IJCTA, 9(5), 2016, pp. 2307-2313

An Implementation of Enhanced Power Sharing Scheme for Islanded Microgrid using VPI Controller

M. Kalaivani* and S. Suganthi**

ABSTRACT

This project deals with the application of distribution generation with energy storage system connected to the low–voltage microgrid by coupling inverter for simultaneous energy management and other aucillary services that include the compensation of power quality disturbances. To address inaccurate power sharing problems in autonomous islanding microgrid, an enhanced droop control method through online virtual impedance adjustment is proposed. First, a term associated with DG reactive power, imbalance power, or harmonics power is added to the conventional real–power frequency droop control. Vector proportional integral (VPI) control algorithm is presented for storage inverter, which enables storage unit to be charged or discharged according to assumed schedule and to contribute to power quality improvement through the compensation of reactive power, current harmonics and unbalance .The feasibility of the proposed method is verified by simulated (by using MATLAB software) and experimental results from a low–power microgrid prototype

Keywords: Distributed generation, droop control, islanded operation, load sharing, microgrid, power sharing scheme, renewable energy system, virtual impedance

1. INTRODUCTION

Now–a-day Renewable energy resource (RES) has been widely used in the distribution system. A DG unit is connected with the distribution system through the power electronics-based interface called inverter, and the control of this is the key for the integration of all DG units [1]. When a number of DG units are connected together, it forms a microgrid which provides power to local loads in a distribution system [2]. A microgrid can be defined as a subsystem of distributed energy sources and their connected local loads. The approach allows the local control of the distributed generation; thereby central controller can be eliminated [4]. A microgrid provides three important merits over a traditional electricity supply involving central generation stations, long distance energy transmission over a network of high voltage lines, then distribution through medium voltage networks:

- Application of combined heat and power technology
- Opportunities to tailor the quality of power delivered to suit the requirements of end users
- Create a more favorable environment for energy efficiency and small-scale renewable generation investments.

In contrast to a normal distribution system, a microgrid can move to autonomous islanding operation when there is a fault in main grid and a direct voltage support can be provided to DG inverter. During the islanding operation, the load demand should be be shared properly by parallel connected DG units [3]. To

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enhance the power sharing requirement without any communications between parallel connected DG units, the real power–frequency and reactive power–voltage magnitude droop control are developed[4],[5]. Most often frequency droop control method is used. In this category, LPF low pass active filters are used to calculate the real power and reactive power.

Accordingly, the ultimate aim of droop control is the sharing of averaged real and reactive power. It has been proved that the real power sharing is always accurate, while the reactive power sharing is not accurate which dependents on the impedance of DG feeders [10-11]. Usually the low voltage microgrid feeder has resistive impedance. In addition to this, it may cause some stability problems. To enhance the power sharing in a microgrid, various types of modified droop control methods has been introduced. To provide an accurate power sharing scheme in a DG unit a dominate inductive virtual impedance can be added along with it [5]. In this method, the reactive power sharing errors problem can be solved and it can also be reduced [9-10]. However, in a weak islanding microgrid if there exist a higher feeder impedance, there should be larger virtual impedance, and hence, the power sharing dynamics can be affected.

2. MICROGRID SYSTEM STRUCTURE

2.1. Principle of Microgrid Power Sharing

Fig. 2. Shows a diagram of an islanding microgrid where a N no of DG units are integrated into the microgrid with *LC* filters at each unit. For each DG unit, the backstage power is provided by a Renewable energy resource along with an energy storage system. An assumption is taken such that, an infinite dc link with fixed dc voltage is taken here. There are few linear, imbalanced, and non linear, balance loads which are placed at the PCC. A microgrid central controller is also located at PCC.

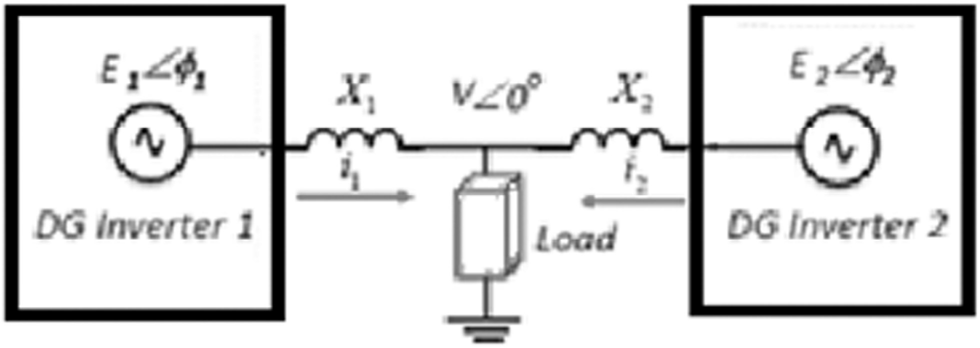

Figure 1: Droop control of AC system

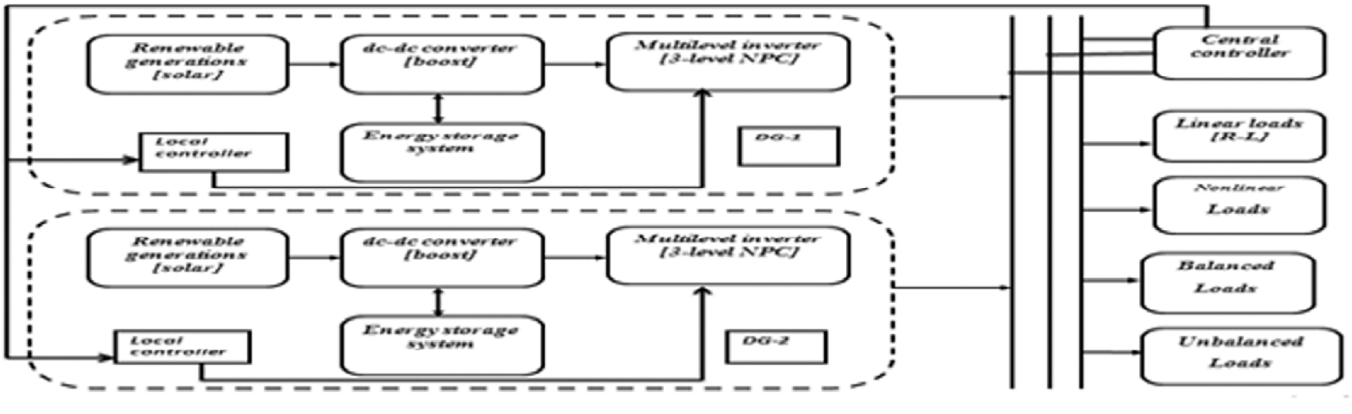

Figure 2: A simple islanded microgrid diagram with one way low bandwidth communication

3. ENHANCED DROOP CONTROL

3.1. Virtual Impedance Control

Line impedance is purely resistive in the low-voltage microgrid. The coupling of active and reactive power can be affected with this type of control. As a consequence, power sharing is inaccurate and the system stability is poor. In order to eliminate the impact of our controller, virtual impedance is added here with advantages like power decoupling and circulating current restraining. (i.e.) When the line impedance is inductive enough (e.g./X≈0.31) as mentioned, either because of long transmission distance or the large output inductor of the output filter, specially here when an LCL filter or transformer are used at the output of the PWM inverter, traditional droop control can achieve proper power sharing among DG units autonomously . In these cases, the DG unit can be modeled as an ideal voltage source whose voltage and frequency are determined by the droop characteristics.

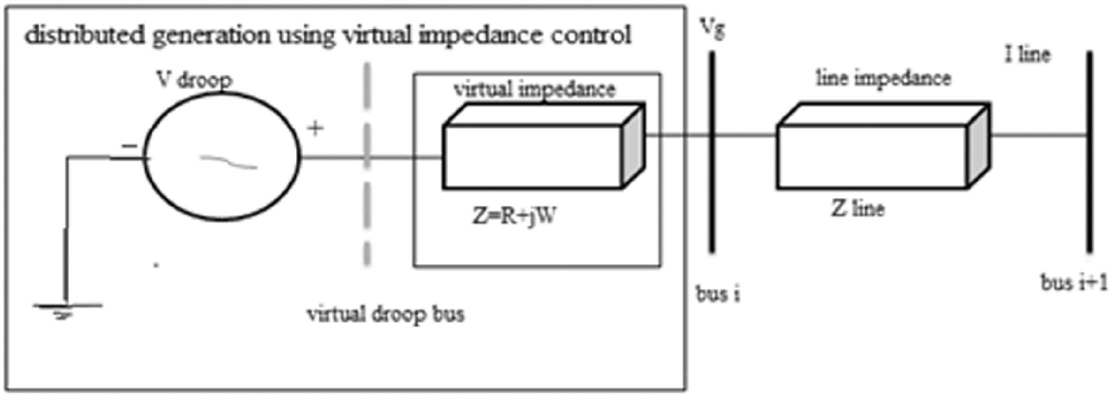

Figure 3: Virtual impedance control

3.2. Voltage Compensation and Reactive Power Sharing

Power coupling is the main reason for the inaccurate reactive power sharing problem. So far, droop control discussion is usually based on the assumption of strict *P-f* and *Q-V* relationship. But in low-voltage microgrid, *R/X* of line impedance is relatively high. So the line and virtual impedance will cause a voltage drop and it will have an impact on the PCC voltage.

3.3. Frequency Autonomous Control

The system stability will decrease due to the deviation in droop control voltage and frequency deviation in droop control. Traditional regulation method could also be used in microgrids, such as reactive power compensation, transformer regulation, etc. the DG inverterre used to determine the system frequency. In traditional power grid, the abovementioned frequency deviation can be regulated through secondary frequency

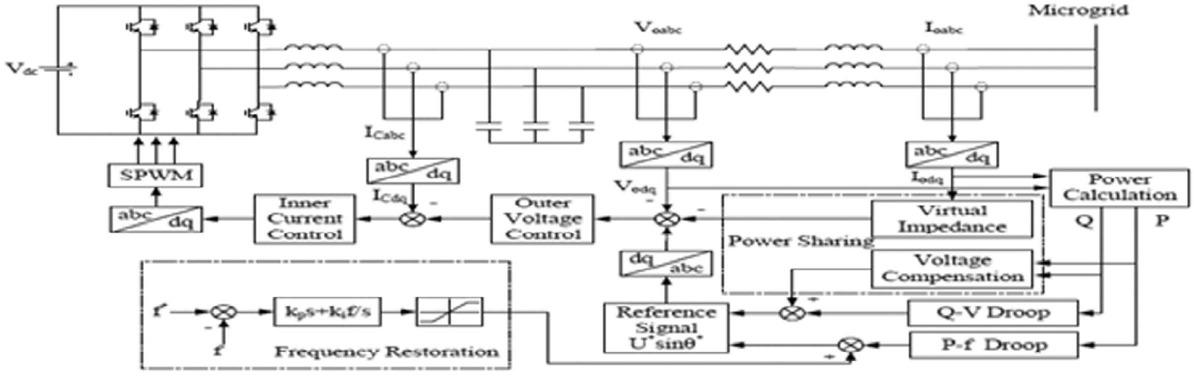

Figure 4: Control block diagram of D Ginverter

control, which may also be achieved in microgrids. The frequency tolerance is normally 50±0.5Hz in low-voltage and small-capacity power grid.

4. VPI CONTROLLER

The VPI controller is combination of series resonant and PI controller .it has been implemented in the fundamental reference frame .it has also been used to solve more no components of higher order current harmonic component. It is simple and it also reduces the computational burden. Hence the resonant controller has the compensation method given only consider the delay times caused by digital implementation. The stability margins are reduced, and undesired peaks appear in the closed-loop frequency response when the order of the compensated harmonic increases. In order to overcome these problems, The VPI controller has been introduced. The transfer function of the VPI controllers in the s-domain i

$$G_{VPI} = \sum\nolimits_{h=6,12,18...} 2\frac{K_{ph}s^2 + K_{rh}s}{s^2 + (h\omega_s)^2}. \tag{1}$$

The VPI controller is able to cancel the coupling term with the form1/ (*sLF + RF)* by selecting the resonant gain as *Krh* = *KphRF* /*LF*, where *LF* and *RF* are the inductance and the equivalent resistance of the *LF* inductor, respectively. Owing to this advantage, the VPI controller is able to remove anomalous peaks appearing in the closed-loop response without demand of delay compensation. Adopting the superiority of the VPI controllers over resonant controllers, VPI controllers given are used to replace resonant controllers; the transfer function of the proposed PI-VPI current controller in the s-domain is given as follows:

$$G_{PI-VPI} = K_{p1} + \frac{K_{i1}}{s}\sum\nolimits_{h=6...30} 2\frac{K_{ph}s^2 + K_{rh}s}{s^2 + (h\omega_s)^2} \tag{2}$$

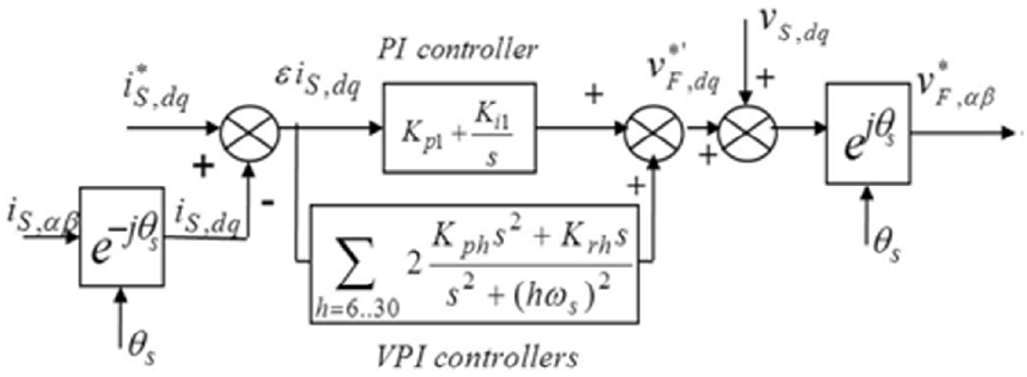

Figure 5: Controller diagram of proposed system

Table 2
Simulation Parameters

System Parameter	*Values*
Main low voltage microgrid	100 v, 50Hz
Fault	Line-ground, line-line, 3 phase fault
LC filter	C_f = 47e-6 uF, L_f = 47e-3mH
PV voltage, Reference voltage switching frequency	V = 200v, 450v, 10 KHZ
DG Feeders	DG1 Feeder inductance L_{DG1} = 100mH, Feeder resistance R_{DG1} = 0.001 Ω, DG2 Feeder inductance L_{DG2} = 100 mH, Feeder resistance R_{DG2} = 0.001 Ω
Double loop voltage control	Kph = 0.5, 2, 5…., Krh = 0.5.., $h = 6n$, $n = 1...5$, $\omega s = 2\pi 60$ rad/s
Load parameters	Case 1: unbalance load; case 2: balance load; case 3: non linear load ; case 4: linear load

5. MATLAB SIMULATION

To test the effectiveness of the proposed power sharing method, simulations have been conducted in the MATLAB/Simulink.

Two DGs has been connected in parallel .The inverter used in the existing system has been converted to multilevel inverter (practically 3-level inverter has been used). In the above simulation both balanced and unbalanced load are connected. The balance load is connected for a period of 0.1-0.15 seconds and the unbalance load (i.e.) linear load is connected for a period of 0.15-0.2 seconds.compensation is done during this period.

6. SIMULATION RESULTS

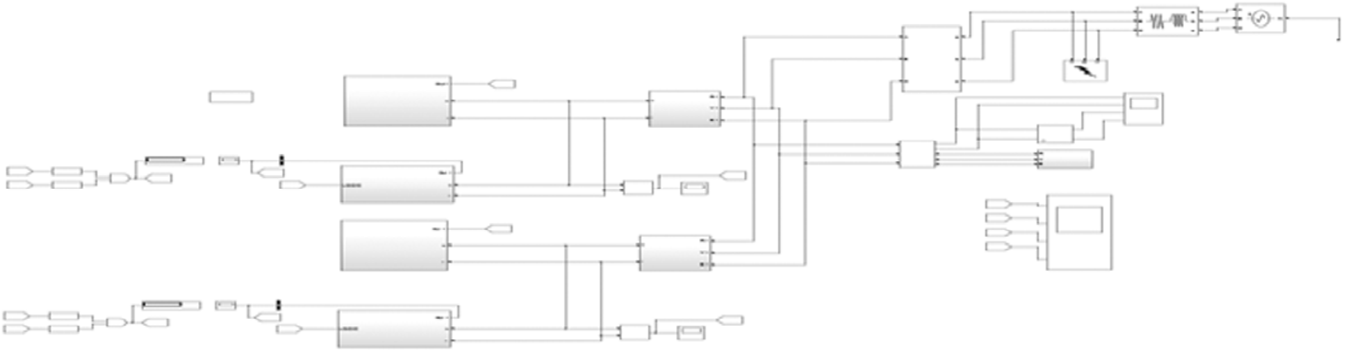

Figure 6: Simulation model

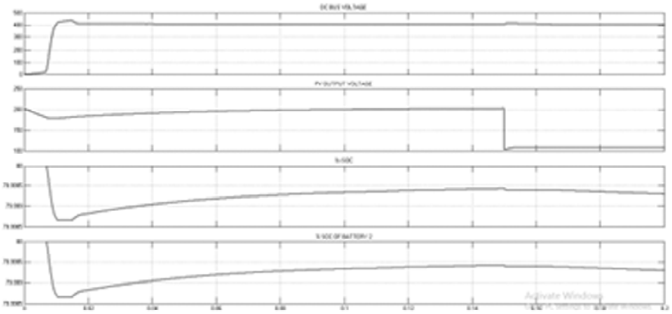

Figure 7: DC Bus voltage, PV output voltage, SOC of battery

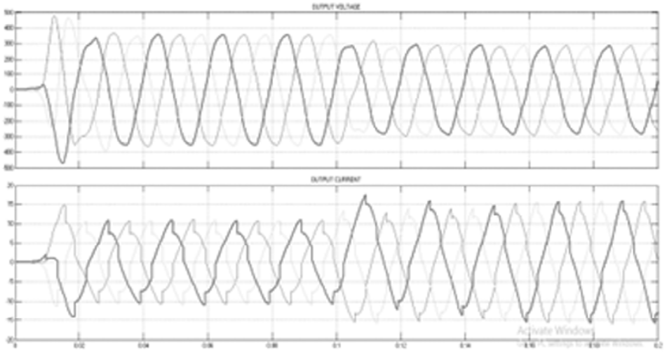

Figure 8: Output voltage and current wave form of proposed system

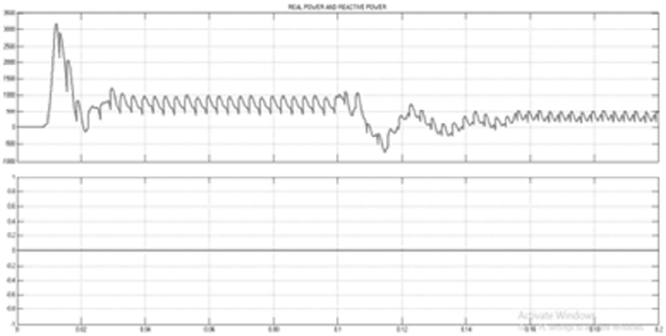

Figure 9: Real and reactive power of proposed system

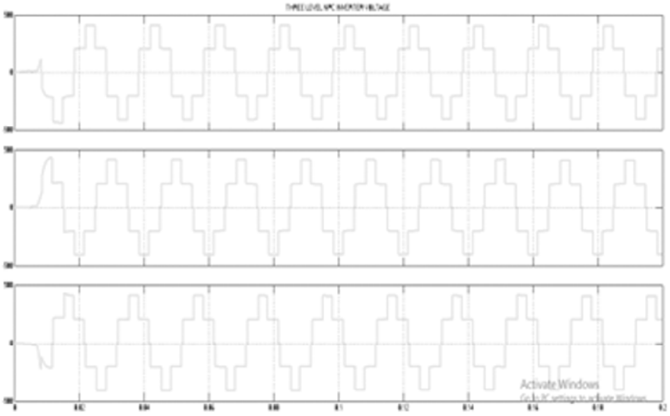

Figure 10: NPC Multilevel inverter (Three level) voltage

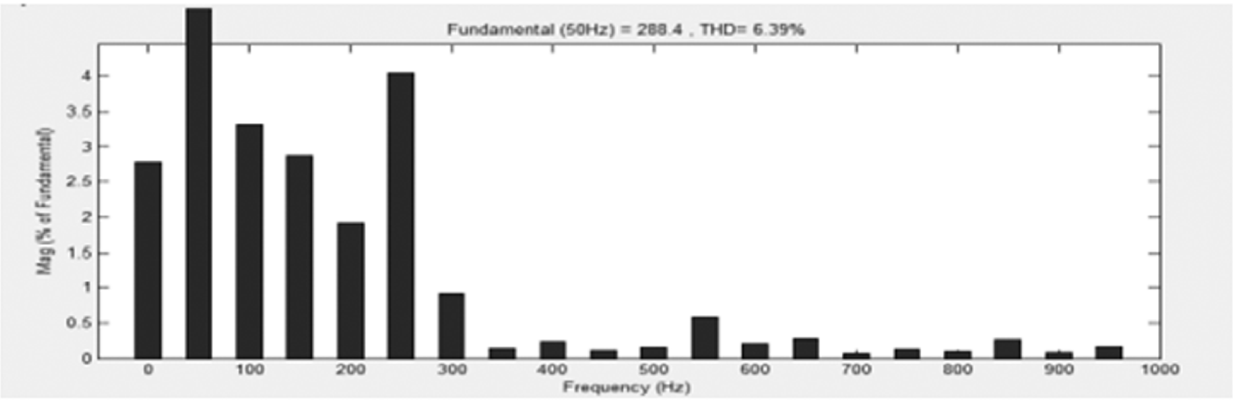

Figure 11: THD of the proposed system

7. CONCLUSION

An enhanced power sharing scheme for islanding microgrids has been dealt in this project. The proposed method utilizes the frequency droop as the link to compensate reactive, imbalance, and harmonic power sharing errors. Specifically, the frequency droop control with additional disturbance is used to produce some real power sharing variations. These real power variations are used to adjust the DG unit virtual impedances. With the interactions between the transient Frequency droop control and the variable DG virtual impedance, the impact of unknown feeder impedances can be properly compensated an accurate power sharing is achieved at the steady state. Comprehensive simulated and experimental results from a low-voltage microgrid prototype verified the effectiveness of the proposed scheme. Vector Proportional Integral (VPI) Control algorithm is used for the compensation of current harmonics and unbalance power and also to reduce the THD to desired level.

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