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Active Power Sharing and Frequency Control of Multiple Distributed Generators in A Microgrid

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Abstract: *Due to increase in demand of electricity as use of devices that consume electricity increases. The major problem is to meet this demand of electricity. However, the electricity supply has become saturated due some factors such as social, environmental and geographical. To fulfill these problems and to meet the electricity demand there are two ways such as via micro grids and distributed generation (DGs). Microgrid works with two operating modes of operation such as grid integrated mode and islanded mode of operation. In case of grid connected operation, micro grid is connected to main grid having large system inertia which helps to maintain micro grid frequency almost to nominal value. But in case of islanded mode operation micro grid must supply its own demand and maintain its frequency which is mainly done by DG units. There are various methods or control techniques for distributed generation to control active power sharing as well as frequency in islanded micro grids. Generally, most commonly used method of control is droop control. In that active power – frequency is used for DG controller and frequency deviation is recovered by DG itself by self-frequency recovery control without using any secondary frequency control. But the electrical distance i.e. impendence between each DG and loads are different which may cause frequency deviation among the DG units. This difference is fed into the integrators of self –frequency recovery control which may cause the error in operation of active power sharing. So, to solve this problem new technique or control method is developed which share active power more accurately, this method is compensation control method. In that active power sharing is done by considering droop coefficients of each of DG units.*
Keywords: *Active power sharing, distributed generation (DG), islanded micro grid, self-frequency recovery.*

I. Introduction

Now a day we know that electricity demand is extensively increases as compare to generation of electrical energy. For the fulfillment of extensively demand of electrical energy, we are using may type of standalone system and as well as microgrid, distributed generation and also used grid connected system. When we are used grid connected system or microgrid system, facing the problem of active power sharing and frequency deviation or we can say unstable system. For the mitigation of active power sharing and frequency deviation or stability of system, we need Active Power Sharing and Self Frequency Recovery in an Islanded Microgrid system.

The Microgrid is defined [1] as one independent grid providing continuous power to load on grid and compromising two or more micro sources with enough capacity so as to operate independently storage assets and load. [18] The Microgrid consists of a low- or medium-voltage distribution network containing loads and distributed energy resources. A micro grid includes central controller (CC), local controllers (LCs), a static switch, loads, and various types of energy sources. A micro grid has operated in two different modes: grid-connected mode and islanded mode, depending on the connection state with the main grid. In grid-connected mode, a microgrid is connected to the main grid, which usually has large system inertia; this is reason of the microgrid frequency is almost identical to the nominal value. So, DG units in a microgrid typically inject the desired output power, and the electrical power mismatch between supply and demand is balanced by the main grid. However, in islanded mode, using DG units the microgrid must supply its own demand and maintain its frequency solely.

The ability of microgrid to employ small scale power generation and also the utilization of waste heat are the most considerable ecological reimbursement. The most recent novelty like photovoltaic (PV) cells, solar cells and fuel cells (FC) are hinge on inverter in order to link up by means of the distribution system. Therefore, VSC (voltage source converter) coupled with microgrid in parallel, to meet a common load [15]. Essentially, a microgrid performs in two operating conditions. Once the microgrid is make contact with the power grid at the intersection of PCC (point of common coupling), then the microgrid operates in grid-tied mode. Once the microgrid is standing apart from the power grid, then it operates in island mode. If there exists any break down occurs in microgrid, it will switch over to island mode automatically.

Most reports have considered frequency deviation in sharing active power however, the frequency must be restored to its nominal value according to the requirements of the grid code, and secondary control is required to achieve. A DG control method that simultaneously implements accurate active power sharing and self-frequency recovery. Using this control method, DG units share the changes in load with a predetermined ratio and are able to restore their output frequency to the nominal value autonomously (hence the term "self-frequency recovery") immediately following a change in load. However, the self-frequency recovery action may lead to (small) errors in power sharing due to variations in the impedance among DG units.

II. Distributed Generation (Dg)

Distributed generations are small electric power generators. DG can be installed close to the customers because of its size and clean energy technology. Installation & operation of electric power generation units connected to the local network or off-grid generation.

Depending on the type and depth of penetration of distributed energy resource (DER) units, load characteristics and power quality constraints, and market participation strategies, the required control and operational strategies of a microgrid can be significantly, and even conceptually, different than those of the conventional power systems. DER units include both distributed generation (DG) and distributed storage (DS) units with different capacities and characteristics. The electrical connection point of the microgrid to the utility system, at the low-voltage bus of the substation transformer, constitutes the microgrid point of common coupling (PCC) [2].

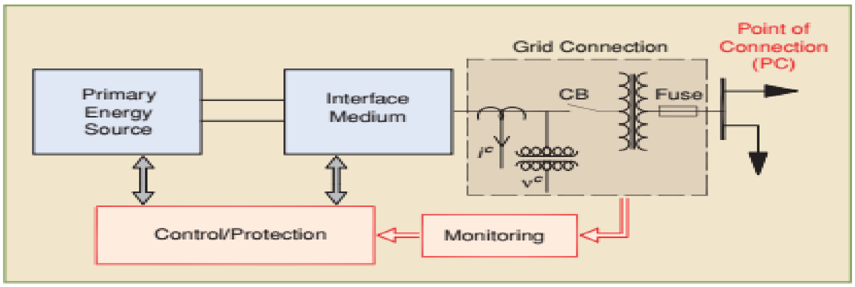

Fig.1: Basic Distributed Generation unit

III. Microgrid Concept

Microgrid is an autonomous small scale power supply network that is designed to provide a power for a small community. It contains various micro sources, controllable loads and storage devices. Two basic classes of micro sources are DC source (fuel cell, PV cells and battery storage) and AC sources (micro turbine). The DC voltage is converted to an acceptable AC voltage using Voltage source inverter.

The main components of Microgrid are mini-hydro, solar cell, wind energy, fuel cell and energy storage system. These are integrated for electricity generation, energy storage, and a load that normally operates connected to a main grid (micro grid). Generation and loads in a Microgrid are usually interconnected at low voltage. But one issue related to Microgrid is that operator should be very alert because numbers of power system are connected to Microgrid. In the past, there was single entity to control. [2] In Microgrid generation resources can include such as fuel cells, wind, solar, or other energy sources. These multiple different electric power supply generation resources have ability to isolate the Microgrid from a large network and will provide highly reliable electric power. Produced heat from generation sources such as microturbines could be used for local process heating or space heating, allowing flexible tradeoff between the needs for heat and electric power.

The followings are parameters of Microgrid:

- Small Microgrid covers 30 - 50 km radius;
- The small Microgrid can produce power of 5 - 10 MW to serve the customers;
- It is free from huge transmission losses and also free from dependencies on long-distance transmission lines.

Basic microgrid architecture is shown in Figure 2. This consists of a group of radial feeders, which could be part of a distribution system or a building's electrical system. There is a single point of connection to the utility called point of common coupling (PCC). Some feeders, (Feeders A-C) have sensitive loads, which require local generation. The non-critical load feeders do not have any local generation. Feeders A-C can island from the grid using the static switch that can separate in less than a cycle. In this example, there are four micro sources at nodes 8, 11, 16 and 22, which control the
operation using only local voltages and currents measurements.

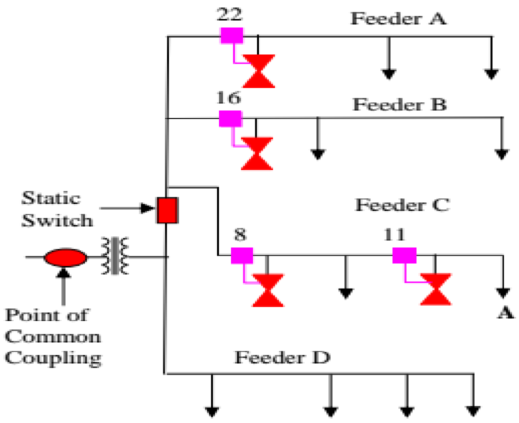

Fig.2: Basic microgrid architecture

When there is a problem with the utility supply, the static switch will open, isolating the sensitive loads from the power grid. Non-sensitive loads (feeder D) rides through the event. It is assumed that there is sufficient generation on feeders A, B, and C to meet the loads on theses feeders. When the microgrid is grid-connected power from the local generation can be directed to the non-sensitive loads.

Fig.3. Shows the Configuration of the microgrid test system model. This system model consists of step down transformer, Static switch, local controller (LC), central controller (CC), loads & various types of energy sources. [13] The microgrid system model, which is connected to a 13.8 KV, 60 Hz main grid system by a static switch. The component models used for the simulation are as follows:

The main grid is represented by a 69 KV three phase voltage source with the short circuit capacity of 1000 MVA & X/R ratio of 22.2. The three-phase triple- pole circuit breakers at both ends of the 69 KV line are modeled as ideal switches which can open at line current zero crossing instants. The substation 69/13.8 KV step down transformer and the load transformers are represented as linear. The rating of transformer is 15 MVA, 60 Hz. The line impendence is 0.15+j0.296. (Resistance is 0.15Ω and inductance is 0.296 H). The static switch is connected between microgrid system. The static switch (three phase breaker) is initially closed and switching of phase-A, phase-B, phase-C.

Fig.3 shows a microgrid system made of a cluster of inverter based DG units empowered by micro sources, such as Photovoltaic Cell, fuel cells, dc storage, etc. [5] A dc/ac VSI is commonly used as an interfacing module. A three-leg VSI with an LC filter with a coupling inductor form the power circuit, whereas three control loops form the control structure. Specifically, a power sharing controller is used to generate the magnitude and frequency of the fundamental output voltage of the inverter according to the droop characteristic.

IV. Proposed Dg Control Method

A. Droop control: -

Droop control is a control strategy commonly applied to generators for primary frequency control (and occasionally voltage control) to allow parallel generator operation (e.g. load sharing). For basic control of active power sharing, the conventional P–f droop control was applied.

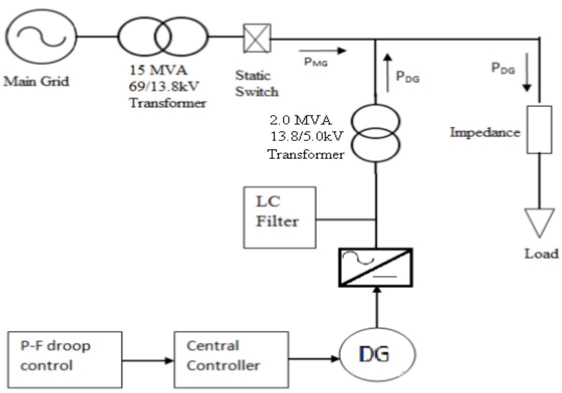

Fig.4 Droop Control Method

The output frequency fi can be expressed as,

$f_i = f_{nom} + m_i (P_{i,dis} - P_i)$ ……..(1)

Without self-frequency recovery control or compensation control, the frequency deviation from the nominal value can be determined using droop control only. And Suppose load sharing having not exact among DG units then droop control method is not efficient. This process can be implemented by exchanging the same output frequency of each DG unit in the steady state; (not for transient state) according to main grid parameter requirement is not sufficient to droop control method so we need to self frequency recovery method is required [18].

B. Self-Frequency Recovery Control: -

When the active power sharing according to predetermined value that particular condition to measures the requirement of frequency among the DG units this is called principle of self frequency recovery.

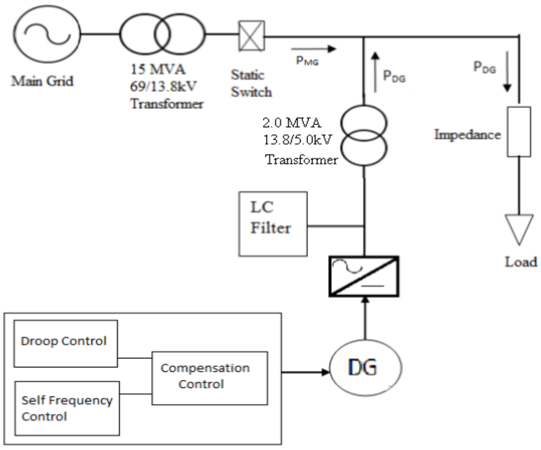

Fig.5 Self- Frequency Recovery Control Method

The frequency restoration of the i^{th} DG unit due to self-frequency recovery control can be expressed as,

$\Delta f_{i,res} = k_f \int (f_{nom} - f_i)\, dt$ ....(2)

Where k_f is all the same value for every DG unit, which means that the burden of frequency restoration is shared equally among the DGs. In the transient state, instantaneous output frequency different for all DG units because impedance is different and load location is different.

V. Case Study

To verify the effectiveness of the proposed control method for DG units, case studies were implemented.
Table I:-lists the simulation parameters for all scenarios.

Microgrid components		Setting
Static switch		Closed → Opened at 1 s
DG units	P1, dis P2, dis P3, dis Q1, dis Q2, dis Q3, dis	1.3 MW 1.3 MW 1.3 MW 0 MVAR 0 MVAR 0 MVAR
Loads	L1 L2 L3	1.5 MW 1.5 MW 1.5 MW→ 0.5MW at 2 s
Integral gains	kf kc	20 10

To verify the effectiveness of the proposed control method for DG units, the simulation results is carried out three cases:

i. Microgrid connected mode (0-1) sec.

ii. Both are connected mode (1-2) sec.
iii. Both are connected mode but load L_3 is decrease (2-3) sec.
(When the static switch was opened at 1 s and for the load change i.e. when L3 was decreased at 2 s).

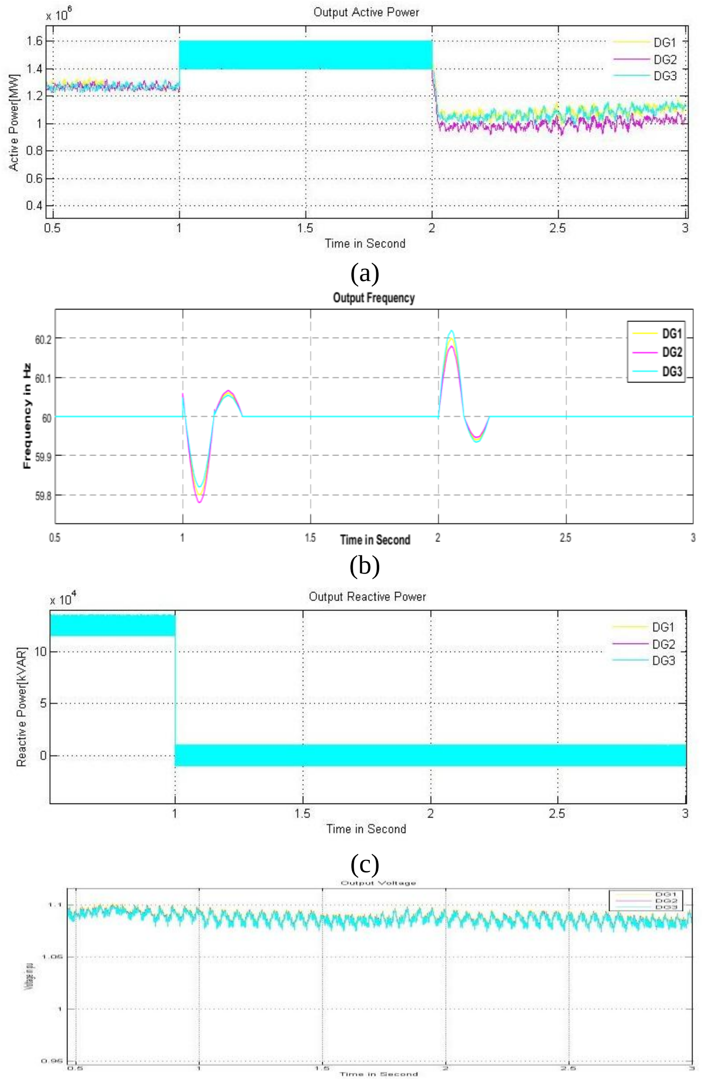

Fig. 7. Simulation results for Proposed control method. (a) Output active power (P). (b) Output frequency (f). (c) Output reactive power (Q). (d)Output voltage (v).

The change in the active power load should be shared equally among the DG units; therefore, the P-f droop coefficients were equal for each DG unit (i.e., m1 = m2 = m3 =0.02, n1 = n2 = n3 = 0.01).Figure. 6 shows the DG controller for the conventional control method, which enables both self-frequency recovery control and compensation control. Figure. 7. (a) shows the simulated active power of each DG unit conventional P-f droop control. Prior to islanded operation of the microgrid, each DG unit injected 1.3 MW (i.e., the dispatched value from the CC) into the grid. Because the total load was 4.5MW (L1 + L2 + L3 = 4.5 MW), 0.6MW of active power was injected from the main grid. At 1 s, the static switch was opened and the microgrid became islanded; hence, 0.6MWof additional active power was required from the DG units. As shown in Figure. 7 (b), this additional 0.6MW of active power was equally shared among the DG units, as the droop coefficients were equal.At 2 s,the load L3 decreased from 1.5 to 0.5 MW. At 1 s, Active power sharing differed slightly among the DGs; however, in the steady state, each DG unit injected the same amount of active power. This process can be implemented according to (6.1), such that the output frequency of each DG unit was equal in the steady state, as shown in Figure 7 (c), the output frequency of each DG unit will differ with the conventional method, frequency deviations are inevitable, as shown in Figure 7 (b).

Figure 7 (c) and (d) show the reactive power and the voltage, respectively. Since there are no reactive power load, the output reactive powers are exactly zero at 1-2 s in Figure 7 (c). This is because for all DG units, the active and reactive power loads are same with same electrical distances (see Figure 3). However, at 1 s, since the load L3 is changed and the voltage deviation is happened, the output reactive powers become slightly different from each other. The voltage swell after at 1 s in Figure 7 (d) is due to the filter capacitance of each DG unit. The frequency should recover to the nominal value, according to the grid code requirements.

VI. Conclusion

Simulation model of islanded microgrid has been developed to implement accurate active power sharing and self-frequency recovery. Active power – frequency (P-f) droop control has been developed for active power sharing by considering power system including synchronous generators. Using this control methods, DG units share the changes in load with a predetermined ratio and are able to restore their output frequency to the nominal value autonomously and immediately follows a change in load. This change in load, which may cause them to reach their output more quickly and hence generation cost increases.

Simulation results shows that the frequency was restored almost immediately following frequency deviation using self-frequency control and also using compensation and droop control active power was shared accurately and effectiveness of the proposed method was verified.

References

[1]. R. H. Lasseter, “Microgrids,” in Proc. IEEE Power Eng. Soc.Winter Meet., Jan. 2002, vol. 1, pp. 305–308

[2]. S.-J. Ahn et al., “Power-sharing method of multiple distributed generators considering control modes and configurations of a microgrid,” IEEE Trans. Power Del., vol. 25, no. 3, pp. 2007– 2016, Jul. 2010.

[3]. Md. Rasheduzzaman, Student Member, IEEE, Shyam N. Bhaskara, Student Member, IEEE and Badrul H. Chowdhury, Senior Member, IEEE ‘Implementation of a Microgrid Central Controller in a Laboratory Microgrid Network”

[4]. Y. A.-R. I. Mohamed and E. F. El-Saadany, “Adaptive decentralized droop controller to preserve power sharing stability of paralleled inverters in distributed generation microgrids,” IEEE Trans. Power Electron., vol. 23,no. 6, pp. 2806–2816, Nov. 2008.

[5]. J. A. Pec¸as Lopes, C. L. Moreira, and A. G. Madureira, “Defining control strategies for microgrids islanded operation,” IEEE Trans. Power Syst., vol. 21, no. 2, pp. 916–924, May 2006.

[6]. J. M. Guerrero et al., “Wireless-control strategy for parallel operation of distributed-generation inverters,” IEEE Trans. Ind. Electron., vol. 53, no. 5, pp. 1461–1470, Oct. 2006.

[7]. J. He and Y. W. Li, “Analysis, design, and implementation of virtual impedance for power electronics interfaced distributed generation,” IEEE Trans. Ind. Appl., vol. 47, no. 6, pp. 2525–2538, Nov./Dec. 2011.

[8]. J. He et al., “An islanding microgrid power sharing approach using enhanced virtual impedance control scheme,” IEEE Trans. Power Electron., vol. 28, no. 11, pp. 5272–5282, Nov. 2013.

[9]. I. U. Nutkani, P. C. Loh, P.Wang, and F. Blaabjerg, “Cost-prioritized droop schemes for autonomous AC microgrids,” IEEE Trans. Power Electron., vol. 30, no. 2, pp. 1109–1119, Feb. 2015.

[10]. Y.-S. Kim, E.-S. Kim, and S.-I. Moon, “Frequency and voltage control strategy of standalone microgrids with high penetration of intermittent renewable generation systems,” IEEE Trans. Power Syst., vol. 31, no. 1, pp. 718–728, Jan. 2016.

[11]. F. Katiraei, M. R. Iravani, and P. W. Lehn, “Micro-grid autonomous operation during and subsequent to islanding process,” IEEE Trans. Power Del., vol. 20, no. 1, pp. 248–257, Jan. 2005.

[12]. F. Katiraei and M. R. Iravani, “Power management strategies for a microgrid with multiple distributed generation units,” IEEE Trans. Power Syst., vol. 21, no. 4, pp. 1821–1831, Nov. 2006.

[13]. N. L. Soultanis, S. A. Papathanasiou, and N. D. Hatziargyriou, “A stability algorithm for the dynamic analysis of inverter dominated unbalanced LV microgrids,” IEEE Trans. Power Syst., vol. 22, no. 1, pp. 294–304, Feb. 2007.

[14]. J. C. Vasquez et al., “Adaptive droop control applied to voltage-source inverters operating in grid-connected and islanded modes,” IEEE Trans. Ind. Electron., vol. 56, no. 10, pp. 4088–4096, Oct. 2009.

[15]. Y. Li and Y.W. Li, “Power management of inverter interfaced autonomous microgrid based on virtual frequency-voltage frame,” IEEE Trans. Smart Grid, vol. 2, no. 1, pp. 30–40, Mar. 2011.

[16]. A. Kahrobaeian and Y. A.-R. I. Mohamed, “Network-based hybrid distributed power sharing and control for islanded microgrid systems,” IEEE Power Electron., vol. 30, no. 2, pp. 603–617, Feb. 2015.

[17]. Yun-Su Kim, Student Member, IEEE, Eung-Sang Kim, and Seung-Il Moon, Senior Member, IEEE “Distributed Generation Control Method for Active Power Sharing and Self-Frequency Recovery in an Islanded Microgrid” IEEE TRANSACTIONS ON POWER SYSTEMS 0885-8950 © 2016 IEEE.

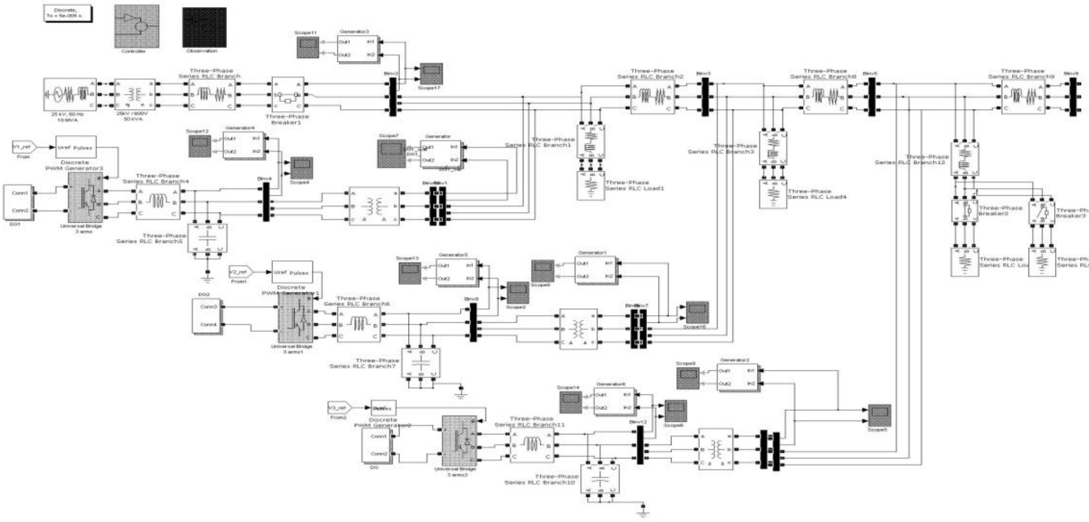

Figure.3: Configuration of the microgrid test system model.

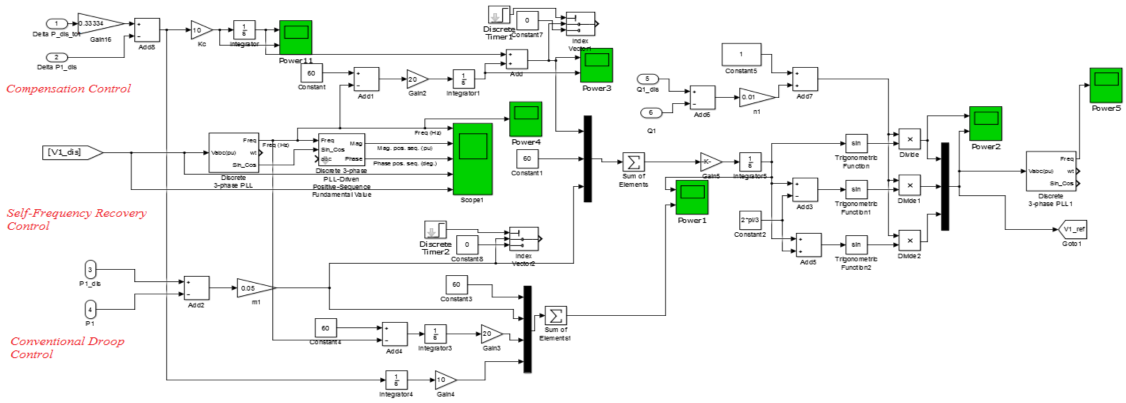

Figure.6: Proposed control scheme for distributed generation DG units.