MITIGATION OF SAG, SWELL AND REDUCTION OF THD IN AN AC MICROGRID USING FUZZY BASED UPQC

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Abstract—This paper investigates about the reactive power compensation in microgrids. The device considered in this paper is Unified Power Quality Conditioner (UPQC). Initially UPQC is to be modeled, simulated and tested in conventional distribution power system. Later the same will be incorporated into the microgrid. The microgrid is developed with two DG units, a PV generator and a wind generator to give an output voltage equal to the conventional 3 phase 4 wire distribution system. The performance of the UPQC with its control technique using fuzzy based controllers in providing the reactive power compensation to resolve the power quality issues in microgrid with dynamically varying load will be examined and verified with the help of simulation results. The simulation work will be carried out using MATLAB/Simulink software.

Keywords—Microgrid; Voltage sag; Voltage swell; UPQC

I. INTRODUCTION

Generally, a microgrid is a small-scale power supply network mainly based on renewable energy sources combined with power electronic system is designed to provide power supply for a small community. It comprises of clusters of load and distributed generators that work as a solitary controllable framework. The microgrid can be operated in two modes: the Grid connected mode where the microgrid exchanges power with the conventional power grid and the Islanded mode where the microgrid is operated independent of the conventional grid to serve the power requirement of a small community/island. The interconnection of the DG to the utility grid through power electronic converters has outstretched concern about safe operating and production conditions of the equipment. A microgrid system comprises of Distributed Energy Resources (DERs) such as photovoltaic, wind and solar cell generators, immediate energy storage, loads, and controller with power electronic converters and Point of Common Coupling (PCC) where microgrid is coupled to the power distribution system. Power electronic based equipment are rapidly emerging as key components in the present modern distributed generation power systems. Power processing utilizing these devices offer vast advantages such as flexible control, cost reduction, overall size optimization, etc. On the other hand, operation of these devices gives rise to some of the serious power quality problems such as the Reactive Power Compensation (RPC) requirement and generation of harmonics that pollutes the power distribution systems. The microgrid power quality problems comprise of wide range of disturbances such as voltage harmonics, voltage sag, voltage swell, voltage unbalance, voltage flicker, current harmonics, load reactive power, current unbalance, neutral current, impulse transients and interruptions. Voltage sags usually occur at any instant in an event of disturbance, with amplitude ranging from 10-90% and a duration lasting for half a cycle to one minute. Whereas, a voltage swell, is defined as an increase in rms voltage or current for durations from 0.5 cycles to 1 minute at the power frequency. Typical magnitudes are in between 1.1 and 1.8 rise. Active power filters are widely used to tackle some of these important power quality problems. Recent trends are geared towards the realization of multi-tasking devices which can handle several power quality problems simultaneously. The Unified Power Quality Conditioner (UPQC) is one of the most versatile active power filters that can compensate the fore mentioned significant power quality
issues. The existing literature suggests the importance of UPQC to deal with several power quality issues especially towards distribution system. Hence UPQC is considered in this work to mitigate supply and load side disturbances in microgrid.

II. PROBLEM STATEMENT

To deal with the power quality problems in the developed MG, UPQC is used as a compensating device in this paper. Initially the performance of UPQC is observed in conventional distribution system later the same is applied in MG. UPQC is developed with the combination of series active power filter (APFse) and shunt active power filter (APFsh). Two voltage source inverters (VSIs) are used to function as series and shunt APFs and are realized by using six Insulated Gate Bipolar Transistors (IGBTs) each and are connected to the network by using coupling inductors. The two APFs are connected back-to-back on the DC side and share a common DC link capacitor. With proper control, the DC link voltage acts as a source for active as well as reactive power. The supply side disturbances such as voltage sags/swells, flickers, voltage unbalance and harmonics are mitigated by the series component of the UPQC, It injects voltage to maintain the supply voltage as balanced and distortion free using its series low pass filter. The shunt component acts for mitigating the current quality problems produced from load side such as low power factor, harmonics in load currents, unbalance in the load etc. by injecting current such that the source currents become balanced and sinusoidal and in phase with the source voltages.

III. LITERATURE SURVEY

T. Ackermann, G. Andersson, and L. Söder, proposed “Distributed generation: A definition”. Distributed generation (DG) is expected to become more important in the future generation system. The current literature, however, does not use a consistent definition of DG. This paper discusses the relevant issues and aims at providing a general definition for distributed power generation in competitive electricity markets. In general, DG can be defined as electric power generation within distribution networks or on the customer side of the network. In addition, the terms distributed resources, distributed capacity and distributed utility are discussed. Network and connection issues of distributed generation are presented, too.

P. Boonchiam, and N. Mithulananthan, proposed “Understanding of Dynamic Voltage Restorers through MATLAB Simulation”. This paper presents the application of Dynamic Voltage Restorers (DVR) on power distribution systems for mitigation of voltage sag/swells at critical loads. DVR is one of the compensating types of custom power devices. An adequate modeling and simulation of DVR including controls in MATLAB environment study and understanding such compensating devices. The DVR which is based on forced commuted voltage source converter (VSC) has been proved suitable for the task of compensating voltage sag/swells. Simulation results are presented to illustrate and understand the performances of DVR in supporting load voltages under voltage sag/swell conditions.

A. Ghosh, and G. Ledwich, proposed “Power Quality Enhancement Using Custom Power Devices”. Power Quality Enhancement Using Custom Power Devices considers the structure, control and performance of series compensating DVR, the shunt DSTATCOM and the shunt with series UPQC for power quality improvement in electricity distribution. Also addressed are other power electronic devices for improving power quality in Solid State Transfer Switches and Fault Current Limiters. Applications for these technologies as they relate to compensating busses supplied by a weak line and for distributed generation connections in rural networks, are included. In depth treatment of inverters to achieve voltage support, voltage balancing, harmonic suppression and transient suppression in realistic network environments are also covered. New material on the potential for shunt and series compensation which emphasizes the importance of control design has been introduced.
V. Khadkikar, proposed “Enhancing Electric Power Quality Using UPQC: A Comprehensive Overview”. This paper presents a comprehensive review on the unified power quality conditioner (UPQC) to enhance the electric power quality at distribution levels. This is intended to present a broad overview on the different possible UPQC system configurations for single-phase (two-wire) and three-phase (three-wire and four-wire) networks, different compensation approaches, and recent developments in the field. It is noticed that several researchers have used different names for the UPQC based on the unique function, task, application, or topology under consideration. Therefore, an acronymic list is developed and presented to highlight the distinguishing feature offered by a particular UPQC. In all 12 acronyms are listed, namely, UPQC-D, UPQC-DG, UPQC-I, UPQC-L, UPQC-MC, UPQC-MD, UPQC-ML, UPQC-P, UPQC-Q, UPQC-R, UPQC-S, and UPQC-VA. More than 150 papers on the topic are rigorously studied and meticulously classified to form these acronyms and are discussed in the paper.

Pavan Kumar, A.V., Parimi, A.M., Rao, K.U., proposed “Implementation of MPPT control using fuzzy logic in solar-wind hybrid power system”. The renewable energy sources such as Solar energy and Wind energy are complementary by nature. Utilizing these natural resources to produce power will reduce the power demand on the conventional power generation sector. One of the applications of Solar-Wind hybrid power system (SWHPS) is to reduce the amount of power consumed from the conventional power generation to charge the storage reserves present in the system. The SWHPS comprises of Photovoltaic array, wind turbine, Permanent Magnet Synchronous generator (PMSG), controller and converter. The efficiency of the SWHPS depends on the MPPT controller, which makes the Photovoltaic (PV) and wind power generation system to operate at its maximum power. In PV system Perturb & Observe (P&O) algorithm is used as control logic for the Maximum Power Point Tracking (MPPT) controller and Hill Climb Search (HCS) algorithm is used as MPPT control logic for the Wind power system in order to maximizing the power generated. This paper presents a comparative analysis of MPPT controller built using P&O for PV system and HCS for Wind power system, with MPPT controller implemented using Fuzzy Logic control (FLC) in the both the renewable sources in the hybrid system. The performance of the different implementation of MPPT controllers in the hybrid system are investigated in this paper in MATLAB, Simulink. The SWHPS with the FLC based MPPT has shown to have a better, faster control as compared with the other controllers.

IV. METHODOLOGY

A system containing a microgrid with two DERs along with a battery storage connected to a common AC reference is considered. The AC bus which acts as a source delivers the loads (resistive, inductive and capacitive).

The microgrid containing two DERs is constructed with one wind generation source and the other one with a PV generation source, along with a storage device. To deal with the power quality
problems in the developed MG, UPQC is used as a compensating device in this paper. Initially the performance of UPQC is observed in conventional distribution system later the same is applied in MG. UPQC is developed with the combination of series active power filter (APFse) and shunt active power filter (APFsh). Two voltage source inverters (VSIs) are used to function as series and shunt APFs and are realized by using six Insulated Gate Bipolar Transistors (IGBTs) each and are connected to the network by using coupling inductors. The two APFs are connected back-to-back on the DC side and share a common DC link capacitor.

With proper control, the DC link voltage acts as a source for active as well as reactive power. The supply side disturbances such as voltage sags/swells, flickers, voltage unbalance and harmonics are mitigated by the series component of the UPQC. It injects voltage to maintain the supply voltage as balanced and distortion free using its series low pass filter. The shunt component acts for mitigating the current quality problems produced from load side such as low power factor, harmonics in load currents, unbalance in the load etc. by injecting current such that the source currents become balanced and sinusoidal and in phase with the source voltages. The fundamental model is considered
in this paper for the UPQC to provide RPC by mitigating sag/swell and also to understand how the active and reactive power flows between source, UPQC and the load. The equivalent circuit and set of its basic modelling equations are given. The source voltage and source current, load voltage and load current, compensating voltage and current are denoted by $V_s$, and $I_s$ for source, $V_L$, and $I_L$ for load, $V_C$, and $I_C$, respectively. $R_S$ and $L_S$ denote the sum of source and line resistance and inductance.

UPQC is controlled to ensure that the load voltage is in sinusoidal nature and with reference value. The voltage that is injected by the series side inverter should be equivalent to the deviation of the reference voltage from the actual voltage. Hence PI controller with feedback control scheme is chosen for the UPQC. The injected voltage is developed from the control circuit by implementing forward progression algorithm. The voltage be injected i.e. $V_{inj}$ by phase angle of series inverter varies from $0^\circ$ to $360^\circ$. A difference in the phase angle of the load voltage from the source voltage exists due to the voltage injected by series inverter. In this paper, the load voltage is supposed to be in phase with the reference voltage irrespective to any variation in the supply voltage. It is due to the fact that the series voltage is injected which may be in phase or phase out w.r.t. the reference voltage, in voltage sag and swell conditions. This provides the flow of real power along the UPQC possibly.

V. SIMULATION RESULTS

VI. COMPARISION OF % REDUCTION IN TOTAL HARMONIC DISTORTION (THD):

| SI. No | Component                                      | % reduction in THD |
|--------|------------------------------------------------|--------------------|
| 01     | Microgrid without UPQC                        | 22.24%             |
| 02     | Microgrid with PI controlled UPQC             | 0.25%              |
| 03     | Microgrid with Fuzzy controlled UPQC          | 0.08%              |

Table No.1 Table showing THD comparison of all cases

VII. CONCLUSION

The performance of UPQC is modelled in providing the reactive power compensation to resolve the power quality issues in conventional distribution system. The performance of the UPQC with
dynamically varying load is observed. The device is very effective to provide the compensation and is able to mitigate both the supply side and load side disturbances. UPQC is also applied in microgrid to mitigate supply and load side disturbances. A microgrid has been modeled and developed consisting of PV and Wind generators. UPQC in microgrid is also modeled and simulated. The simulations show that UPQC is able to mitigate the supply side disturbances easily using its series converter while shunt converter is providing load side compensation by mitigating disturbances like sag, swell, simultaneous sag and swell. Also the total harmonic distortion (THD) along load side is reduced to significant level.

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