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A Review on New Inverter Control For Balancing Standalone Microgrid Phase Voltages

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***Abstract*—Increasing of distributed generators and need for improving the quality of the power system led to appearance of the microgrid. The voltage unbalancing due to single phase and unbalanced loads is a major power quality problem in standalone microgrids. Usually, the distributed generation interfacing inverter is designed as a compact three- phase unit which does not account for any improvement in the voltage profile of the microgrid. In order to overcome this drawback here we come across a new inverter topology where the three phase compact unit interfacing inverter is rebuilt in the form of three single phase inverter units. Each of these are controlled independently to achieve microgrid phase voltage balancing. The distributed generation's active and reactive power will be divided among the inverter phases with different ratios in accordance to an algorithm verifying the micro grid phase voltage balancing. In the proposed model a modification to the old inverter is given to implement the new inverter control. The proposed inverter control is very simple and highly economical attractive**

***Keywords*—microgrid, phase voltage, inverter**

I. Introduction

Increasing of Distributed Generators (DGs) and need for improving the quality of the power system led to appearance the Micro Grid(MG). In this context, the MG can be considered as one of the most promising and growing concepts . The MG is an active distribution network which enables a high penetration level of renewable micro sources such as PV and wind turbines. Existence of DGs in the MG enhances power quality and the reliability of the power supply especially at the end users . Because the currently developing technologies for DGs units are based on the renewable sources (wind ,and PV) and the low emission DGs (fuel cell, and micro turbine), large scale integration of MG highly contributes in reducing CO2 emissions and helps the climate change mitigation. During the normal operating condition, the MG is connected to the main grid (distribution network). Disturbance occurrence on the main grid transfers the MG to the islanding (standalone) mode. In the standalone mode, the MG acts as an isolated power system and feeds the loads locally. The associated technical challenges with the operation and control of the standalone MG are immense

The MG has its individual behavior and power quality challenges if it is compared with the conventional power system. The MG power quality challenges are due to its individual configuration, operating mode (standalone or grid connected) and the performances of the MG Distributed Generators (DGs). In general, the MG power quality problems can be classified to four main types. The first type is caused by the operating conditions of the MG DGs (power output fluctuating of the renewable sources like wind turbine and PV).The second type is the voltage and current harmonics of the DGs power electronic interfacing inverter. Also, the current and the voltage harmonics may be generated by existence of the non linear loads in the MG. The third type is maintaining of the MG stability during and subsequent fault occurrence. The fourth type of the MG power quality issue is the MG phase voltages unbalancing. Existence of single phase loads and unbalanced three phase loads in the MG originates the voltage unbalancing problem. In the literature, several publications discussed and investigated the first three types. This paper concerns with the fourth type (MG phase voltage unbalancing problem).This paper proposed and developed a new inverter configuration and control for reducing and mitigating the standalone MG phase voltage unbalancing.

II. STRATEGIES AND SCHEMES FOR PHASE VOLTAGE BALANCING

The MG is a low voltage network (distribution voltage level). Due to existence of several single phase and unbalanced loads, the MG phase voltages suffer from very high unbalancing. Both the electronic interfacing of the MG DGs and nonlinear loads cause current harmonics and voltage harmonics at all MG buses. Several schemes were put forward for improving the power quality of micro grids. Systems using combination of Static VAR Compensator (SVC) and Series Active Power Filter (SAPF) has been employed to enhance the power quality of the standalone MG system. The SAPF is

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inserted near the DG to eliminate the source (DG) harmonic voltages. The SVC is connected at the load side to compensate reactive power which in turn lead to suppress the load voltage variations. Employing both SVC and SAPF simultaneously reduced the Current Total Harmonic Distortion (ITHD) from7.25%to1.77%.Also,the Voltage Total Harmonic Distortion (VTHD) dropped from11.43%to0.94%. The Unified Power Quality Conditioner (UPQC) has been used to improve the MG power quality. The UPQC is a combination from series and shunt controllers linked by a common DC bus . The shunt controller has the capability of either generating or absorbing reactive power at the point of connection. The series controller is connected with the MG line in series for controlling the line parameters. Fuzzy logic controller has been applied upon UPQC to mitigate the current and voltage harmonics. Employing the fuzzy logic controller suppressed the total harmonic distortion to3.34% compared with 8.93% when using the conventional PI controller.

All the previous described techniques and schemes for MG voltage balancing require additional and new hardware to achieve and verify their goal (MG phase voltage balancing). In this paper, we come across a new scheme able to completely mitigate the MG phase voltage unbalancing. The proposed scheme does not require any additional hardware. This feature makes the proposed technique highly economically attractive. The proposed technique will be implemented by only modifying the DG interfacing inverter control.

III. DGs Interfacing Inverter Design and Control

Fig. 1 shows the full layout of every component that appears in the DG circuit. From the left to the right, there is the prime mover(PV arrays ,battery bank, and super capacitors) responsible to generate a DC voltage, and then there is the DC bus that needs to include some storage (to guarantee a constant DC voltage). The power electronic inverter is the interface between the DC and the AC system and is responsible for the operation of the DG. Immediately connected to the inverter terminals there is an L–C filter bank to eliminate the higher harmonic from the voltage waveform, and then there is a coupling inductance X_L that determines how active power and reactive power can be dispatched.

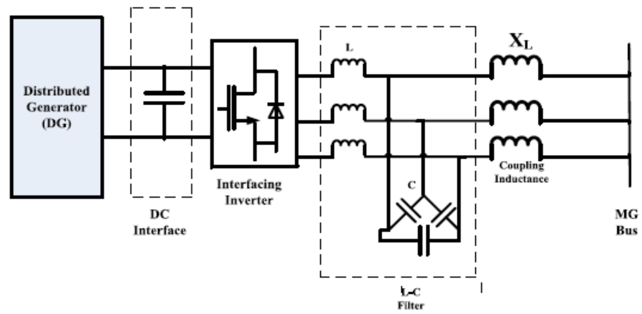

Fig.1. DG component part

A. *Sizing of coupling inductance, inverter voltage and power angle*

Each DG needs a power electronic block to perform the DC/AC conversion and to interface with the MG where it is installed. The inverter terminals are connected to the AC system (MGbus) through a coupling inductance X_L. Fig. 2 shows the details of the interface with the MG .Measurements are taken from both sides of the coupling inductance X_L and the controller generates desired values for V and δ_v to track the externally commanded values for active power (P) injection, and voltage magnitude (E) at the point of connection

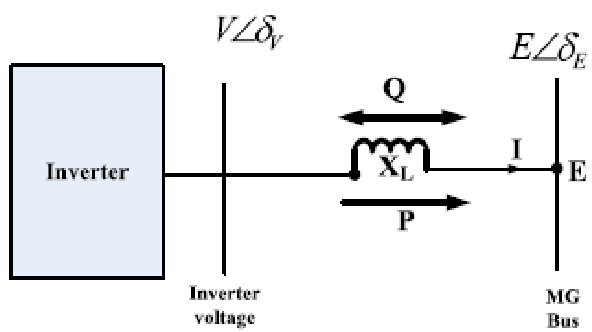

Fig.2. Single line diagram of the interfacing inverter

with the MG. The values of active power and reactive power are given by the following equations;

$$P = (VE/ XL) \sin(\delta_V - \delta_E)$$

$$Q = V(V-E \cos(\delta_V - \delta_E))/ XL$$

The size of the coupling inductance X_L is derived from the inverter voltage ratings (V_{Max}), MG bus voltage (E) and the

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limits on the power angle. The power angle is the angle difference between the voltage at the inverter terminal (V) and the MG bus voltage (E) (δP= δV –δE). Typical limits can be as follows:

(1) Limits on V: This condition is dictated by the value of the voltage at the DC bus and the kind of the used power electronic bridge in the inverter.

(2) Limits on δP : This condition derives from the need for controller to operate in the linear portion of the power-angle characteristics.

B. New inverter topology and control for balancing the MG phase voltages

Usually, the DG interfacing inverter is designed as a compact three-phase unit. The active and the reactive powers are divided equally among the three phases (phaseA, phaseB, and phaseC). Each phase injects one third of the total DGs active and reactive powers. In this paper, the DGs active and reactive powers will be divided among the inverter phases with different ratios. The injected active and reactive powers have been divided among the inverter three phases according to an algorithm verified the MG phase voltage balancing. [5] proposed a principle in which another NN yield input control law was created for an under incited quad rotor UAV which uses the regular limitations of the under incited framework to create virtual control contributions to ensure the UAV tracks a craved direction. Utilizing the versatile back venturing method, every one of the six DOF are effectively followed utilizing just four control inputs while within the sight of un demonstrated flow and limited unsettling influences. Elements and speed vectors were thought to be inaccessible, along these lines a NN eyewitness was intended to recoup the limitless states.Fig.3. shows the configuration of the proposed DG interfacing inverter. As shown, the conventional compact three phase inverter unit has been split to three single phase units. The DG active power will be divided equally between the three single phase inverter units. On the other side, the injected or the absorbed reactive power of each single phase inverter unit will be separately controlled to balance the phase voltages. With other words, each single phase inverter unit runs at a power factor differs than the two other single phase inverter

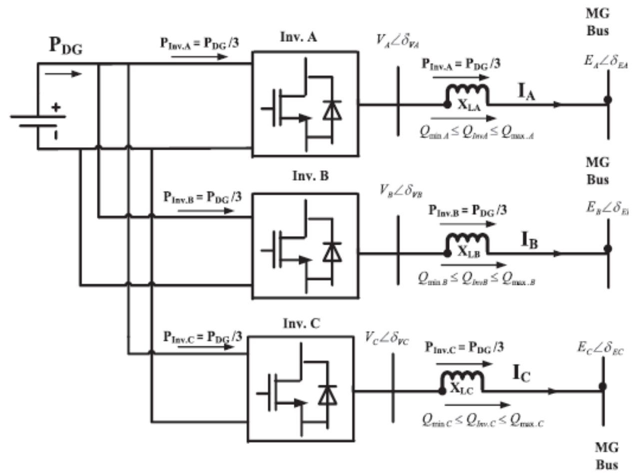

Fig.3. New interfacing inverter configuration.

units. Also, some single phase inverter unit may be operate at lagging power factor (absorbing reactive power), while the other single phase inverter unit runs at leading power factor (injecting reactive power). Amount of the injected or the absorbed reactive power by each single phase inverter unit is determined according to the MG bus voltage. The value of the single phase inverter unit reactive power is limited by its apparent power rating. The active and reactive powers of each single phase inverter unit are determined according to the following procedure. Apparent power of each single phase inverter unit is given by

$$S_{inv.A} - S_{inv.B} - S_{inv.C} - \frac{S_{3-phase\ inv.}}{3}$$

The injected active power by each single phase inverter unit is given by

$$P_{inv.A} = P_{inv.B} = P_{inv.C} = \frac{P_{DG}}{3}$$

Reactive power capability of each single phase inverter unit is determined by

$$Q_{inv.A} = \pm\sqrt{S_{inv.A} - P_{inv.A}}$$

$$Q_{inv.B} = \pm\sqrt{S_{inv.B} - P_{inv.B}}$$

$$Q_{inv.C} = \pm\sqrt{S_{inv.C} - P_{inv.C}}$$

The positive reactive power represents the capacitive (injected) reactive power (leading power factor), while the negative reactive power represents the inductive (absorbed) reactive power (lagging power factor). The reactive power capability of each single phase inverter unit lies between the following two limits:

$$-\sqrt{S_{inv.A} - P_{inv.A}} \leq Q_{inv.A} \leq +\sqrt{S_{inv.A} - P_{inv.A}}$$

$$-\sqrt{S_{inv.B} - P_{inv.B}} \leq Q_{inv.B} \leq +\sqrt{S_{inv.B} - P_{inv.B}}$$

$$-\sqrt{S_{inv.C} - P_{inv.C}} \leq Q_{inv.C} \leq +\sqrt{S_{inv.C} - P_{inv.C}}$$

By controlling the injected or the absorbed reactive power of each single phase inverter unit, the phase voltages balancing at each MG bus can be achieved if the required reactive power lies with the inverter reactive power capability. Both the value and the direction (injected or absorbed) of each single phase inverter unit reactive power depend on its phase voltage magnitude. The reactive power direction (injected or absorbed) of each single phase inverter unit will be determined as follows:

If │EA│≥ Rated Voltage (220 V),there active power Q is negative (absorbed) reactive power. At this condition, the single phase inverter unit A will operate with lagging power factor. If │E_A│≤ Rated Voltage, there active power Q_A is positive (injected) reactive power to raise the phase A voltage. The single phase inverter unit A will run with leading power factor to raise the phase A voltage. The same situation is applicable for both the phase B and the phase C inverter units. The reactive power control block diagram of each single phase inverter unit is shown in Fig. 4a. The developed model using Matlab simulink environment for reactive power control of each single phase inverter units is shown in Fig. 4b.

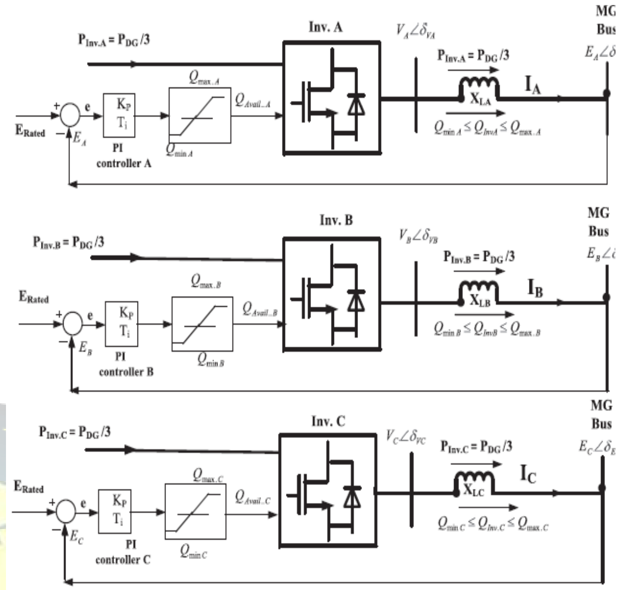

Fig.4(a). proposed controller for the new inverter configuration

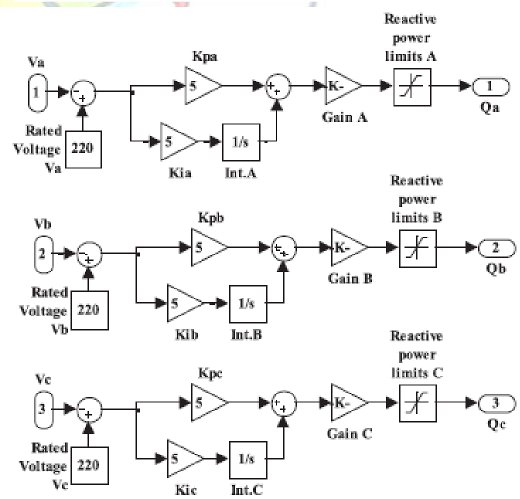

Fig. 4(b). simulink model for the control

The proposed inverter configuration and control acts as a local control and does not act as a central control. The proposed control has little effects on the voltage of the far buses due to resistive nature of the MG network. With other words, adapting the reactive power at certain MG bus has little and negligible influence on the other buses phase voltages.

IV. CONCLUSION

This study presented a comprehensive survey about the MG power quality issue. The paper reported the available techniques and schemes for improvement the standalone MG power quality. Also, this paper proposed and employed a new configuration and control for the DG interfacing inverter. The proposed inverter configuration and control is highly effective in balancing the MG phase voltages under different load conditions. It is found that, by employing the proposed inverter control, the perfect balancing between three phase voltages can be achieved at all MG buses The proposed control shows a superior performance on MG phase voltage balancing if it is compared with the two other inverter control. The proposed control has a local control effect. This feature represents the main drawback of the proposed inverter control. With other words, the proposed inverter control able to balance the phase voltages at the bus which the inverter is connected. It has no ability to balance the phase voltages at other MG buses (especially the far buses). The proposed inverter control is not a central control. It can improve the voltage at other buses but it cannot balance those voltages In conclusions, by including the proposed inverter configuration and control, the phase voltage balancing and the overall MG power quality will be dramatically improved.

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