011
	Lower Jurala HEP	120	Unit 1 by May ,2011; Unit 2 by Sept , 2011 and Unit 3 by Jan,2012
	Total	235	
2012-2013	Lower Jurala HEP	120	Unit 4 by May ,2012; Unit 4 by Sept , 2012 and Unit 6 by Jan, 2013
	Sri Damodaram Sanjeevaiah TPP (JVP at Krishnapatnam)	1600	Unit 1 by June 2012 and Unit 2 by Dec, 2012
	Kakatiya TPP Stage II	600	May 2012

	Total	2320	
	Grand Total (I)	3946	
2012-2013	Rayalaseema TPP Stage –IV unit 6	600	Jun,2012
	Integrated gasification Combined Cycle plant at Dr.NTTPS	182	Jun, 2012
	Combined Cycle Gas based Project near karimnagar, (JVP)	1400	1st Module (700 MW):Sept,2012 2nd Module: Mar,2013 (Dependent upon Gas Availability)
	Total	2182	
2013-2014	Combined Cycle Gas Based Project near Karimnagar (JVP)	700	3rd Module: Sept,2013 (Dependent upon Gas Availability)
	Sattupally TPS	600	Mar, 2014
	Polavaram HEP	320	Units 1 To 3: unit 1 by Jun,2013
	Dummugudem HEP	160	Unit 2 to 6: April, 2013 to Mar, 2014
	Kanthanapally HEP	150	Unit 2 to 5: April, 2013to March,2014
	Vodarevu thermal power project	800	Unit 1 by Nov,2013
	Total	2730	
2014-2015	Polavaram HEP Dummugudem HEP	320 160	Unit 4 to 6 Unit 5 to 8
	Kanthanapally HEP	200	Unit 4 to 6
	Vodarevu Thermal Power Project	2400	Unit 2 by April,2014 and Unit 3 by Oct,2014, Unit 4 by March, 2015

	Nuclear Power Plant in Kadapa District	1000	Unit 1 by mar,2014
	Srikakulam TPP	800	
	Total	4880	
2015-2016	Polavaram HEP	320	
	Kanthanapally HEP	100	
	Vodarevu Thermal power Project	800	
	Nuclear power Plant in Kadapa District	1000	
	Srikakulam TPP	1600	
	Total	3820	
	Grand Total	13612	

Grand Total (I + II)	17558
Grand Total (including New Projects already Commissioned)	18595

It is highly recommendable for APGENCO instead of relying over depleting source of water resources, to take up petty renewable sources of energy in many number of cluster groups to avert the worst situation of water shortage for especially non-renewable sources of energy based power plants.

References

1. Arnaud Buchs, Fevrier (2008), "Standards Applied to Water Use: An attempt to built up Dynamic Indicators"- A Manuscript published in "Global Changes and Water resources: Confronting the expanding and Diversifying Pressures: XIIIth World Water Congress, Montpelier: France.

2. Al-Kayiem, Theeb M.A. W (August, 2006) "Cooling tower evaluation to suit 200 Megawatt Thermal power plant", organized by Universiti Tenaga Nasional, Bangi, Seangor, Malaysia .

3. Ananda Saver, Pietklop and Sumeet Agrawal (2010), "Over heating: Financial Risks from water constraints on power generation in Asia, India, Malaysia, Philippines, Thailand and Vietnam". World Resources Institute Report.

4. Aaron Twolf, Shira B. Yoffee and Mark Glodana, "International Waters: Indicators for Identifying Basins at Risk", UNESCO, Department of Geo Sciences, Oregon State, University, USA.

5. Benjamin K Savacool (2009), "Running on Empty: The Electricity water Nexus and the US Electric Utility Sector", Energy Law Journal, Volume 30.

6. Benno Rothstein and Guido Halbig (2009)," Management of Weather and Climate Risk in the Energy Industry", PP 3-12, Weather Sensitivity of Electricity Supply and data Services of the German Met Office, Springer, Nether lands, Benno Rothstein, Guido Halbig.

7. Benedy Kt Dziegielewski, Thomas Bik (August 2006), "Water Use Bench Marks for Thermo Electric Power Generation" Project report, Southern Illinois University, United States Geological Survey, 2004, USGS National Competitive Grants Program.

8. Central Electricity Authority, (2010), Ministry of power, Government of India, New Delhi.

9. Caroline A Sullivan (2005), "Method to develop and describe community level water poverty index scores", Centre for Water Research, CEH, Wallingford, UK.

10. Dankreis (2009), "Water Scarcity and Nuclear power Industry", WISE Intern, Missouri University of Science and Technology.

11. Dominguez-Faus, Susan E powers et.al (2009), Status paper on “The water foot print of bio-fuels: A Drink or Drive Issue” Environmental Science and Technology, Vol.43, 3005-3010.

12. Ernest Orlando & Lawrence Berkeley, (December 2008), “Physical Impacts of Climate Change on the Western US Electricity System: A scoping Study”, Katie Coughlin and Charles Goldman, Environment Energy Technologies Division.

13. Falken Mark Malin (1990), “Population Growth and water supplies: An Emerging Crisis “, People 17(1), 18-20.

14. Falken Mark, Malin (1991), “Rapid Population Growth and water scarcity: The predicament of tommarrow‘s Africa”, in K. Davis and M Bernstam (eds) , Resources, Environment and Population: Present Knowledge and Future Options (pages 81-94), Newyork, Oxford University Press.

15. Falken Mark, Malin (1994),” Population, Environment and Development: A water perspective” In population Environment and Development: Proceedings of the United Nations Expert Group meetings on population, Environment and Development (pages 99-116), Newyork, United Nations.

16. Falkenmark, Malin and Lundquist (January, 1997)” Comprehensive assessment of the fresh water resources of the World”, World Fresh water problems call for a new realism. Stockholm Environment Institute.

17. Gareth James Lloyd, Henrik Larsen (Project Managers and quality assurance), October 2007, Status paper of DHI water for Energy Crisis? Examining the role and limitations of water for producing electricity”

18. Goldstein and Smith W (march2002), “ Water and Sustainability (Volume 3) US water consumption for power production – The Next Half Century. , Technical Report of Electric Power Research Institute (EPRI), California.

19. Gerbens Leenes P.W., Hoekstra AY, VanderMeer TH, (March 2008), “Water Foot Print of Bio-energy and other primary energy carriers”, Value of water Research Report Series No.29, University of Twente, Enschede Netherlands.

20. Gardner-Outlaw, Thomas and Engelman Robert (1997), “Sustaining water, easing scarcity: A second update”, Washington DC, Population Action International.

21. Gleick, Peter (1993),”An introduction to Global Fresh Water issues” In Peter Gleick (Ed) Water in Crisis (pages 3-12), Newyork Oxford University Press.

22. Gleick Peter (2000),”The World’s Water 2000-2001”,Washington DC, Island Press.

23. Gosain AK, Sandhya Rao, Debajit Basuray, (February 2006)” Status paper on Climate Change impact assessment on hydrology of Indian river basins”, Current Science, Vol.90, No.3. Indian Institute of technology, NewDelhi, India INRM Consultants.

24. Gbadebo Oladosu and Stan Hadley et.al (September 2006), “Electricity generation and Water related Constraints: An empirical analysis of Four South Eastern States’, Oak Ridge Laboratory.

25. Gichuki (2000), “Makueni District Profile: Water Management, 1989-1998 “Dry lands Research WP3.

26. Hoekstra A.Y. and Chapagain (2007), “Water Foot prints of nations: Water Use by People as a function of their Consumption pattern”, Water Resource Manage, 21: 35-48.

27. Jason Morrison, Mari Morikawa et.al (May 2009), “Climate change and the Global water crisis. What Businesses need to know and DO” White paper by United Nations Global Compact, Pacific Institute.

28. Jean Albergel and Jean Claude Bader and Jean Pierre Lamgat (April 1997), “Flood and Drought: Application to the Senegal River Management”, Sustainability of water resources under increasing uncertainity, Proceedings of Robot Symposium, SI, IAHS Publication no.240.

29. James Griffiths, Evazobey and Anne-Leonore Boffi , Status Paper “ Water, Energy and Climate Change: A contribution from business community”, Prepared by Business Council for Sustainable Development.

30. Jyothi Parikh and Kirit Parikh, “Clean water and Environmental Governance” National project Co-ordinators for capacity 21 project, Ministry of Water Resources, Government of India.

31. Jason Morrison, Mari Morikawa et.al (February, 2009), “Water scarcity and Climate Change: Growing risks for Businesses and Investors”, Aceres Report, Authored by the Pacific Institute.

32. Kagal J.A, Role of Total Productivity Maintenance in power plant performance” IIPE: LF 0923.

33. Krol M S and Van.Oel P "Integrated Assessment of water stress in Ceara, Brazil under climate change Forcing ", Water Engineering & Management , Department of Civil Engineering, University of Twente.

34. Kent Turner (October 2008), "Status Paper on "The Energy –Water Nexus: Vicious Cycle or Integrated Solution", President California, American water, 111th NAWC, annual Conference.

35. Kabat P, Schulze R.E, Hellmuth M.E et.al, Wagenningen (November, 2002)," International Dialogue on water and climate: Coping with impacts of climate variability and climate change in water management: A scoping Paper".

36. Linda Hwang, Sissel Waage, Emma Stewart, Jason Morrison, Peter H. Gleick et.al. (September, 2007), "At the Crest of a Wave: A proactive Approach to Corporate water Strategy", BSR (Business for Social Responsibility) and Pacific Institute.

37. Morgan, JP (March 2008), Watching Water: A guide to evaluating corporate risks in a thirsty world", Global Equity Research, Environmental, Social and Governance research.

38. Malini Mehra (December, 2008)" India: Emerging Leader Ship on Climate Change", Centre for Social Markets, Heinrich Boll Foundation, North America.

39. Morecos do Monte (2007), "Water Reuse in Europe", E-Water, Publication of European Water Association.

40. Nikolay Voutchkov (April 2007), "Water for GDP or Water for HDI"- The Golden Dilemma for Gujarat, Government of Engineering.

41. Pascal O. Girot, Seminar Paper on "Resilience to Hazards and the importance of cross-scale linkages", Environmental Risk Advisor, UNDP- Bureau of Development policy Costa Rica.

42. Plummer N, Tuteja N, Wang et.al (July, 2009), "A seasonal water availability prediction Service: Opportunities and Challenges", 18th world IMACS/ MODSIM Congress, Australia 13-17.

43. Rakesh Kumar, Singh R.D and Sharma K.D (September, 2005)" Water Resources of India", Current Science, Volume 89, National Institute of Hydrology, Roorkee.

44. Ratnesh Sharma, Amipshah et.al (2008), "Water Efficiency Management in Data Centers: Metrics and Methodology", Sustainable IT Ecosystem Hewlett-packard laboratories, USA.

45. Ramachnadra TV, Subramanian D.K. and Joshi N.V., (April 2000), "Optimal Design of hydro electric projects in Uttara Kannada, India", Centre for Ecological Sciences, Hydrological Sciences Journal 45 (2).

46. Reddy KV, Laffour (March, 2006), "Over view of the cost of desalinated water and costing methodologies", Desalination (pp; 340-353).

47. Shadananan Nair (October 2007), "Exploiting Hydel Power Potential to main Energy and Water securities in Kerala", International Conference on Small Hydro power –Hydro Srilanka.

48. Suresh Nautiyal, (January, 2003), "Water Crisis in India: Agenda for the 21st Century".

49. Seth D Sheldon (2008), "Water, Energy and Drought: Water Use for Energy Production in the US", University of Massachusetts.

50. Stone J.C. Singleton Jr, Gadkowski M, Salewicz A and Sikorski .W (1982), "Water Demand for Generating Electricity: A mathematical programming Approach with application in Poland" International Institute for Applied System Analysis, Laxenburg, Austria.

51. Vanderzaag P and Savenije H.H.G, (July, 2006), "Water as an economic good: The value of pricing and the failure of markets" Research Report Series, No.19.

52. Xiaoying Yang & Benedy Kt Dziegielewski (February,2007), " Water Use by Thermo Electric power plants in the United states" Journal of the American Water Resources Association, Vol 43, No.1.

53. Aqua stress (2007), The 13 s Document Series" Using Case Based Reasoning for the solution of water stress problems".

54. "Beyond the River: A transboundary Waters", (May, 2009), A forum for global Water Issues, No. 1, special Issue, International Water Institute.

55. Coping with water scarcity, Challenge of the 21st Century"(2007), World Water Day, UN Water.

56. Discussion Paper on" From Foot prints to Public Policy: The business Future for addressing water issues", (March, 2009), Pacific institute, The CEO Water Mandate.

57. EPTRI, "Water Resources", State of Environment, AP.

58. "Estimating Fresh Water Needs to meet future Thermo electric Generation requirements", (2008), Update DOE, NETL-400/2008/1339.

59. EU water saving potential (part 2- case studies), 19th July, 2007, Institute for International and European Environmental Policy.

60."Emerging Water Shortages", from Lester R Brown, plan B20, "Rescuing a planet under stress and a civilization in Trouble" (New York w. w. Nortan & Co., 2006), Earth Policy Institute.

61. Economic Review, 2009-2010.

62. "Estimating Water Use in United States: A new Paradigm for National Water Use Information Programme" (2002), http://books.nap.edu/openbook.php?record_id=10484&page=95

63. Intergovernmental panel on Climate Change, (2008)" Climate and water", IPCC, Technical Paper.

64. International Energy Agency Report, (2006) and World Energy Outlook (2006) Reports

65. "India's Ecological Foot print: A business perspective", (2008), Global Foot print Network and Confederation of Indian Industry.

66. Report of the Steering Committee on water Resources for 11th Five Year Plan (2007-2012), Government of India, and Planning Commission.

67. Solutions for water short World, Population Reports M, and No.14.

68. Status Paper on "Water Foot Printing: Identifying and addressing water risks in the value chain", SABMiller Plc and WWF UK.

69. Stabilizing water Tables, " Out growing the Earth: The Food Security Challenge in an Age of Falling water tables and Rising temperature", (NY:w.w. Norton& Co.2005)

70. Technology Status of thermal power plants in India and opportunities in renovation and modernization", An OPET international action on "Refurbishment of thermal power plants in India", TERI, New Delhi.

71. The United Nations World Water Development Report 3 (2009), "Water in a changing World", published joined by the United Nations Educational, Scientific and Cultural Organization (UNESCO).

72. "2007 A Water Year: Future water Solutions for India, (January, 2007), South Asia Network on Dams, Rivers and India.

73. Water Scarcity & Droughts, second interim Report, (June, 2007), prepared by DG Environment European Commission.

74. Water Energy Vision, (2009), "Thirsty Energy: Water and Energy in the 21st Century" World Economic Forum in partnership with Cambridge Energy Research Associates.

75. "Water Management Issues in power plants", 2010, Power Magazine, various Issues.

76. "Water- The India Story", March 23, 2009.

77. Water Figures: Turning Research in to Development" (2009), Quarterly Newsletter of the International Management Institute, Issue 1.

78. "Water Resources across Europe- Confronting Water Scarcity and Drought"(2009) European Environment Agency Report", No.2, Copenhagen.

79. "Water & Sustainability (Volume 3): US Water Consumption for power production- The Next Half century, Topical Report March, 2002, EPRI Concord, viewed, November, 2006.

80. "Water Security for Multi national Water Systems"(August, 2000)-Opportunity for Development, Stockholm.

81. "Water Resource Evaluation and management for Morar River Basin Gwalior district MP, Using GIS", (July, 2009), e-journal, Earth Science India, Vol 2 (III), pp.174 -186.