ISSN(Online) : 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 4, April 2016

Power Quality Enhancement in Distributed Generation System

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ABSTRACT: Power quality enhancement in single Distributed generation (DG) system is proposed in this paper. The main constraints of this paper are consideration of both the power quality of the micro grid and the quality flowing between the micro grid and utility system. There are two inverters connected in shunt and series are used for each distribution generation (DG) system on the micro grid. Each inverter having positive and negative sequence components is controlled to compensate. The shunt inverter is controlled to regulate power dispatches among parallel-connected DG systems and to ensure balanced voltages within the micro grid. The series inverter balances the line currents by injecting suitable voltage components. The proposed power quality enhancer has been tested in simulation.

KEYWORDS: Fault current limitation, micro grid, positive- sequence components and negative-sequence components, power quality enhancer.

I. INTRODUCTION

In Present industry is increasingly shifting towards automation. There are two principal components are used in industrial automations are programmable controllers and robots. So as to aid the dull work and to serve the mankind, today there is a general tendency to increase an intelligence operation. In this industrial revolution the many industries are concerned about unbalanced system faults which affects on the overall system performance. If the unbalance voltage is serious, the solid state circuit breaker connected will open to isolate the load, but when the voltage unbalance is not serious, the circuit breaker may remain closed resulting in sustained unbalanced voltages at the point of common coupling. An unbalanced voltage can cause an increase in losses in motor loads and abnormal operation of sensitive equipment in the industries. An obvious solution to the above mentioned problem is to balance the sensitive load voltages in the system using some voltage regulation techniques.

On the other hand large unbalanced currents can flow, which can cause over stress on the semi-conductor devices. Therefore, to control both the sensitive load voltages and unbalanced currents. The power quality compensator using two inverters (A and B) is used. In the middle, the unified power quality conditioners were used to balance the voltages and currents. The UPQC's whose series inverters are controlled to balance the load voltages and series inverter is controlled to reject the harmonics.

II. CONTROL OF POWER QUALITY ENHANCER

A. Control of Shunt Inverter A

The control scheme of shunt inverter A contains two loops. One is internal voltage/current regulation loops and another one is external power control loops. Here attention is focused on the design of shunt inverter A, internal voltage/current control loops, after an introductory description of the power control loops to give an overview of the functionalities of shunt inverter A. The power loops are designed to control real and reactive power flows. It makes easy power sharing between the paralleled distributed generation systems when a utility fault occurs and the micro grid operates in islanding mode. The power loops achieve this suitable sharing of power by producing the desired command frequency, phase and positive-

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ISSN (Print) : 2320-9798

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sequence voltage Magnitude E, which is subsequently transformed into the stationary-frame references of V_{α}^{*} ,V_{β}^{*} to be used in the internal voltage/current regulation loops. The power loops should perform these reference calculations separately with no physical communication link between the distributed generation systems and can suitably be implemented by introducing artificial “real power against supply frequency” and “reactive power against voltage magnitude” droop characteristics to the power loops.

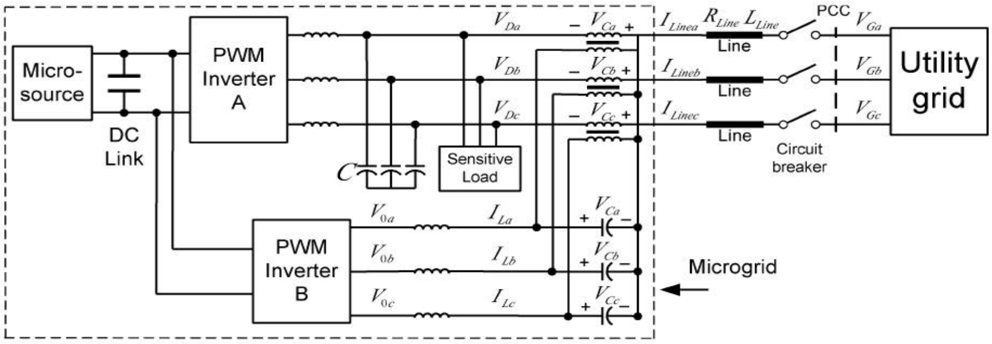

Fig1. Proposed micro grid configuration

The power loop's output contains only positive-sequence components. When the power loops are functioning, the output consists of only negative-sequence components, since the calculation of these outputs is independent of the series inverter outputs. In the next subsection B, the featured control and functions of the series inverter are presented. The external power loops govern the synchronization of micro grid and utility to ensure smooth and safe reconnection of the two grids due to power control. When the fault is cleared and the system returns to grid-connected mode of operation. The voltage phasor at the micro grid and utility ends of the circuit breaker are aligned in order to attain synchronization and can suitably be implemented by adding two separate synchronization PI regulators to the external real and reactive power control loops. As shown in Fig. 2, at both ends of the circuit breaker, the inputs to these synchronization regulators are the magnitude ΔE and phase Δδ errors of the two voltage phasor. Their outputs are then fed to the real and reactive power loops to make the voltage Phasor at the micro grid end and tracks the phasor at the utility end closely both in magnitude and frequency (PI regulators forcing ΔE 0 and Δδ 0).

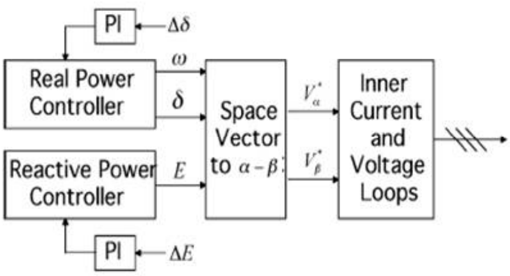

Fig 2. Overall control structure of shunt inverter A

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ISSN (Print) : 2320-9798

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An outer load voltage control loop and an inner filter inductor current control loop are contained in the voltage control scheme of shunt inverter A as shown in Fig. 3. Alternative second-order stationary-frame controllers with zero tracking errors and a higher computational efficiency for the outer voltage loop are chosen for this work. These second-order controllers can be derived by transforming PI controllers from the synchronous to the stationary frame. A systematic method for presenting the voltage control loop is first presented theoretically and then the analysis in the positive- sequence and negative-sequence reference frames rotating in the opposite directions are presented. It is represented by the control block diagram enclosed within dotted box in Fig. 3 and subsequently converts the developed synchronous voltage controllers to the stationary frame. By using matrix A, the three-phase line-to-line load voltages are first transformed from the stationary a-b-c frame to the α –β { V_α ,V_β} stationary.

$$A = \begin{bmatrix} \sqrt{\frac{2}{3}} & -\sqrt{\frac{1}{6}} & -\sqrt{\frac{1}{6}} \\ 0 & \frac{\sqrt{2}}{2} & -\frac{\sqrt{2}}{2} \end{bmatrix} * \begin{bmatrix} \frac{1}{3} & 0 & -\frac{1}{3} \\ -\frac{1}{3} & \frac{1}{3} & 0 \\ 0 & -\frac{1}{3} & \frac{1}{3} \end{bmatrix}$$

$$= \begin{bmatrix} \sqrt{\frac{1}{6}} & 0 & -\sqrt{\frac{1}{6}} \\ \frac{-\sqrt{2}}{6} & \frac{\sqrt{2}}{3} & \frac{-\sqrt{2}}{6} \end{bmatrix} \quad (1)$$

Before subtracted from their reference values $\{V_\alpha^*, V_\beta^*\}$ to give the voltage errors $\{e_\alpha ,e_\beta \}$. By using the d – q synchronous transformation matrices T_1 & T_2, for ensuring zero tracking errors is to first convert the stationary α –β voltage errors to their positive- and negative-sequence components $\{e_d^+ ,e_q^+, e_d^- ,e_q^-\}$.

$$T_1 = \begin{bmatrix} \cos(wt) & \sin(wt) \\ -\sin(wt) & \cos(wt) \end{bmatrix}$$

$$T_2 = \begin{bmatrix} \cos(wt) & -\sin(wt) \\ -\sin(wt) & -\cos(wt) \end{bmatrix}$$

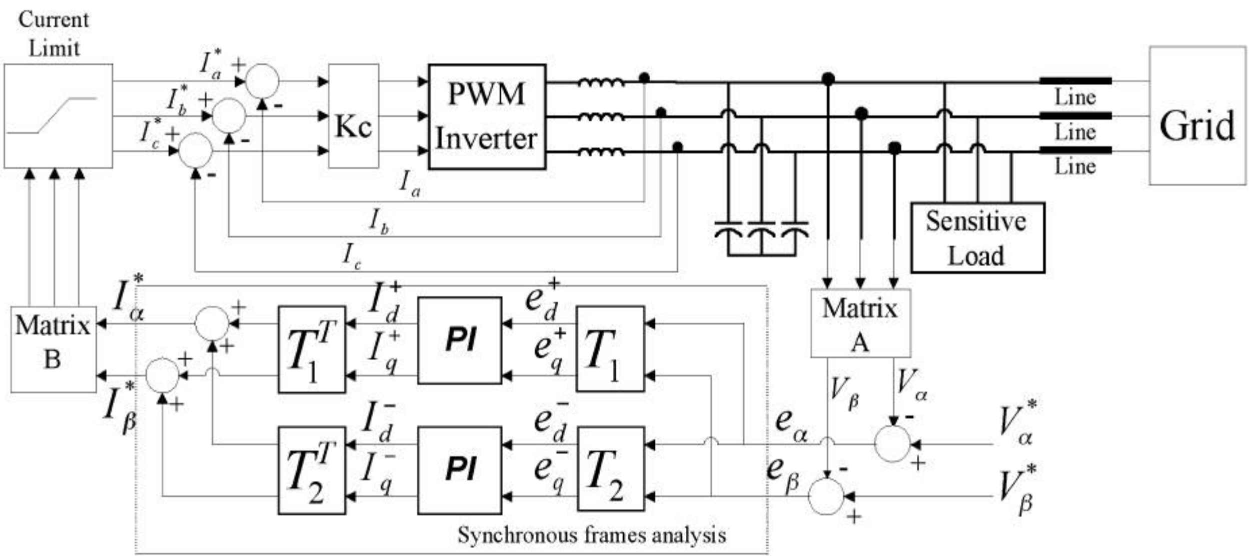

Fig.3. Voltage control scheme of shunt inverter A

 DOI: 10.15680/IJIRCCE.2016. 0404201

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ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

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(T1and T_2 is selected such that in both positive- sequence and negative - sequence rotating frames, q-axis is leading the axis by 90^0). For eliminating the tracking errors, these synchronous frames errors are then passed through two PI controllers placed along the control paths.

The outputs of the voltage controllers are the sums of the positive- sequence and negative-sequence reference inductor currents which is expressed in the stationary frame as $\{I_\alpha^*, I_\beta^*\}$. These demanded reference current signals are transformed to the stationary a-b-c frame using matrix B.

$$B = \begin{bmatrix} \sqrt{\frac{2}{3}} & 0 \\ -\sqrt{\frac{1}{6}} & \frac{\sqrt{2}}{2} \\ -\sqrt{\frac{1}{6}} & -\frac{\sqrt{2}}{2} \end{bmatrix} \quad (2)$$

It is then fed in to the inner current control loop with peak current limiting capability. Since it does not influence the tracking accuracy of the outer voltage loop, this inner current loop is implemented using only proportional controllers with the three-phase inductor currents chosen as feedback variables. The voltage and current controllers represent the inner current loop as a constant gain block. The closed-loop "output voltage to reference" transfer function of shunt inverter A, derived is valid for both grid-connected and islanding modes. The second "output voltage to load current" transfer function can be derived. Since the system can easily be made load-insensitive by using relatively large controller gains.

B. Control of Series Inverter B

As shown in Fig. 4, the restraining of negative-sequence current flow through the injection of correct negative-sequence voltages is done along the distribution feeder to maintain a balanced set of line currents which is controlled by series inverter for the proposed micro grid applications. As the series inverter B injects only negative-sequence voltages along the feeder which is expected to supply zero real and reactive power to the grid system, which now conducts only positive-sequence currents. The main functionality of series dynamic voltage restorer (DVR) to improve the downstream load voltage quality by generating suitable series voltages to compensate the upstream utility voltage dips which are different from this method of control. In this mode of operation, the series inverter is not designed for controlling the positive-sequence currents, since these are already regulated by shunt inverter A. In this method, an inner voltage loop is shown embedded within an outer current loop.

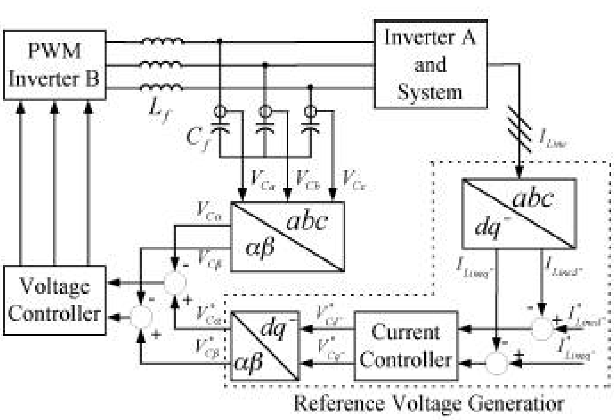

Fig 4. Control scheme of series inverter B

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ISSN (Print) : 2320-9798

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By using the negative-sequence line currents as inputs, the outer current loop functions to generate reference voltages for the inner voltage loop. The measured line currents are first transformed to the negative synchronous reference frame and then controlled to follow zero reference values. The outputs of the outer reference voltage generator consist of negative- sequence components which are then transformed back to α –β frame and fed into the inner voltage control loop.

The proposed control algorithm for the series inverter begins with the voltage loop in the a–b frame. The voltage generated at the series transformers will have both positive and negative-sequence components, if open-loop voltage control is to be applied with pure negative-sequence reference voltages. The positive-sequence line currents induce positive-sequence voltages across the filter inductors and in series transformers, although inverter B (unfiltered) output contains pure negative-sequence voltages. Therefore, closed-loop voltage control scheme is used to produce the desired pure negative-sequence voltages across the series injection transformers to balance the line currents. To improve the dynamic response, initial comparison between the controls of shunt inverter A and series inverter B might suggest that a filter inductor current loop can be embedded within the inner voltage loop of inverter B. The dynamics of inverter B is limited solely by the relatively slower outer reference voltage generation loop. Therefore, filter inductor current feedback is considered unnecessary and only a single voltage loop is used for this application.

III. SIMULATION RESULT

Simulations using Matlab / Simulink have been carried out to test the effectiveness of the proposed compensator, as shown in Fig. 5. In addition, to emulate the digitally controlled experimental system implemented in Section V, simulations have been performed with zero-order-hold blocks of 100- s sampling added to all feedback variables. Fig. 7(a) and (b) show the utility and micro grid load voltages, respectively. Initially, the utility voltages are maintained balanced. At t=1.5 s, they are intentionally made unbalanced by introducing 0.1 p.u. negative-sequence and 0.1 p.u. zero-sequence voltage components to the utility grid.

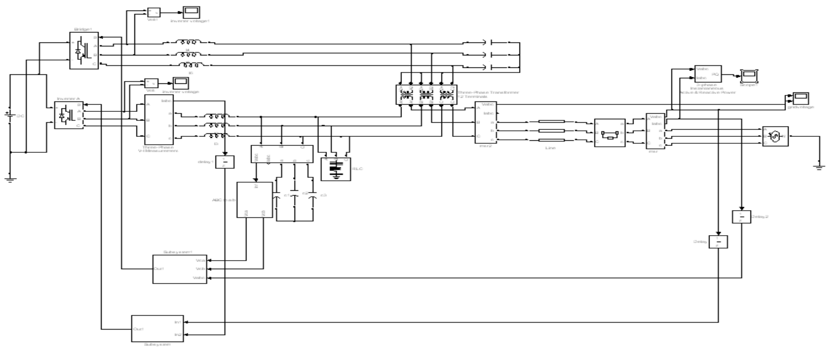

Fig.5. Simulation of Proposed Compensator

MATLAB FUNCTION

MATLAB Function 1
```
function [v]=mat1(u)
v=[ u(2)    u(1) ;
-u(1)   u(2)];
```
MATLAB Function 2
```
function [v]=mat2(u)
v=[ u(2)    -u(1) ;
-u(1)   -u(2)];
```
Where

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u(1) = cos (wt)
u(2) = sin (wt)

The system parameters used have been selected to represent those of typical distribution systems in [7], and are given in Table I (the transformer leakage resistance and inductance are lumped R_{line} with L_{line}).

TABLE I
SYSTEM PARAMETERS

Parameter	Value
Nominal line-to-line grid voltage	120V
Frequency	50Hz
DC supply voltage	250V
Switching frequency for both inverters	10kHz
Series inverter filter capacitance	10µF
Series inverter filter inductance	3.9mH
Series transformer turns ratio	1:1
Shunt inverter filter capacitance	30µF
Shunt inverter filter inductance	5mH
Line resistance R_{Line}	3Ω
Line inductance L_{Line}	10mH
Grid dispatch power	300W, 160Var
Sensitive load in the microgrid	120W, 90Var

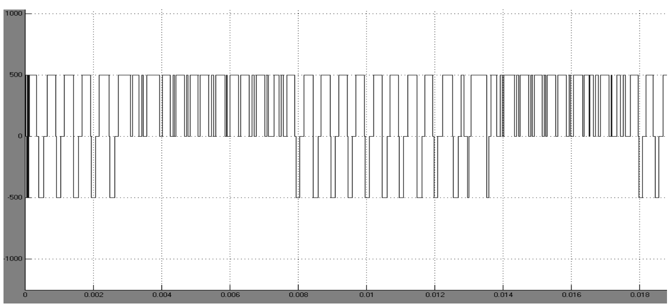

Fig.6. Inverter Voltage

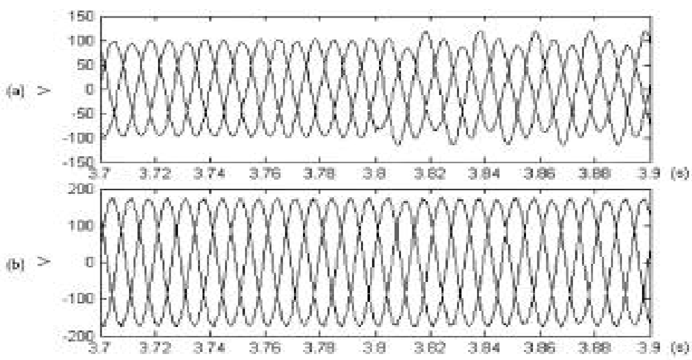

Fig.7. (a) utility grid voltages
Fig.7. (b) sensitive load voltages in the micro grid

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Fig.8.shows the Utility Grid voltage versus time and the micro grid voltage versus time under normal working condition,the voltage value is 200v.

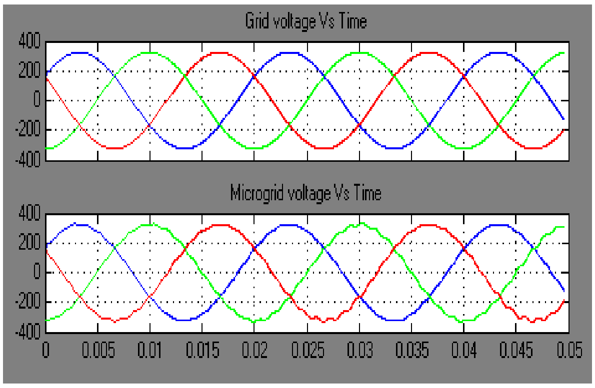

Fig.8.Utility Grid voltage & micro grid voltage
under normal working condition

Figure 9 shows the Sag voltages at PCC and sensitive load voltages in the micro grid,the value of voltage is 100v

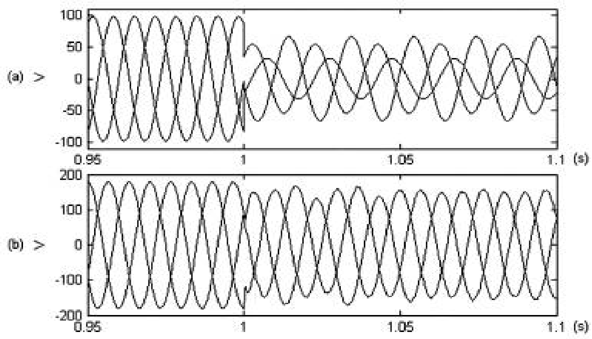

Fig.9. Sag voltages at PCC and sensitive load voltages in the micro grid

Figure 10 (a) and 10 (b) shows the Sensitive load voltage Vs Time, the value is 450 load voltage and Utility Grid voltage Vs Time.

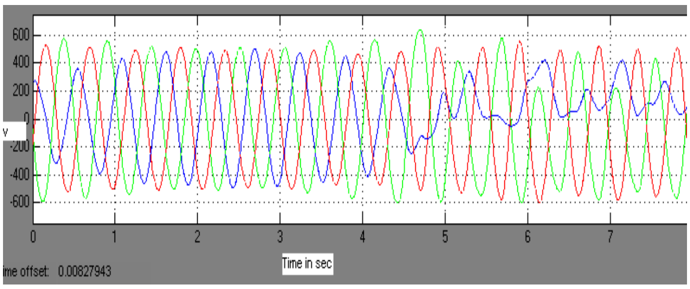

Fig.10 (a) Sensitive load voltage Vs Time

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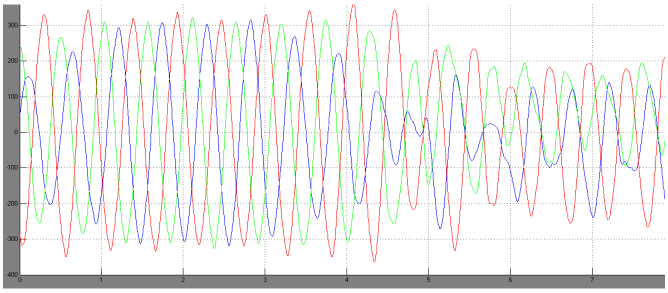

Fig. 10 (b) Utility Grid voltage Vs Time

IV. CONCLUSION

This paper proposed in a Power quality enhancement in single Distributed generation (DG) system. In a micro grid, the grid-interfacing power quality compensator to be used with individual Distributed Generation systems. The compensator is implemented using shunt and series inverters with both inverters optimally controlled to enhance the power quality in the micro grid and the quality of currents flowing between the micro grid and utility. During the utility voltage sags, the series inverter can also be controlled to limit the flow of large fault currents, hence protecting equipment in the micro grid from serious damage. The proposed compensator is verified by the simulation and experimental results.

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