IRIS Reactor a Suitable Option to Provide Energy and Water Desalination for the Mexican Northwest Region

Gustavo Alonso, Ramon Ramirez, Carmen Gomez, Jorge Viais
Instituto Nacional de Investigaciones Nucleares
Km. 36.5 carretera Mexico-Toluca, Ocoyoacac 52045, Estado de Mexico, México

Abstract

The Northwest region of Mexico has a deficit of potable water, along this necessity is the region growth, which requires of additional energy capacity. The IRIS reactor offers a very suitable source of energy given its modular size of 300 MWe and it can be coupled with a desalination plant to provide the potable water for human consumption, agriculture and industry. The present paper assess the water and energy requirements for the Northwest region of Mexico and how the deployment of the IRIS reactor can satisfy those necessities.

The possible sites for deployment of Nuclear Reactors are considered given the seismic constraints and the closeness of the sea for external cooling. And in the other hand, the size of the desalination plant and the type of desalination process are assessed accordingly with the water deficit of the region.

1. Introduction

Electricity and water for human consumption, agriculture and industry are the two basic components for the improvement of the quality of life and sustainable development.

The Northwest region of Mexico is a semiarid region suffering scarcity of water and having electricity demand due to the normal population growth. These two components will be evaluated during the present study.

2. Mexican Water Resources

Population and water resources are the two factors that define the pressure over the water demand in the different regions of Mexico. Figure 1 shows the water pressure all over the Country [1]. From this figure can be seen that the North part of Mexico is the region with higher potable water demand and also Mexico City and its surroundings due to the high population concentration. On the other hand, the south part of Mexico is a tropical region and they have just a small pressure over the water resources.

Table I shows the water deficit for the different states with greater pressure over the water resources. As can be seen Mexico City is the one with the higher demand due to the overpopulation.

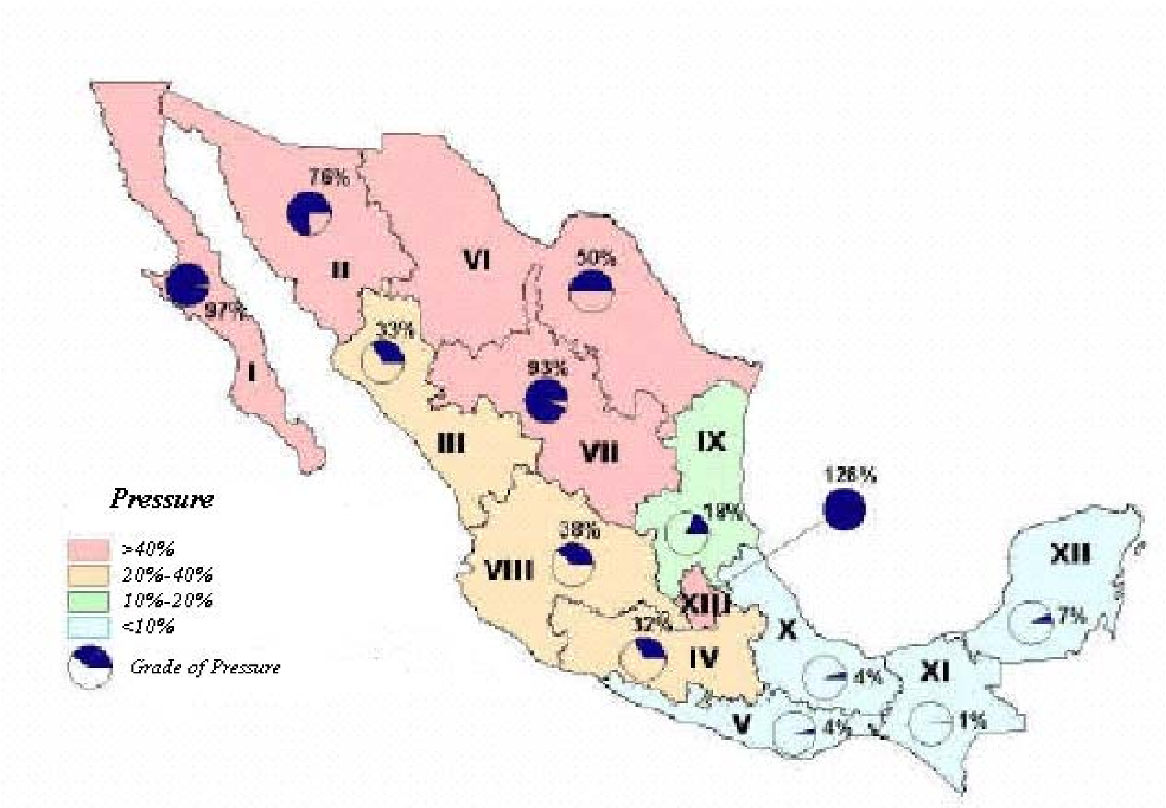

Figure 1. Pressure over the water resources in Mexico

Table I. Water deficit in Mexico

State	Water Deficit (m^3/year)	Percentage (%)
Distrito Federal (México City)	969,582,526	28.4
Chihuahua	591,179,652	17.3
Zacatecas	361,707,380	10.6
Sonora	343,654,396	10.1
Coahuila	312,630,564	9.2
San Luis Potosí	194,336,055	5.7
Nuevo León	176,796,606	5.2
Durango	171,165,154	5.0
Estado de México	163,913,921	4.8
Baja California Norte	86,984,232	2.5
Sinaloa	17,114,248	0.5
Tamaulipas	12,404,009	0.4
Baja California Sur	11,019,478	0.3
Total	3,412,488,221	100

3. 2010-2012 Mexican Electricity Requirements

The Mexican Electrical Sector Prospective 2003-2012 [2], assumes an annual increment of the gross domestic product of 4.7%. It identifies in the most of the cases the type of technology that will be used to cover the electricity demand in the different Mexican regions.

However, in the period 2010-2012 there is some electricity needs that has not technology associated. It opens the possibility that this demand can be cover by using nuclear power. Table II shows the gross capacity by states for the period 2010-2012 that has not engage with any technology.

Table II. 2010-2012 Energy requirements

State	Gross Capacity (MW)	Percentage (%)
Estado de México	2,200	23.4
Guerrero	2,100	22.4
Veracruz	1,070	11.4
Sonora	938	10.0
Chihuahua	900	9.6
Tamaulipas	550	5.9
Campeche	550	5.9
San Luis Potosí	523	5.6
Baja California Norte	513	5.5
Baja California Sur	38	0.4
Total	9,382	100

From Table I and II can be notice that there are several states that require electricity and water, they are shown in Table III.

Table III. States with requirements of water and electricity

State	Gross Capacity (MW)	Water Deficit (m^3/year)
Estado de México	2,200	163,913,921
Sonora	938	343,654,396
Chihuahua	900	591,179,652
Tamaulipas	550	12,404,009
San Luis Potosí	523	194,336,055
Baja California Norte	513	86,984,232
Baja California Sur	38	11,019,478

Now, if nuclear power will be used to cover the electricity requirements, then it is necessary to consider the external cooling for the reactor, and it will be done by using water. The nuclear power plant must be located in a coastal state to guarantee the water supply.

The only states that are under this consideration are: Sonora, Tamaulipas, Baja California Norte and Baja California Sur. On the other hand a reactor must be located in a geologic stable zone, Baja California is under the San Andres fail, so no reactor can be allocated on those states. Therefore, Sonora and Tamaulipas are the possible choices.

Sonora would be the best selection, because there are specific places in the state that are geologic stable. Furthermore, it requires greater amounts of electricity and water and due to its closeness to Chihuahua, Baja California Norte and Baja California Sur, also it can supply any electricity or water surplus to these states.

4. IRIS reactor

IRIS is a novel light water reactor with a modular integral primary system configuration with a net electrical output of about 335 MWe/module [3]. It is designed to satisfy four key requirements: enhanced safety, improved economics, proliferation resistance and waste minimization. Figure 2 shows IRIS configuration.

The IRIS reactor has an integral design-the steam generators, pumps, and pressurizer inside the reactor vessel. This design enhances safety, because it eliminates external loop piping, the source of accidents involving a large loss of coolant. Each unit would have eight modular, once-through steam generators that would be connected to four steam and feed piping connections. The reactor uses comparatively little water, so that there would be only a minimal amount released within the containment in case of a steam-line break.

Because of its simplified design requiring fewer pumps, valves, pipes, and other components, the IRIS reactor needs to shut down for major maintenance only every four years. Other maintenance can be performed while the reactor is still operating. On-line maintenance is further simplified by the use of redundant, modular, easily replaceable components. Because the IRIS reactor avoids the use of boron in its primary system and pressurization structure, its steam generators are expected to last longer, the tubes being less susceptible to stress corrosion cracking.

IRIS philosophy is based on “Safety by Design”. Thanks to its integral configuration, in IRIS a variety of accidents are, by design (i.e., with no intervention of either active or passive systems), either eliminated or their consequences and/or probability of occurring are greatly reduced. In fact 88% of class IV accidents (the ones with the possibility for radiation release) are either eliminated outright or downgraded. This provides a superb defense in depth which may allow IRIS to claim no need for an emergency response zone.

The overall aim of any modular reactor system is to match the construction of generating capacity to a utility’s future power requirements. IRIS offers utilities this scheduler flexibility, with construction time of each power module of two to three years. Thus, it makes IRIS a suitable economic option to provide electricity power according to the demand required instead to have big power plants with the consequent high investments.

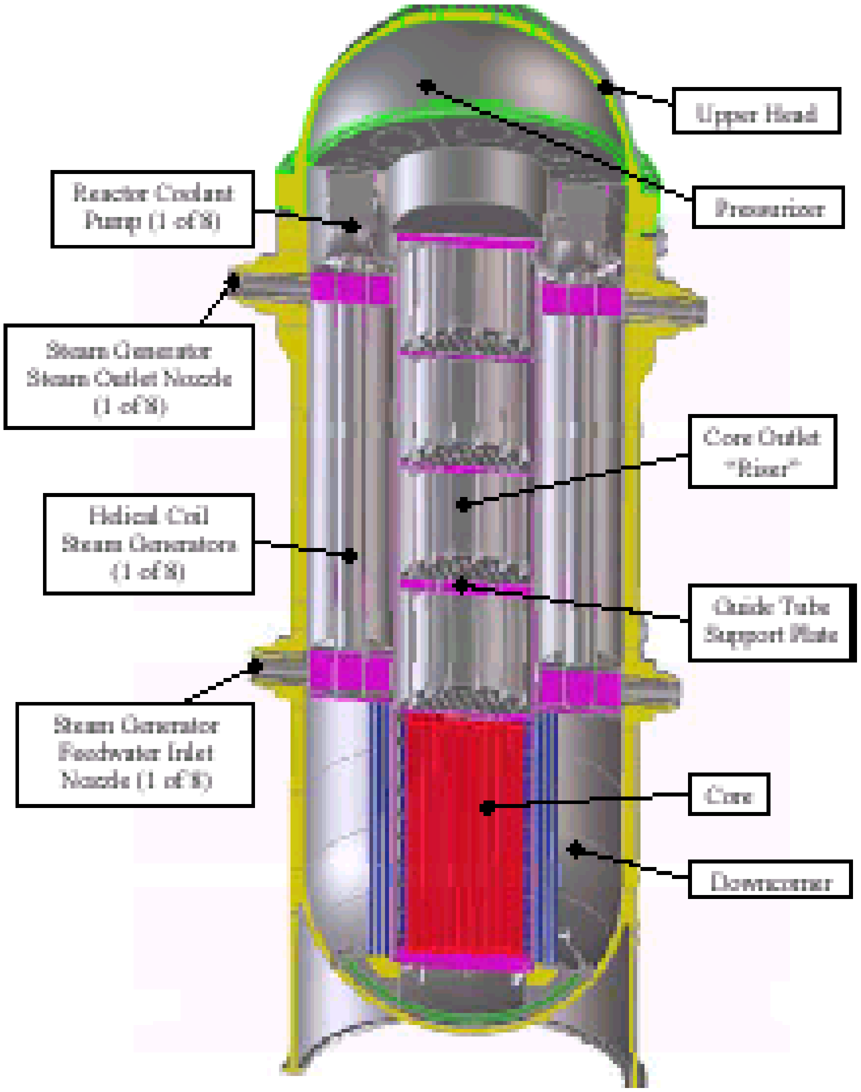

Figure 2. IRIS: Integral reactor coolant system

5. Desalination

To assure the adequate quality of the human life, it is necessary to guarantee a sufficient amount of water per person. A promising option to supply this potable water is the seawater desalination.

Seawater desalination is the processing of seawater to obtain “pure” water through the separation of the seawater feed stream into a product stream that is relatively free of dissolved substances and a concentrated brine discharge stream. After more than 40 years of intensive research and development three desalination technologies have achieved commercial large scale application. These are: Multi Stage Flash, Multi Effect distillation, and reverse osmosis process.

In particular in this study the technology used to assess the viability of having a nuclear power plant with a dual objective is the reverse osmosis process. This is a separation process in which pure water passes from the high pressure seawater side of a semi-permeable membrane to the low pressure permeate, or “pure” water, side of the membrane. In order to overcome the natural osmotic process (migration of pure water from a solution of low concentration into a solution of higher concentration in order to balance the osmotic pressures), the seawater side of the system has to be pressurized to create a sufficiently high net driving pressure across the membrane. In practice, the seawater can be pressurized to pressures as high as 70-80 bar.

Also, in this study the reverse osmosis considered is in a contiguous connection, which assumes that the desalination plant shares a common seawater intake and outfall with the power plant cooling system and may take advantage of other shared facilities and services. Figure 3 shows a standard connection under this configuration.

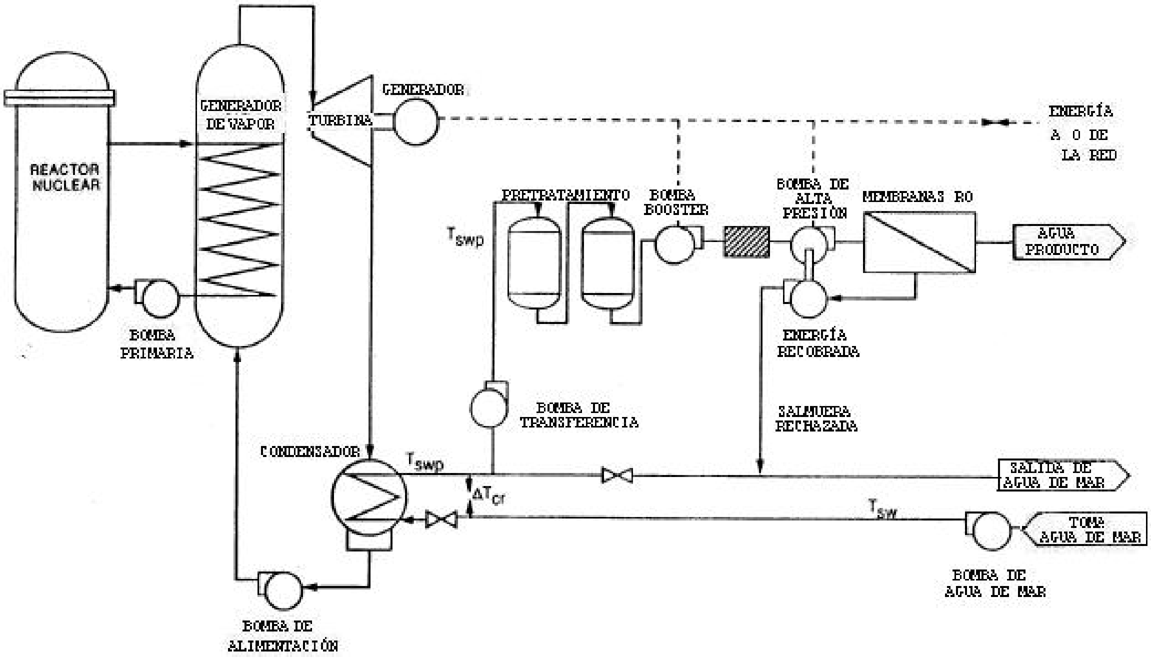

Figure 3. Dual plant using reverse osmosis

6. Economic Evaluation

To assess the economic viability of a dual plant we use the DEEP code [4] and consider the use of three IRIS modules to provide a electric output of 1005 MWe and consider a generation of 140 000 m^3/day of potable water.

DEEP code (Desalination Economic Evaluation Program) is intended to be used as a tool to provide guidance and insight. It enables side by side comparisons of a large number of design alternatives on a consistent basis with common assumptions. It also enables quick identification of the lowest cost option for providing specified quantities of desalination water and/or power at a given location and it gives an approximate cost of desalted water and power as a function of quantity and site specific parameters including temperatures and salinity.

The analysis consider different seawater temperatures, Table IV shows the water cost and the levelized cost of the power plant.

7. Conclusions

Electricity and water are two main components in a sustainable development of a region, this analysis already identified the potential place to allocate a dual plant in Mexico. Three IRIS modules will satisfy the energy requirements, however 7 desalination plants with a capacity of 140,000 m^3 will be necessary to cover the Sonora´s water defictit.

Finally, a levelized cost of 38 US$/MW-h and 0.62 US$/m^3 are very competitive with other sources of energy and water desalination making a dual plant a feasible option to cover energy and water demand in this region.

References

[1] Diario Oficial de la Federación, 31 de enero del 2003, Disponibilidad de agua, reporte de la Comisión Nacional del Agua. México.

[2] Prospectiva del Sector Eléctrico 2003-2012, www.sener.gob.mx

[3] M. Carelli, K. M;iller, C. Lombardi, N. Todreas, E. Greenspan, H. Ninokata, F. Lopez, L. Cinotti, J. Collado, F. Oriolo, g. Alonso, M. Moraes, R. Boroughs, “IRIS: Proceeding Towards the Preliminary Desig,” *Proc. 10th International Conference on Nuclear Engineering (ICONE-10)*, April 14-18, 2002, Arlington, VA, USA, Paper ICONE 10-22497.

[4] Examining the Economics of Seawater Desalination Using the DEEP code, IAEA-TECDOC-1186, November 2000.

Table IV. Cost evaluation of the dual plant

TD	PSIC	TSSB PPNO	TSSNO	RO PPU	NSP	SPC	TRRAP	TRRAW	TCC	IDC	TIC	WSIC	WC	WPA O&MC	LEC
21	1384	1035	1035.5	-25.3	1010.2	4.33	0.042	6.48	133.6	5.2	138.8	991.7	0.62	8.26	0.038
22	1389	1032	1031.8	-25.3	1006.6	4.33	0.043	6.48	133.5	5.2	138.8	991.3	0.62	8.26	0.038
23	1394	1028	1028.2	-25.3	1003	4.33	0.043	6.48	133.5	5.2	138.7	990.8	0.62	8.25	0.038
24	1399	1025	1024.6	-25.3	999.4	4.33	0.043	6.48	133.4	5.2	138.7	990.4	0.62	8.24	0.038
25	1404	1021	1021	-25.3	995.8	4.33	0.043	6.49	133.4	5.2	138.6	989.9	0.62	8.24	0.038
26	1409	1017	1017.5	-25.3	992.2	4.33	0.043	6.49	133.3	5.2	138.6	989.8	0.62	8.23	0.038
27	1413	1014	1013.9	-25.2	988.7	4.32	0.043	6.49	133.3	5.2	138.5	989.6	0.62	8.23	0.038
28	1418	1010	1010.3	-25.2	985.1	4.32	0.044	6.49	133.3	5.2	138.5	989.5	0.62	8.23	0.038

Management personal cost = 75000 ⇒ Average management salary = 1.1 * 75000 = 82500
Maintenance personal cost = 32000 ⇒ Average labor salary = 1.1 * 32000 = 35200
Optional Unit size specification = 20000 and required water plant capacity at site = 120000
PSIC ($/kW) = Power specific Investment cost
TSSBPPNO (MW) = Total site specific base power plant net output
TSSNO (MW) = Total site specific net output
ROPPU (MW) = RO plant power use
NSP (MW) = Net saleable power
SPC ($/kW (e) h) = Specific power consumption
TRRAP ($/kWh) = Total required revenue allocated to power
TRRAW ($/m3) = Total required revenue allocated to water
TCC (M$) = Total construction cost
IDC (M$) = Interest during construction
TIC (M$) = Total investment cost
WSIC (m3/d) = Water specific investment cost
WC ($/m3) = Water cost
WPAO&MC (M$/a) = Water plant annual O&M cost
LEC ($/kWh) = Levelized Electricity Cost