

# Power Quality Analysis by using Active Filter in AC/DC Microgrid

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## ABSTRACT

Power supply to rural area has always been a major challenge due to their distance from the power generation plants. It is highly capital intensive to design and maintain long distance transmission line. Rural area with marginal or no axis to primary grid bar can get power supply from microgrid. Fortunately, technology exist that can give the assurance of quality of electricity in an isolated area which is far away from the regular power network. The present scenario is the coexistence of both AC and DC micro grids, because of the evolutions of different types of loads. The hybrid microgrid concept assume a cluster of different types of loads and distributed generator operating as a controllable system which maintain the quality of power and its stability to its local area. Power system harmonics are caused due to certain highly nonlinear loads. These harmonics do have undesirable effect of the performance on the synchronous and induction machines, telephone interference, and power capacitor failures. Because of the increment in quantum of Total harmonic distortion, lead the power factor redactor, induction heating and some power losses, ultimately reduces the efficiency of the system. Therefore, we propose a harmonic mitigation technique introducing the active filter for multiple load and calculate the total harmonic distortion for the of the supply. The different filter has been investigated for power quality enhancement in microgrid. The performance of various filter are compared and active filter is found to be the best solution to get purely sinusoidal signals. The Simulink work is done by taking the MATLAB 2014 software .

**Keywords :** APF, AHF, Microgrid, Power Quality, MATLAB, SVM

## I. INTRODUCTION

The electric grid is term used to describe the system and equipment require to get electric power from various generating station. A microgrid is a small grid which assumes a cluster of different types of loads and distributed generator operating as a controllable system. The main purpose to design the microgrid is to maintain the quality of power and its stability to its local area by making ecofriendly environment.

Microgrid is a semiautonomous power system which can capable to manage the power flow from the local micro sources. The key feature that design the microgrid is power electronics, control and

communications network with integration of renewable energy source.

When the power demand is high, the microgrid can provide benefits to the utility by dispatching power to shave the peak loads . Hence it helps to maintain system stability when generation doesn't meet demand. Cost of electricity for the end users can be reduced when the microgrid meet the load demand especially when electric prices are high . Microgrid helps to reduce the transmission losses by producing power at local facilities. Moreover, any upgrades needed by the transmission system to increase its capacity can be postponed. Many of the sources used in the microgrid like solar array, wind farm,

rechargeable batteries are environmental friendly, and hence there are less carbon emissions.

Distribution network are designed by calculating the short circuit capacity of the network. A fundamental requirement for the connection of distributed generation (DG) resources to the network, besides voltage regulation and power quality constraints is the total fault current, determined by the combined short-circuit contribution of upstream grid and the DG, should remain below the network design value. Here the IEC 60909 Standard is applied for the calculation of the resulting fault level in medium and low voltage distribution network with DG[1]. Overview of power management strategies for a hybrid ac/dc micro grid system, which includes different system structures (ac-coupled, dc coupled, and ac-dc-coupled hybrid microgrids), different operating modes, a thorough study of various power management and control schemes in both steady state & transient conditions[2]. A Centralized controller is proposed which provides an accurate & optimized power exchange between both AC/DC sub grids & compared with the autonomous scheme [3]. Compensation of PV power reduction due to partial shading using bidirectional half bridge converter with battery storage is done. This system considers fulfilling the local load demand through PV production and, then, to manage the power among the battery and grid. [4]. Control and power management system (CAPMS) for hybrid PV-battery systems with both DC & AC buses and loads, in both grid connected and islanded modes is explained. It came to know that the presented CAPMS is able to manage the power flows in the converters of all units. [5] This paper proposes a hybrid islanding detection method which uses voltage unbalance (vu) & high-frequency (HF) impedance. The proposed method merges the advantages of both active & positive techniques. [6]. A three phase dual voltage source inverter (DVSI) transfers the active power between grid and microgrid based on renewable power availability & state of charge (soc) limits of

hybrid energy storage system (HESS)[7]. The power management scheme of PV based islanded microgrid using battery and supercapacitor hybrid energy storage under dynamic load condition is designed. The control scheme which is proposed enhances the battery life & manage the power variations under varying irradiance condition without losing MPPT of PV system. [8]. An automatic control method for modular PV converters is proposed to realize smooth switching between constant voltage operation and MPPT operation, which enables the DC bus voltage regulation capability of modular PV converters. This control method maintains the power balance of DC microgrid under extreme conditions such as islanding mode with full charged batteries[9]. Coordination control strategy for the autonomous hybrid AC/DC microgrid is proposed & comprehensively studied, the controllers for different converters are designed to work cooperatively to maintain the voltage stability and ensure the freedom of power exchange under various resources & load condition.[10]. Transient stability analysis of microgrid is analysed. Frequency and Voltage is monitoring after application of islanding & load shedding techniques with correct relay setting.[11]. An efficient power management in islanded microgrid is implemented by balancing power management in islanded microgrid is implemented by balancing power different sources and sinks dynamically. The proposed topology results in reduced DC link voltage thereby reducing the voltage rating of all the power electronics converters in the microgrids and DC link filter size. DVSI (Dual Voltage Source Inverter) scheme is proposed which increased reliability & better utilization of microgrid power [12]. A new decentralized power management and load sharing method for a photovoltaic based, hybrid single/three-phase islanded microgrid consisting of various PV units, battery units, and power flow among different phases is performed automatically through three-phase units [13]. A novel analysis for the dynamics of self-excited induction generator (SEIG) driven by a variable speed

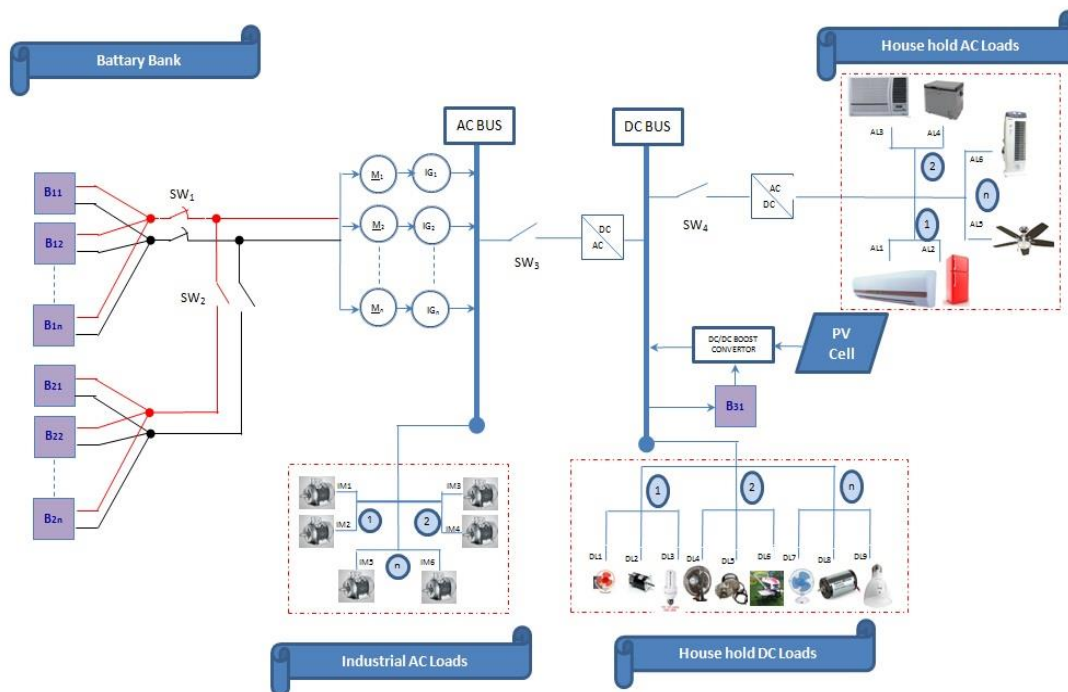
prime mover taking iron loss into account [14]. In this paper, a distributed control strategy for Decentralized power management & its distributed control strategy is implemented to meet the power demand in hybrid ac/dc/ds system [15]. Interaction dynamics in hybrid ac/dc DG networks have been investigated & small signal analysis is used to mathematically model the input /output dc-side admittance of hybrid network entities [16]. Active power sharing of autonomous hybrid microgrid [17] is monitoring. Hybrid ac/dc microgrid is proposed for various control methods which has been incorporated to harness the maximum power from dc and ac sources.[18]. A real-time energy management algorithm is developed in order to mitigate pulsed loads effects on system performance in hybrid micro grids. The main objectives of the algorithm is to manage the energy storage devices in real time in order to maintain system stability and performance in the short term operation and minimize the energy storage devices in real time [19]

A new decentralized controller for dc microgrid is developed which are high reliability, low-voltage regulation, and equal load sharing, utilizing low-bandwidth communication. To evaluate the dynamic performance, mathematical model of the scheme is derived. Stability of the system is evaluated by eigenvalue analysis [20]. Electrical grids tend to be more distributed, intelligent, and flexible. New power-electronic equipment will dominate the electrical grid in the next decades. The trend of this new grid is to become more and more distributed, and hence, energy generation and consumption areas cannot be conceived separately [21]. A new improved harmony search-based hybrid firefly algorithm (IHBFA), a comprehensive controller gain parameter estimation of all distributed resources-based microgrid is proposed [22]. Considering the multiple delays in the hierarchical control processes, the maximum delayed time (MDT) is defined to assess the stability margin for a HESS. An accurate and effective method based on small signal stability model is then proposed

to determine the MDT of a HESS to maintain its stability.[23]. A new hybrid islanding detection approach for microgrids (MGs) with multiple connection points to smart grids (SGs) which is based on the probability of islanding (PoI) calculated at the SG side and sent to the central control for microgrid (CCMG). The PoI values are determined using a combination of passive, active, and communication islanding detection approaches based on the utility signals measured at the SGs sides which are processed by discrete wavelet transform using an artificial neural network (ANN).[24]. A highly integrated and reconfigurable microgrid testbed is presented in this paper. The microgrid testbed contains various distributed generation units and diverse energy storage [25]. A microgrid (MG) system equipped with a classical proportional-integral (PI) control operating in two conditions, i.e., grid-connected and islanding modes. The proposed microgrid mainly consists of hybrid photovoltaic/wind sources, a synchronous generator, a battery storage and a load. The microgrid is able to provide a power factor correction close to unity in the grid-connected mode. Moreover, it can regulate the MG voltage and frequency through the contribution of the photovoltaic and wind sources in the islanding mode. An islanding detection method is used as a trigger for transition between grid-connected and islanding control modes[26]. The proposed control method stabilizes the power fluctuation in three time scales, of which the first two are conducted at the sub grid level and the last is conducted at the system level. In the first-time scale, the ac frequency or dc voltage is changed to regulate the load power through the droop control. Further, in the second time scale, the output power of distributed generations (DGs) is changed according to the deviations of ac frequency or dc voltage [27]. The proposed microgrid system integrates a governor-less micro-hydro turbine driven single-phase two winding self-excited induction generator (SEIG) with a wind driven permanent magnet brushless DC (PMBLDC) generator, solar photo-voltaic (PV) array and a battery

energy storage system (BESS). These renewable energy sources are integrated using only one single-phase voltage source converter (VSC)[28],an adaptive sliding mode control (ASMC) of an improved power quality standalone single phase microgrid system. An autonomous power sharing approach for hybrid microgrids interconnected through multiple ICs by introducing a superimposed frequency in the dc sub grid. Hence, a suitable droop approach is presented to manage the power among the dc and ac sources as well as ICs. The outcomes are proportional power sharing, preventing circulating power and overstressing the ICs as well as acceptable dc voltage regulation. [29]. The main problems and solutions of power quality in microgrids, distributed-energy-storage systems, and ac/dc hybrid microgrids. First, the power quality enhancement of grid-interactive microgrids is presented. Then, the cooperative control for enhance voltage harmonics and unbalances in microgrids is reviewed [30]. A novel type of voltage control strategy based on internal model robust and compound control is proposed for three phase /single

phase hybrid multi –microgrid, which is composed of two parts, feedforward control and internal model robust feedback control.[31].The controller can get better output voltage characteristics and robustness in dealing with the micro-sour output power fluctuations. A new investigation on islanding detection method is presented for PV-based VSC system. The proposed PV-VSC is represented as one of the distributed energy resource (DER) for a microgrid environment. A new multivariable dynamic model is presented in terms of two stage conversion with a dc-dc converter for the proposed PV-VSC system. The proposed VSC system is controlled primarily by a positive sequence P-Q loop, at the PCC[32]. A new backstepping fast sliding mode control (BFSMC) is proposed for primary PWM control of VSC system. During sudden grid disconnection an islanding protection loop based on rate of change in voltage harmonic profile injection is proposed.



**Figure 1.** Microgrid Archetechture

The power management system is designed to power system harmonics and maintain the automatic eliminated the power disturbances which is called connection among multiple sources depending on the

the load demand. Two sets of Battery bank can be taken as back up of Induction generators which are the micro sources of AC grid. A set of PV cell, battery and wind turbines are taken as the micro sources of DC Grid. IEC standard 60909 determines the short circuit currents of the distribution lines. Power quality can be analyzed by taking the different loading condition. The analysis can be done by taking the individual sources and then the integrated sources. In the absence of the generation of any one micro sources, the voltage and current profile analyzed in various length of the line by considering different loading condition. Several combination of micro sources and loads have been examined to determine the effect on voltage and power profile. In order to simulate the system 8.98 kV, 5km long line is divided into 5 section of 1 km each. The section are represented in the form of pi-network by its series inductance, resistance and capacitance to the ground. The PV cell is represented by a source stepped up to 8.98 kV

The problems related to transient and voltage stabilities due to dynamic behavior of induction motor loads have been a major area of attraction for the AC/DC Grid system, both active and reactive powers are kept constant during the load flow iteration. Conventional load flow algorithm has been upgraded and modified to incorporate the nonlinear characteristics of induction motor load.

The load flow solution gives the nodal voltage and phase angles. Hence, power injection at all the buses and power flows through interconnecting power channels. It is helpful in determining the best location as well as optimal capacity of proposed generating station, substation and view lines.

To establish a stable power supply for a remote area where a weak grid is established, a new microgrid has been designed by integrating PV cell, battery and induction generators in an island mode of operation. Different micro sources like, PV cell, wind turbine,

induction generator, battery have been analyzed individually and combining to fulfil the load demand.

This specific field of research is comparatively new and possible future outlooks have to be highlighted, so that new techniques can be comprehended

## II. ACTIVE HARMONIC FILTER (AHF)

An inverter can act as active power filter which is placed between the PV cell and the AC bus. It will absorb the whole or a part of the disturbance produced by this receiver. currents taken from the supply are sinusoidal. Fundamentals of these currents are in phase with the corresponding supply voltages. A Currents meet these two conditions at the same time. Figure 1 shows the APF operation in this case: shunt APF compensates harmonic current components by injecting equal-but-opposite harmonic current (Mora'n et al., 1997) Static response of passive harmonic filter and other problems have led to a power electronic solution of harmonic distortion i.e. Active Harmonic Filters (AHF); a modern solution to old harmonic current problems. Nowadays, passive filters are used to cancel the switching frequency of active filters and high frequencies. Tuned filters are used besides the active filters to cancel specific frequencies and decrease the power of active filters. Active filters have been designed, improved, and commercialized in the past three decades. They are applicable to compensate current-based distortions such as current harmonics, reactive power, and neutral current. They are also used for voltage-based distortions such as voltage harmonics, voltage flickers, voltage sags and swells, and voltage imbalances and load unbalancing and neutral shifting. Moreover, unlike passive filters, they do not cause harmful resonances with the power distribution systems. Consequently, the AHFs performances are independent of the power distribution system properties.

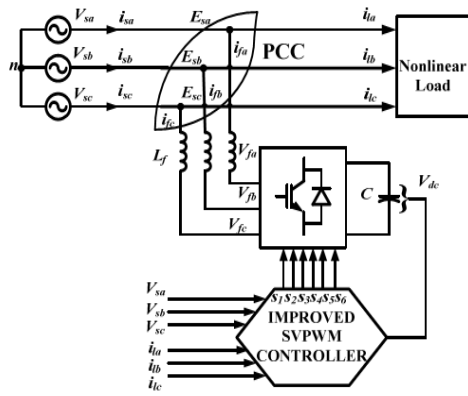


Figure 2. Active filter position

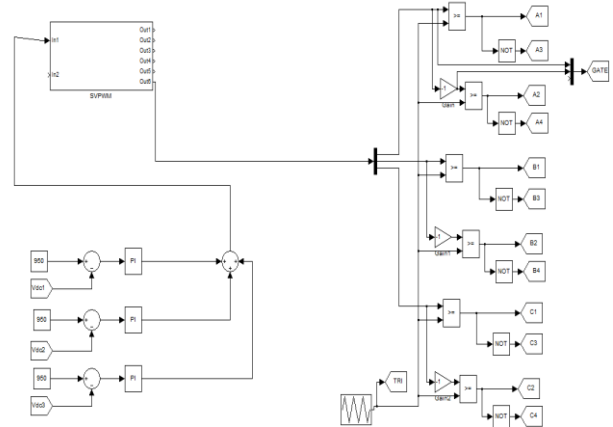


Figure 5. Control Unit for generation of signals

III. RESULTS AND DISCUSSION

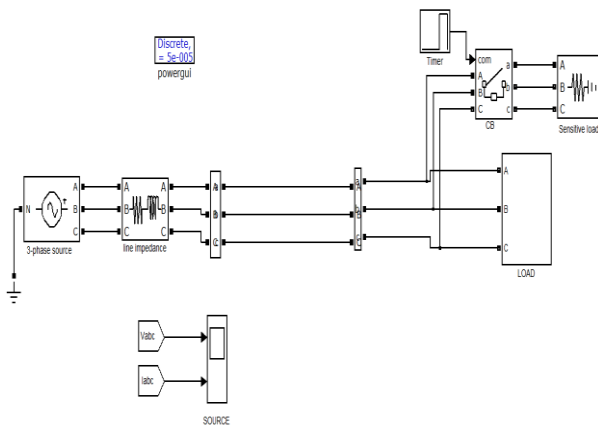


Figure 3. Simulink model of without shunt active power filter

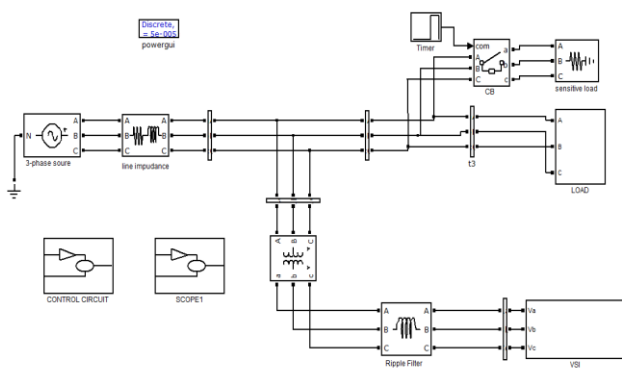


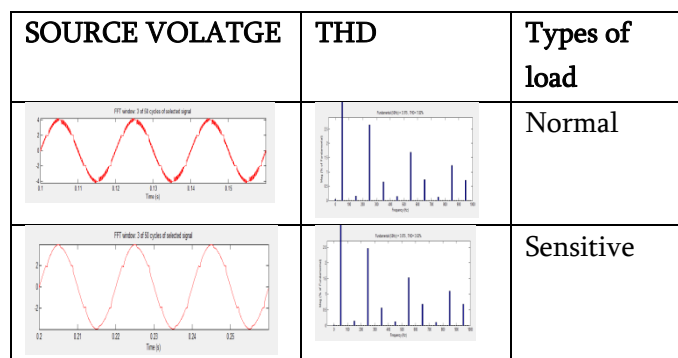
Figure 4. simulink model with active filter

With modified space vector pulse width modulation (SVPWM) technique, we will generate gate pulses to turn on the inverter which is connected to PV cell and block is as follows

SOURCE CURRENT	THD	Types of load
		Normal
		Sensitive
SOURCE VOLATGE	THD	Types of load
		Normal
		Sensitive

Figure 6. Without shunt filter

SOURCE CURRENT	THD	Types of load
		Normal
		Sensitive



**Figure 7.** With shunt filter

Figure 5 and Figure 6 shows the total harmonic distortion (THD) analysis for different types of load. For DC load the THD value is represented in table 1 and for both AC and DC. Loads THD value represented by table 2.

**Table 1.** For Dc load at 0.1sec

Sources	THD Without APF	THD With APF
Source Current	13.97%	9.58%
Source Voltage	15.30%	7.82%

**Table 2.** For Both Ac & Dc loads at 0.2sec

Sources	THD Without APF	THD With APF
Source Current	11.37%	6.91%
Source Voltage	8.45%	3.63%

It has been seen that harmonics content in the source current and source voltage drastically changes and shows a permissible percentage value. This algorithm reduces the component in the system to get pure sinusoidal waveform.

#### IV. CONCLUSION

In this paper, an improved SVPWM based shunt APF is implemented in the inverter. So that source signal gives the pure signal to the distributed load . The performance of shunt APF with this proposed SVPWM method for harmonic compensation is examined and proved to be worthy where the THD of

the source currents was reduced about 31.42% for dc load and reduced 31.22% for different loads.

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