OVERVIEW OF CUSTOM POWER DEVICES IN MICROGRID DURING AUTONOMOUS OPERATION MODE

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Abstract : Microgrids are an eco friendly power system and becoming more attractive to consumers. Micro grids can face several technical issues especially when it is operated in island mode. The key aspect of this paper is to conduct comprehensive study of power quality issues such as voltage imbalance due to requirement of high reactive power ,harmonics caused by power electronic devices and role of custom power devices (CPD'S) such as D STATCOM,DVR and UPQC in mitigation of these issues for micro grid systems. At last, a brief survey on different optimization techniques to solve optimal placement problem of custom power devices is discussed in this paper.

***IndexTerms* - Micro grid, Distributed generation, power quality, Custom Power devices, optimum location**

I. INTRODUCTION

Microgrids have made an appearance as flexible architecture for the utilization of distributed energy resource (DERS) such as solar, wind energy etc that can reach the wide ranging needs of different neighborhood from metropolitan New York to rural India. The idea of microgrid evolved in United States and Europe in the late 1990's. Scientists and engineers of these countries started working on new idea based on centralized solutions that lead to the amalgamation of number of DERS. The conclusion they arrived was a grid architecture that can able to maintain power generation as well as to provide services to the end user or to the local community when that could be automatically isolated from the main grid , even when the grid at large fails. This approach was given the name "Microgrid[1]. Micro-Grid is basically a low voltage (LV) or medium voltage (MV) distribution network which comprises of several distributed generators (DG's); micro-sources such as photovoltaic array, fuel cell energy storage systems and loads and operating as a single controllable entity. A microgrid can operate in both grid-interface mode or in isolated mode from the main grid [2]. The microgrid can function irrespective of whether it is connected to the main grid or not. There is no relationship between size of the distributed energy resources and the types of technologies in concern with the definition of microgrid that can be used. In the grid-connected mode, a microgrid can exchange power with the main power grid to solve the power imbalance. The primary objective of islanded operation is to enhance system reliability, resilience and service continuity; however island mode can be introduced intentionally or in unexpected manner for maintenance purposes or economical reasons., islanded operation is the only mode of operation especially in rural electrification. The main requirenment of microgrid operation is to maintain a constant frequency, such as 50 Hz or 60 Hz. However, DGs are responsible for regulating voltage and frequency in the microgrid. When a microgrid operates in islanding mode, a small deviation may occur from the nominal voltage and frequency. Therefore, DGs are required to maintain the stability of the system by reducing this variation [3]. Any interruption of the power quality leads to unnecessary wastage of power, economy and results in poor efficiency of the system. This result in financial burden on the consumers. In many cases, control of the power quality refers to the control of voltage only. This is because in many cases voltage can be controlled more easily than current [4]. Previous works have been carried out on various topics such as power quality issues, standards, mitigation techniques etc. This paper provides a detailed study of all the technical issue especially when microgrid operating in island mode and also promising mitigation techniques using custom power devices such as D STATCOM, DVR and UPQC. This paper is organized into 6 sections. In section II different components of microgrid architecture are explained. In section III technical issues of island microgrid are studied. In section IV role of custom power devices in power quality enhancement are discussed. Optimal locations of custom power device (CPD) are analyzed in section V and section VI gives brief outline about optimization technique.

II COMPONENTS OF MICROGRID

A number of microgrid definitions and functional classification schemes can be found in the literature. A broadly cited definition, developed for the U.S. Department of Energy by the Microgrid Exchange Group, an ad hoc group of research and deployment experts, reads as follows: ''A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid[5,6] .
The five main components of a microgrid consist of the DG, loads, DS, interconnection switch and control system as shown in figure 1.

i) Distributed Generator (DG): Distributed generators or micro sources are the units that provide power in the microgrid. These are normally placed near the loads. These energy sources can be either conventional or renewable energy units. The renewable energy power units such as solar panels and wind turbines require powered electronic devices to convert the power into AC power to feed into the grid

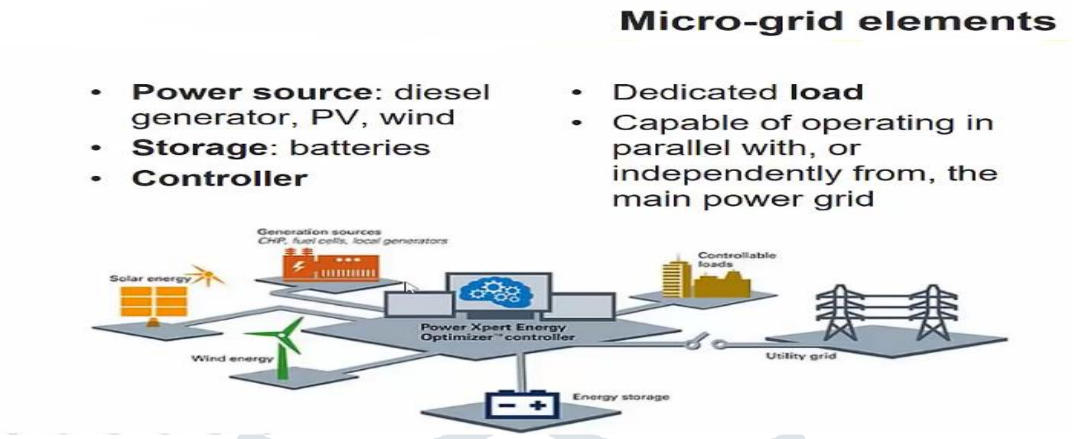

Figure 1 Components of Micro grid

ii) Loads: Two categories of loads are connected to the microgrid. The first category is the critical load. This type of load relates to those customers that require an uninterrupted supply of electricity; for example, hospitals, police stations, banks, etc. These types of loads need a reliable and good quality power supply. The second category consists of the non-critical loads, which are those that can be disconnected. When the grid operate in island mode, in order to guarantee sufficient power to the critical loads. The non-critical loads are the loads that do not require power all the time or are able to function without power for a temporary period. For example houses, clubs, restaurants and libraries are able to survive without electricity. In the case of disconnected mode, the microgrid controller will give priority to the critical loads, and if there is any excess power, only then will it be fed to the non-critical loads.

iii) Distributed Storage (DS): DS are used to store excess energy in the microgrid. DS is a very important component of the microgrid because it is responsible for providing power in case of a shortfall in supply from the renewable energy units or if the microgrid is operating in islanding mode. DS can be compared to the spinning reserve in main power generators. The three main types of DS are batteries, flywheels and capacitor banks.

iv) Interconnection switch: An interconnection switch is basically a switch that can be used to disconnect and isolate the microgrid from the main grid in case of any faults or shortage in the main grid. It is also used to reconnect the microgrid to the main grid when the problem no longer exists. In this thesis, we will deal with the Point of Common Coupling (PCC), which is one of the most commonly used interconnection switches in Microgrids.

The PCC is a very important element in the microgrid because it protects the local loads from any unexpected or unacceptable power that may damage the loads. For example, a PCC will isolate the microgrid if the frequency in the main grid is not within the acceptable limits. Also, this action will be invoked if there is a fault that will lead to a high current being directed towards the microgrid. Therefore, the coupling PCC is a compulsory element in the microgrid.

III TECHNICAL ISSUES IN ISLANDING MODE

Many issues need to be taken into account when a microgrid is operated in disconnected mode. The following points are adopted from an article published by the Institute of Electrical and Electronics Engineers (IEEE), which summarised the main issues of microgrid island mode operation [7].

Voltage and Frequency Control: Under the island mode, the voltage and frequency of the microgrid are controlled by adjusting the voltage and frequency of one or more micro sources. It is very important to keep the frequency within the acceptable limits. Otherwise, if it falls outside the limits, then the load may temporarily shed.

Balance between Supply and Demand: There are three possible operation conditions of power balance between supply and demand in islanding operation mode: supply surplus, supply shortage and equilibrium. In case of supply surplus, the decrease of power generation in micro sources can be used to balance the system. However, in case of supply shortage, then the load-shedding technique on the non-critical loads can be used to keep the system in balance [4]. Furthermore, if the microgrid is exchanging power with the main grid before switching to islanding mode, then the secondary control actions should be applied to make sure the initial power is balanced in the microgrid after a sudden fluctuation in supply or demand.

DG Issues: There are many issues that relate to the distributed generators in the disconnected mode. For example, some generators have a delayed response when implementing secondary control for voltage and frequency. Moreover, the microgrid has no spinning reserve like the utility grid, but it has DS and DG with built-in battery banks that can be considered to act as a microgrid spinning reserve. The inverter reacts quickly to a fast demand signal and adjusts the power flow levels.

Communication among Microgrid Components: The implementation of a proper communication infrastructure between microgrid components is a very important issue when selecting the control approach

Power Quality: The power quality of the microgrid should always be in a good condition. The microgrid should take the responsibility to preserve an adequate power quality with a sufficient supply of reactive power in order to minimise voltage sags.

Planned Microgrid Islanding: Other than the above factors, the microgrid should be prepared for planned islanding. It is very important to include this aspect in the microgrid because it is responsible for maintaining the continuity of power supply during planned outages.

The main goal of this paper is a detailed analysis of power quality issues in autonomous grid and suggesting a possible solution to mitigate it through custom power devices. ‘‘Power Quality” refers to the electrical system’s ability to create a perfect power supply that has a pure noise-free sinusoidal wave shape, and is always stable if voltage and frequency is considered. Inverters can play an important role in frequency and voltage control in islanded Microgrids [8]. The static disconnect switch (SDS) is a key micro grid component for islanding and synchronization; it can be programmed to trip very quickly on overvoltage, under voltage, over frequency, under frequency, or directional over current [9].

As defined by the IEEE standard 929-2000 there are four major parameters to evaluate the power quality in PV systems such as voltage unbalance, voltage flicker, power frequency variations and harmonic distortion[10]. Among these parameters voltage unbalance is the most serious one which indicates changes in voltage amplitude. “Voltage sag” refers to the reduction in supply voltage magnitude i.e. Under voltage, whereas “voltage swell” refers to the increase in supply voltage beyond the normal tolerance levels [11].

“Voltage flicker” is the fluctuation of voltage, which is between 90% to 110% of nominal, coming from the power supply. Power frequency variation is the deviation of the power system fundamental frequency from its specified nominal value (50Hz or 60Hz). The term harmonics refers to a waveform distortion of the voltages or currents, which are caused by non linear loads. According to EPRI, power quality issues vary with severity. One possible path to identify this severity is based on the economic damage they do to the equipment. To summarize the discussions of this section, impact of power quality issues based on their severity are depicted in table I

PQ ISSUES	CAUSES	EFFECTS	SEVERITY
Voltage fluctuations	Load switching	Over/under voltages	Severe
flicker	Fluctuation of supply voltage	Damage the equipment at the load side	Moderate
Power frequency variations	Heavy load	Have impact on sensitive devices	Mild
Harmonics	Due to nonlinear load	Overheating of transformers	Moderate

TABLE I: Impact of power quality issues based on their severity

IV ROLE OF CUSTOM POWER DEVICES IN PQ ENHANCEMENT

Power grid side disturbance is another reason of power quality problems in renewable energy based system. Recently, the Power electronics controllers are gaining concern to provide the quality of power for both power suppliers and consumers Various power filtering technology i.e. passive filters, active power filters, hybrid filters have applied from time to time for giving the solution of power quality problems to users, But could not fully satisfied them. Now day’s a new concept of custom power is used for customers’ satisfaction.

Custom power devices (CPD) are used to protect conventional and sensitive loads against power quality disturbances such as voltage sag/swell and harmonic distortion in power systems. The custom power devices are mainly divided into two groups: i) network reconfiguring type and ii) compensating type. The main network reconfiguring type custom power devices are: solid state current limiter, static transfer switch, static breaker, ups. The compensating custom power devices are used for active filtering, load balancing, and power factor improvement voltage regulating (sag / swell). These devices are mainly three types: static shunt compensator, series and hybrid compensator. These are also called as DSTATCOM, DVR and UPQC respectively [4].

A D-Statcom which is a shunt connected custom power device, corrects power factor and current harmonics, and thus improves the power quality.

DVR is a series connected custom power device, used to mitigate Voltage sag and swell protection Voltage balancing Voltage regulation Flicker attenuation.

Unified power quality controller (UPQC) is an integration of series and shunt active filters connected back to back. The Series components compensate voltage sag/swells, flicker and harmonics whereas shunt component mitigates the issues of low/poor power factor, load harmonic current and load unbalance. Also UPQC injects in the system in order to make source currents balanced sinusoids in-phase with the source voltages [3]. Table II depicts the compensating type devices with their performance levels. Table II depicts the compensating type devices with their performance levels

Compensating Device	PQ issues that are mitigated	Performance level
D-STATCOM	Power factor, current harmonics, voltage regulation, and load balancing	Satisfactory
DVR	Voltage sag and swell	Acceptable
UPQC	Power factor, current harmonics, voltage regulation, and load balancing	Excellent

Table II: Compensating type devices with their performance levels

V OPTIMAL PLACEMENT OF CPD

The proper placement of CPDs has an important effect on the quality of improvement and ensures that the total costs are minimal in accordance with maximum efficiency [23]. Any deviation from the predesigned characteristics can cause power quality problems and failure of equipment on the customer side [13]. Among the power quality disturbances, voltage sags and harmonic distortions are the most important power quality issues that can affect all customers in the distribution systems [14]. Generally, locating the CPDs for power quality improvement can be categorized as either "central improvement" or "distributed improvement" [15]. In the central improvement schemes the CPDs are installed at the point of common coupling to support all customers supplied from the feeder, while in the distributed improvement schemes the CPDs are installed at the individual buses to improve power quality for specific customers. The general constraints that are usually applied to locate CPDs are defined as follows:

i) **Bus Voltage Limits: The** bus voltage magnitudes must be kept within acceptable operating limits throughout the optimization process as

$$V_{min} \leq |V_i| \leq V_{max}$$

where V_{min} is the lower bound of the bus voltage limits, V_{max} is the upper bound of the bus voltage limits, and V_i is the rms value of the bus voltage. In the case of CPDs, these limits are set based on the voltage sag considerations. Therefore, the voltage limits for sensitive loads should be within 80% to 90% while these limits should be kept at the desired level for overall system bus voltages [16].

ii) **Frequency of Voltage Sag**: This limit should be set to mitigate voltage sag in the distribution system based on yearly voltage sag frequency assessment as

$$VS_i \leq VS_{i\,-limit}$$

where V_{Si} is the voltage sag frequency in the bus, while I and $V_{Si\text{-}Limit}$ is the maximum acceptable value of the voltage sag frequency for the same bus. This assessment can be done using the statistical measurement method or analytical modeling method [17].

iii) **CPD Rating Limits:** The pre-specified maximum power rating of individual CPDs should not be exceeded as

$$S_{CPD} \leq S_{CPD}\text{-max}$$

Where $S_{CPD\text{-}max}$ is the maximum acceptable size of CPDs.

iv) **Total Harmonic Distortion (THD) Limits**: The harmonic distortion at the bus I should be compensated to meet the allowable harmonic distortion level as

$$THD_i \leq D_{max}$$

where D_{max} is the maximum allowable harmonic distortion level at each bus. After making a thorough study of general constraints suitable optimization techniques must be determined that solve the optimal CPD placement problem.

VI OPTIMIZATION TECHNIQUE

The optimization technique is necessary in order to determine the optimum location, parameters of each CPD. The main objective of the optimization technique is to minimize the overall generating cost, operation cost, emission cost and economic subsidy available for renewable energy sources [23]. The cost of islanded microgrid depends on two factors i) operation strategy and ii) the unit generating a cost of different DG units. The optimum placements of CPDs have a high impact on the power quality of improvement and ensure that the total costs are minimal in accordance with maximum efficiency. The various optimization techniques is applied in order to determine proper placing and sizing of CPD'S are:

Heuristic Optimization technique: This is technique is mainly used to solve multi-objective combinatorial optimization problems in the power system. The main advantage of this technique is to determine the optimal placement of CPD which mitigates voltage sag in distribution system thereby improves power quality problems.

Genetic Algorithm: This is a kind of evolutionary algorithm, mainly based on the principle of evolution, which provides solutions to many optimization problems. The main function of this technique is to reduce voltage sag in the distribution system using the power electronic controller which includes D STATCOM and DVR.

Particle Swarm Optimization: This method was first introduced by Kennedy and Eberhart**.** This technique is mainly applied to solve the optimal placement of FACTS devices [18,19] and Distributed Generations [20] which improve power quality in transmission as well as in distribution systems.

Simulated Annealing: This is the most powerful optimization technique, mainly used to determine the optimal size and location of DVR in the distribution system.[16]

Gravitational Search Algorithm (GSA): Gravitational search algorithm (GSA) is an optimization algorithm inspired by the law of gravity [21]. In 2012, a method was proposed to enhance reliability and mitigate voltage sag propagation in power distribution systems by optimal placement of D-STATCOM using GSA [22].

CONCLUSION

This paper presents a survey of the work published on microgrid architecture, power quality issues, the application of custom power devices for mitigating the power quality problems and different optimization technique for the optimal placement and sizing of CPD in microgrid during island mode are discussed. From the outcomes of this work, it has been found that voltage fluctuation is the most dangerous power quality issue. UPQC, D STACOM have been found to be most effective compensating devices for resolving power quality issues in a microgrid. Among all optimized technique Simulated annealing is found to be the most powerful optimization technique.

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