Research on Control Strategies for Islanding Operations of AC Microgrids

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Abstract

Micro grid is a new concept for future energy distribution system that enables renewable energy integration. It generally consists of multiple distributed generators that are usually interfaced to the grid through power inverters. For the islanding operation of ac micro grids, two important tasks are to share the load demand among multiple parallel connected inverters proportionately, and maintain the voltage and frequency stabilities. This research reviews and categorizes various approaches of power sharing control principles. Simultaneously, the control schemes are graphically illustrated. Moreover, various control approaches are compared in terms of their respective advantages and disadvantages. Finally, this report presents the future trends.
Keywords: Power sharing, Islanding Operations, A C Micro grids, Distributed generators, energy distribution

I. INTRODUCTION

With the expansion of the electrical power grid, conventional power system has become increasingly vulnerable to cope with the reliability requirements and the diverse demand of power users. Moreover, distributed generators (DG) has advantages of pollution reduction, high-energy utilization rate, flexible installation location, and low-power transmission losses. DG units also present a higher degree of controllability and operability compared to the conventional generators, which will allow micro grids to play a major and critical role in maintaining the stability of electrical networks. So, micro grids will gradually be a strong and effective support for the main power grid and potentially one of the future trends of power system[1].

The DG units of a micro grid can be classified into grid forming (voltage-controlled) and grid-following (current controlled) DG units. In grid-connected mode, the units are often controlled as grid-following. The most adopted control strategies for grid-following inverters are discussed in islanding mode, the electronic converter interfaces between the loads and the micro-source act as voltage sources, which are responsible for the power sharing according to their ratings and availability of power from their corresponding energy sources or prime movers.

This report focuses on control strategies of grid-forming DG units in islanding mode. Researches on control of grid forming units were performed initially in uninterruptible power supply systems with parallel operation. Power sharing control strategies of DG units based on communication include concentrated control, master/slave control, and distributed control. On the other hand, the control strategies without communication are generally based on the droop concept, which include four main categories:

1) Concentrated type control strategy.
2) Distributed type control strategy.
3) Droop type control strategy.
4) Reactive power type control strategy.

The final method is an extension method which gives us great picture of the stability of the system. The details and characters of various control methods will be illustrated later.

A. *Concentrated Control*

The control method requires common synchronization signals and current sharing modules. The phase locked loop (PLL) circuit of each module can ensure the consistency between the frequency and phase of the output voltage and the synchronization signal. Also, the current sharing modules can detect the total load, which define the reference value of the current for each module. This reference current iref is a fraction of the load current iload. For N equal modules, iref = iload/N. In the meantime, every inverter unit measures itself output current in order to calculate the current error. In case of parallel units controlled by synchronization signals, they have negligible differences of frequency and phase among each other, thus the current sharing error of each unit can be caused by voltage amplitude inaccuracies. Therefore, this method directly adds current error to each inverter unit as a compensation component of the voltage reference in order to eliminate the differences among their output currents.

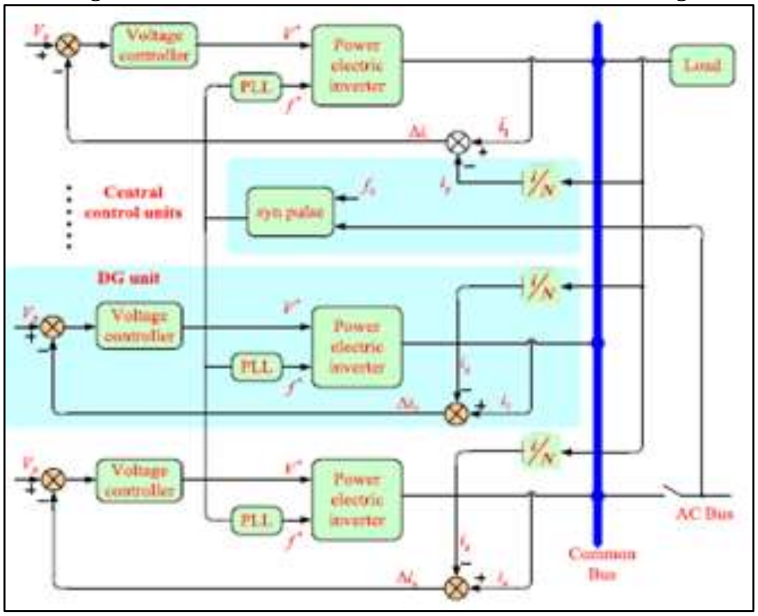

Fig. 1: Control scheme of Concentrated Control

B. Distributed Control

The distributed control is often applied to parallel converters. The instantaneous average current sharing is a typically distributed control for parallel converters. In this control technique, individual control circuit is used in each inverter, but no central controller is needed. Further, average current sharing requires a current sharing bus and reference synchronization for the voltage. An additional current control loop is used to enforce each converter to track the same average reference current, provided by the current sharing bus. When a defect happen in any module, it can smoothly detach from the micro grid, and the rest of modules can still operate normally in parallel. Fig.2 shows a control block diagram of the distributed control scheme. The average current sharing bus value is regarded as a current reference of each paralleled converter. The current error ien is decomposed into active and reactive components, iend and ienq, then the output voltage frequency and amplitude are regulated through current regulators, respectively[2].

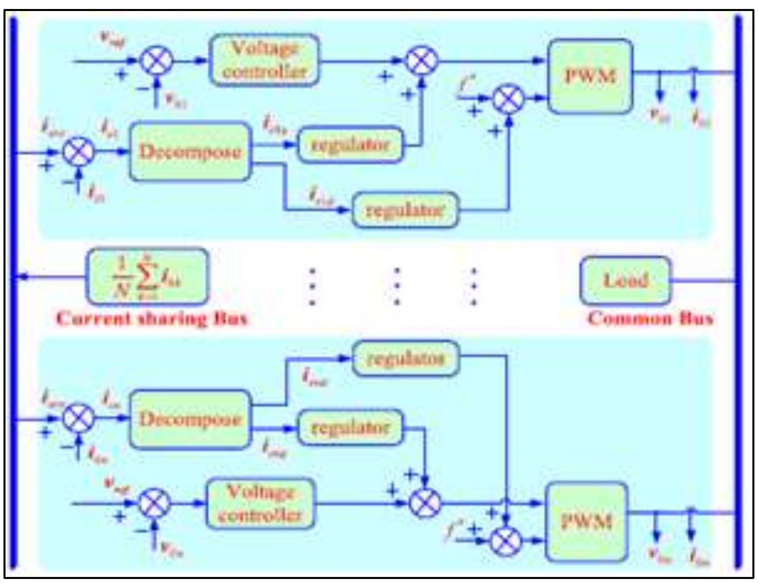

Fig. 2: Control scheme of Distributed Control

C. Voltage Based Droop Control

This control method is another type of P/V control. The control strategy presents a constant power band control of islanding ac micro grid, which operates without interunit communication in a fully distributed manner and takes the specific characteristics of the micro grid into account. These characteristics include the lack of rotating inertia, resistive line, and high share of DGs, which are less controllable than central generators and require optimal power exploitation[1] . The voltage-based droop control strategy consists of a P/V droop controller which is divided into two droop controllers (Vg/Vdc and P/Vg droops) and constant-power bands. First, the Vg/Vdc droop control principle is based on the specific characteristics of islanding ac micro grid. If an unbalance occurs between the generated power and the absorbed power, the dc link voltage Vdc of the power source changes. Therefore, Vdc is the indicator for ac power change.

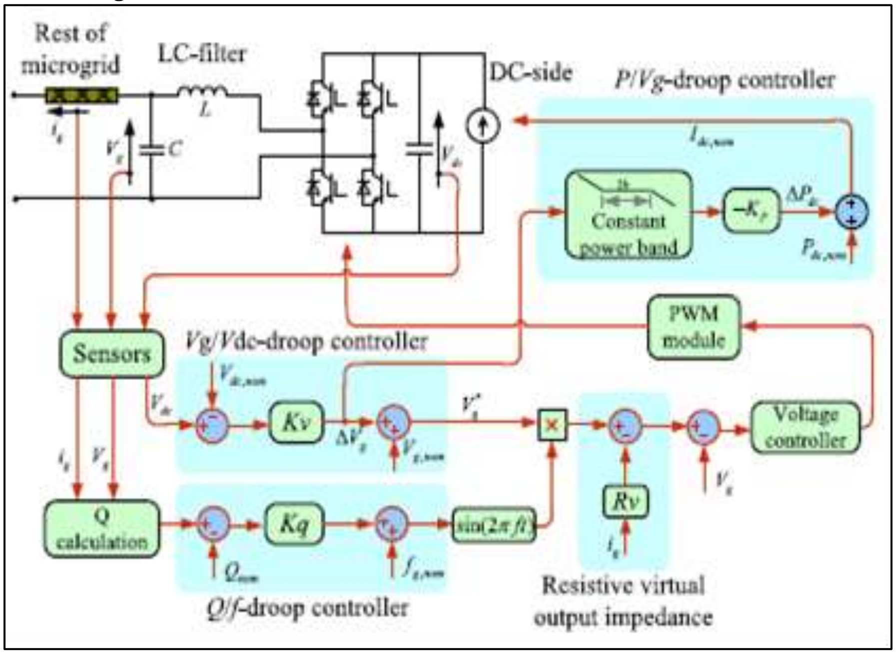

Fig. 3: Control scheme of droop Control with constant power band

D. *Reactive Power Control Technique*

Reactive power optimization configuration includes two aspects: the choice of the reactive power compensation point and the reactive power compensation capacity. If these can be determined reasonably, voltage quality and system voltage stability can be effectively improved. This can also reduce network losses and improve power supply economics by avoiding long distance transportation of a mass of reactive power.

This is one of the best method compared with other methods of control techniques. By applying this method we can obtain a minimum harmonics level. Also, this method properly shows the power consumption in a power system. This technique shows that appropriate level of reactive power to be consumed to the corresponding active power component.

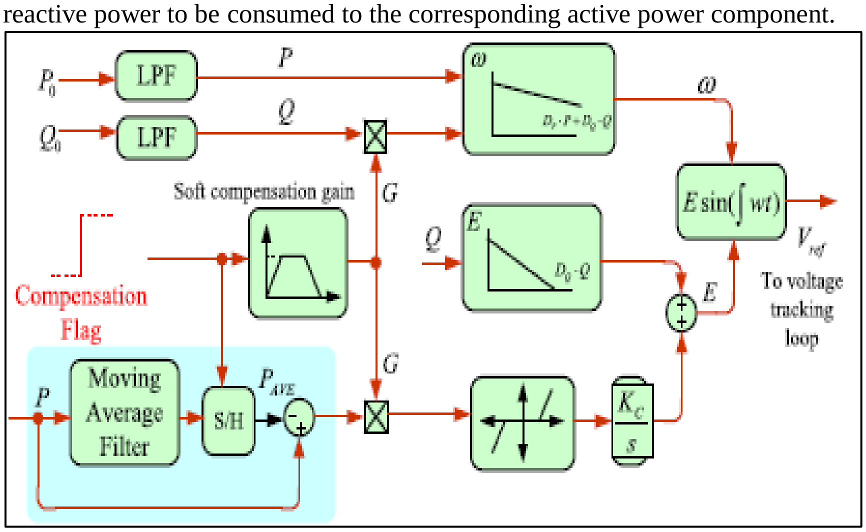

Fig. 4: Control scheme of reactive power control

II. SIMULATION BLOCK DIAGRAM

The block diagram which is used for simulation is performed in MATLAB. In order to get the desired simulation results, we are performing the simulation mainly for the three Distributed Generation units to look after the islanding operations. Also, for each DG we look after the each parameter such as the phase angle, power factor, harmonic distortions and many more parameters

DG1 –Solar Unit-It consists of PV array, dc-dc converter for stabilization of output voltage from the PV array and three phase inverter to convert DC to AC. The transformer gives constant voltage. The boost converter used to converts source of DC from one voltage level to another. This is used in photovoltaic to maximize energy harvest. The MPPT technique is used in photovoltaic circuits to maximize power extraction under all conditions. As amount of sunlight varies, load characteristics that gives highest power transfer efficiency charges so that efficiency of the system is optimized when the load characteristics changes to keep the power transfer at highest efficiency. The filter is used to remove the unwanted frequency components from the signal.
This is the important part of the report inclusive of all divisions (chapters), subdivisions (sections, subsections, etc.), tables, figures, etc.

DG2 –Wind energy Unit-It consists of wind turbine, permanent magnet synchronous generator, rectifier, dc-dc converter for stabilization of output voltage from the rectifier and three phase inverter to convert DC to AC. The transformer gives to constant voltage. The MPPT technique is used in wind turbine circuits to maximize power extraction under all conditions. As amount of sunlight varies, load characteristics gives highest power transfer efficiency charges so that efficiency of the system is optimized when the load characteristics changes to keep the power transfer at highest efficiency. The filter is used to remove the unwanted frequency components from the signal.

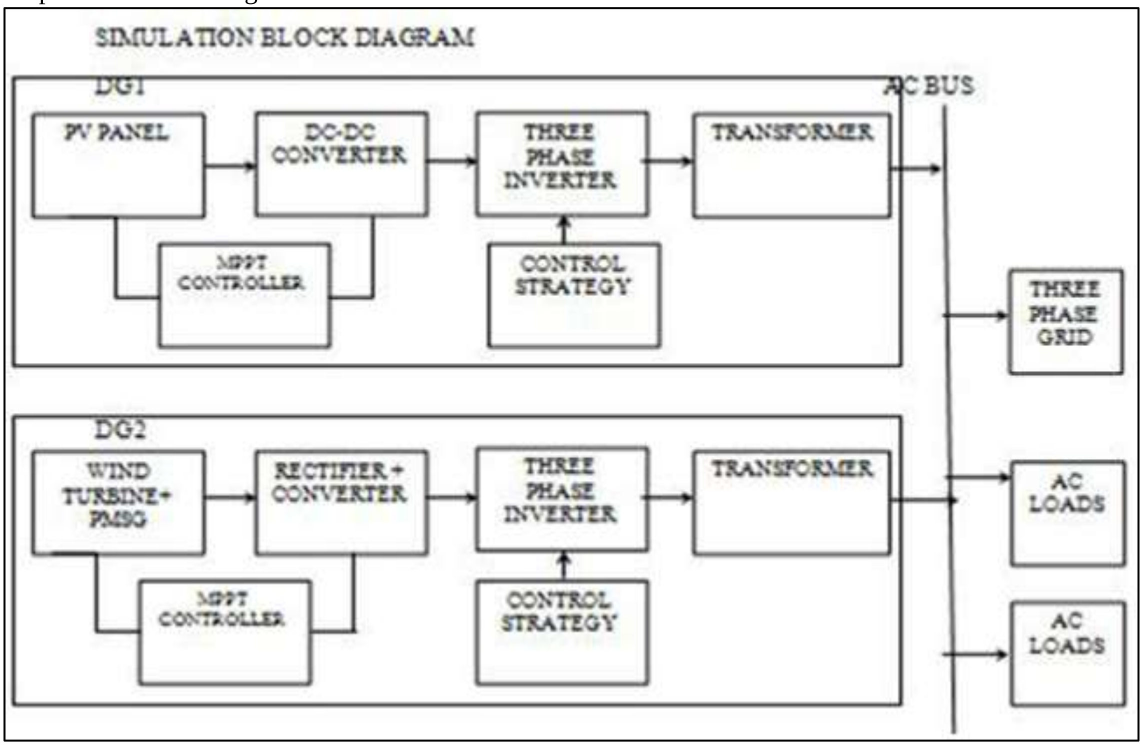

Fig. 5: Simulation Block Diagram

A. Simulation Requirements

Wind Turbine Modelling Scheme

One of the commonly used renewable energy is wind energy. Wind energy is obtained from wind turbine farms. Initially the wind is allowed to turn the shaft creating mechanical energy which then changed into electrical energy. The items required for wind energy generation are:-

1) Wind Turbine
2) Generators
3) Converters

Wind Turbine- The wind turbine converts the kinetic energy of the wind to the mechanical energy and in turns converts it to electrical energy, then it's called wind generator. Wind turbines are of two types are two types;-

Horizontal - The plane of rotating axis is parallel to ground.

Vertical- The plane of rotating axis is perpendicular to the ground.

Under constant acceleration[3] , Kinetic energy of a body having mass M, and velocity v, then its equal to work done W, in displacing that object form rest to a distance s, under a force F.

$$E = W = F \times S \quad .....eq(1)$$
$$F = M \times a \quad ....eq(2)$$
$$E = ma \times s \quad ....eq(3)$$

Similarly, also looking for equation of motion

$$v^2 = u^2 + 2as$$

We get 'a' as

$$a = \frac{v^2 - u^2}{2s} \quad ....eq(4)$$

Since initial velocity v=0

$$a = \frac{V^2}{2s}$$

Substitute for 'a' in the equation for 'E'

$$E = \frac{mv^2}{2s} \times s = \frac{1}{2}mv^2$$

Power =Rate of change of energy ....eq(5)

$$P = \frac{dE}{dt} = \frac{1}{2}mv^2 \times \frac{dm}{dt}$$

$$\frac{dm}{dt} = \rho A \frac{dx}{dt}$$

ρ = density

A=Swept area

$$P = \frac{1}{2}V^2 \rho \frac{dx}{dt}$$

$$P = \frac{1}{2}AV^3 \quad ....eq(6)$$

No wind turbine can convert more than 59 percent of kinetic energy to mechanical energy

$$C_{Pmax}=0.59$$

This called bentz limit.

Then the overall power co-efficient becomes

$$P = \frac{1}{2}\rho AV^3 C_p \quad ....eq(7)$$

Power co-efficient is not a static value . It depends on the tip speed ratio of the turbine.

$$\text{Tip speed, } \lambda = \frac{\text{blade tip speed}}{\text{wind speed}} \quad ....eq(8)$$

$$\text{Blade tip speed} = \frac{\text{rotational speed} \times \pi \times D}{60} \quad ....eq(9)$$

B. PV Panel Modelling Scheme

Semiconductors p-n junction based photodiodes it generates electric power when exposed to lights. PV cells are commonly made up of mono-crystalline silicon and poly-crystalline silicon. When PV cells are connected in series high voltage can be obtained. During, parallel connection high current and high power can be obtained during proper series and parallel connection.
We commonly use polycrystalline silicon for the manufacture of solar cells due to its wide availability and better performance.

Operating temperature in Kelvin T_{ak}

$$T_{ak} = 273 + T_{oc}$$

T_{oc} = cell temperature in celsius

The two inputs of solar cell are radiations and temperature

Step 1

1. $I_{ph} = G \times I_{sc}$

I_{sc} = short circuit current at given T_{ak}

$$I_{sc} = I_{sc} - T_{rk} \times (1 + a(T_{ak} - T_{rk})) \quad .....eq(10)$$

Reactive Power Control Modelling Scheme

$$P_{cal} = 1/2\ [V_{g\alpha}\, i_{g\alpha} + V_{g\beta}\, i_{g\beta}] \quad \text{......................eq(11)}$$

$$Q_{cal} = 1/2\ [V_{g\beta}\, i_{g\alpha} + V_{g\alpha}\, i_{g\beta}] \quad \text{........................eq(12)}$$

Droop Control Method Scheme

$$P_i = (VE_i / X) * \sin\phi \quad \text{...................eq(13)}$$

$$Q_i = (VE_i\cos\phi - V^2) / X \quad \text{.................eq(14)}$$

C. *Simulation Results*

1) *Concentrated Control Method*

This method is the most frequently used but we cannot depend on this method because it is not much reliable as it depends on external parameters. It creates harmonics level of about 6 percent. This method doesn't provide detail picture about stability. The THD level of this method is obtained by the process called FFT analysis.

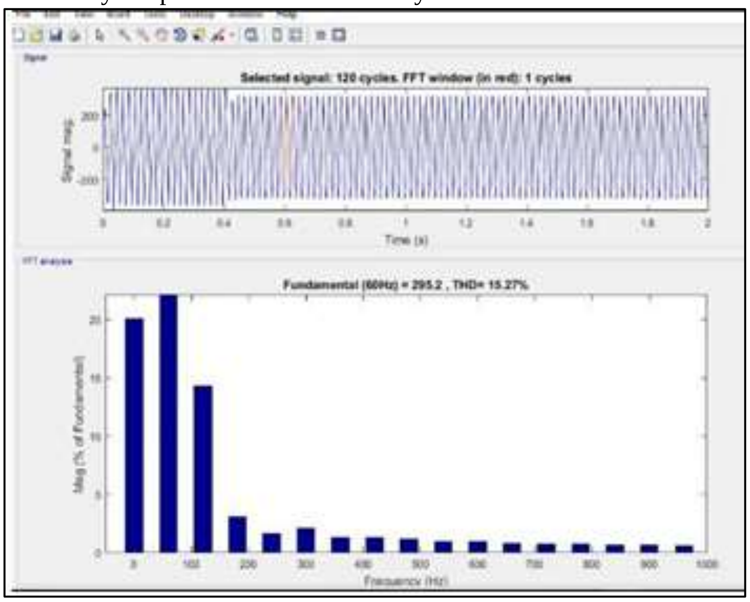

Fig. 6: Showing harmonics level in concentrated control method

2) *Distributed Control Method*

In this method we are able to find the number of voltages from a single bus bar voltage. Due to this it creates lot of losses. The THD level produced during operation is around 120-130 percent. In conclusion this method has no central board and every module is symmetric. Voltage regulation and fundamental power sharing are well controlled. However interconnections between the inverters are still necessary. This degrades the flexibility and redundancy of the system. As a number of parallel modules and distance of the interconnected lines increase, more interference is expected in the system.

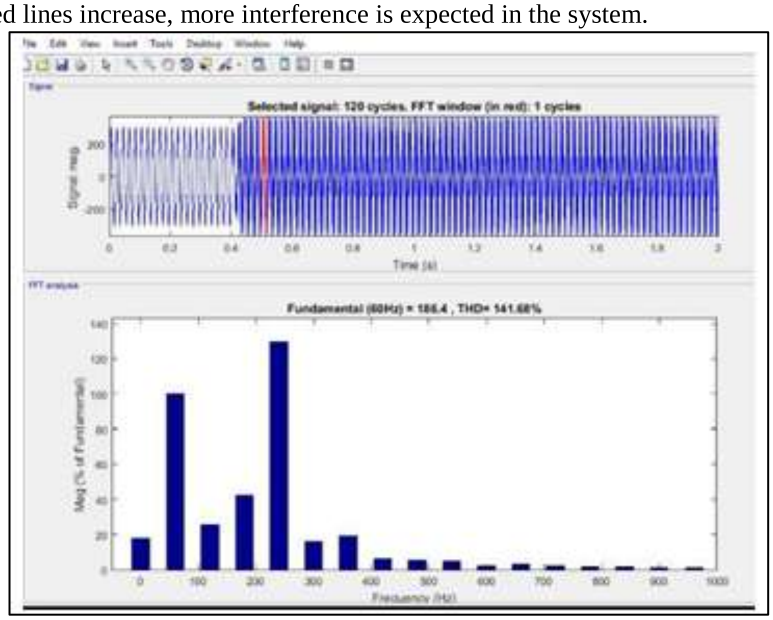

Fig. 7: Showing harmonics level in Distributed control method

3) Droop Control Method

This shows the THD which is very much near to 0.1 percent. In islanding mode, the voltage and frequency of the micro grid are load dependent. Steeper drop ensures better load sharing, yet results in larger frequency and voltage deviation, and even may causes instabilities in the micro grid. This is the inherent trade-off between the frequency , voltage regulation and load sharing accuracy .Another drawback of the droop method is the poor performance of the renewable energy resources because the output active power of micro-source is usually fluctuant and changeable. This method focuses on fundamental power sharing but does not take harmonic sharing into account of nonlinear loads. If it is coped properly, it would lead to harmonic circulating currents and poor quality. Moreover, the calculation and smoothing of active and reactive power take some delays, thus it presents a slow dynamic response.

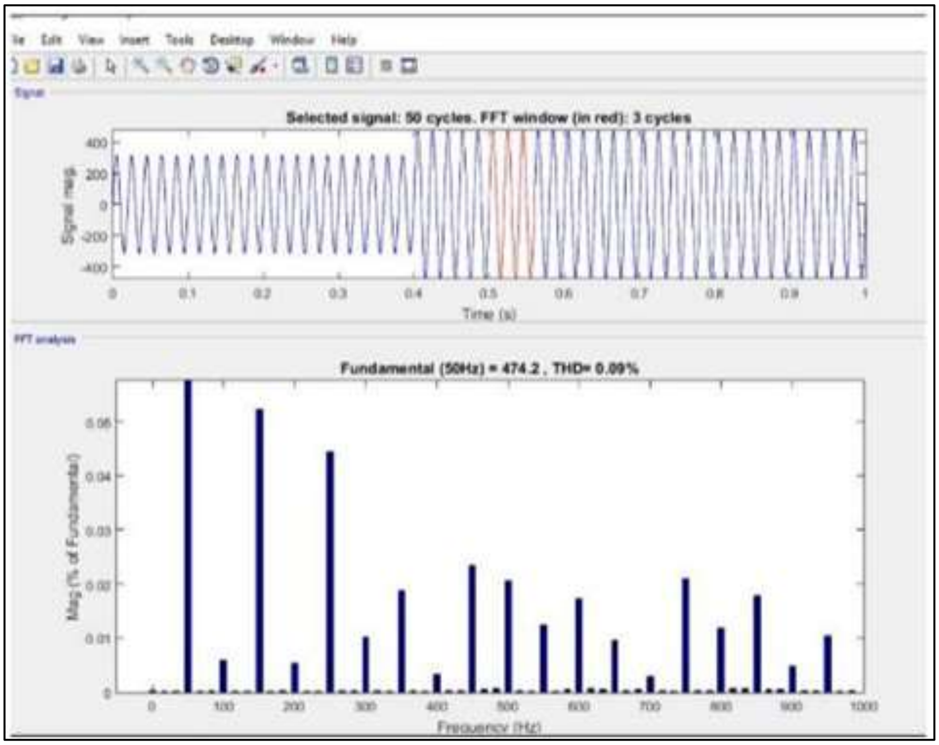

Fig. 8: Showing harmonics level in Droop control method

4) Study Results of Reactive Control Method

This control strategy is the best method compared to other methods. We cannot depend on the concentration control method due to its low reliability and reductancy. Since, concentration control method uses maximum PLL and sensors which causes lot of losses. We are able to lower down these disadvantages to some extend with the help of our reactive power control method strategy.

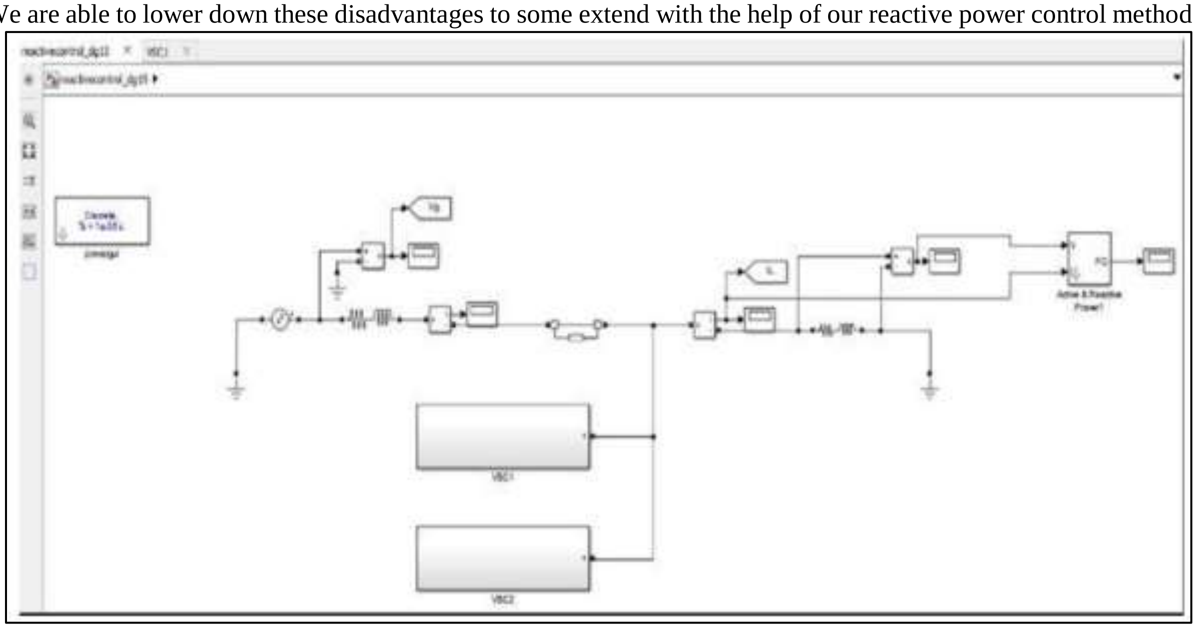

Fig. 9: Simulation circuit diagram of the implemented reactive power control

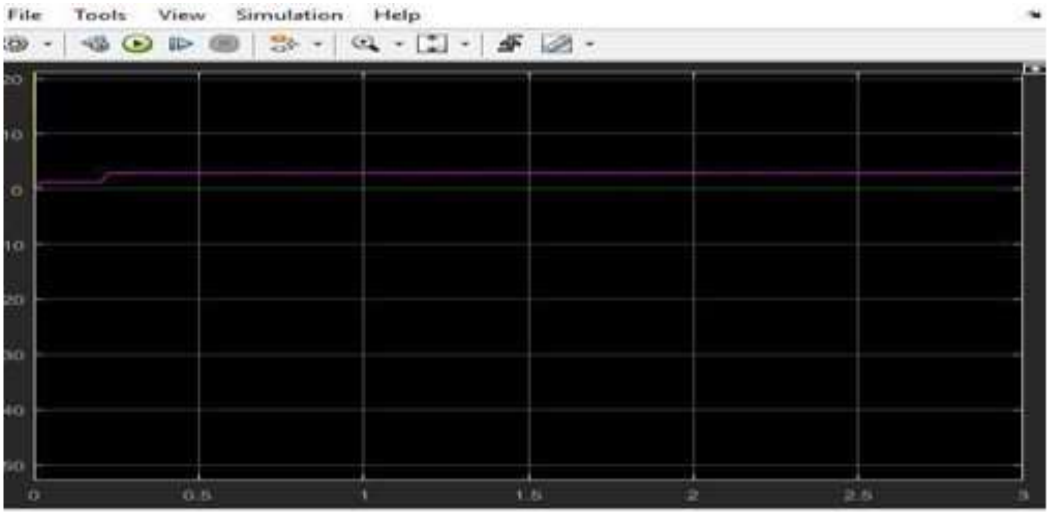

Fig. 10: Graph showing power stability

In this graph the component which tends to rise to a certain level and then after stabilizes to particular value is called active power component. The component showing small deviations around the 0 region is the reactive power component. The reactive power is kept minimum to obtain smooth working active power component.

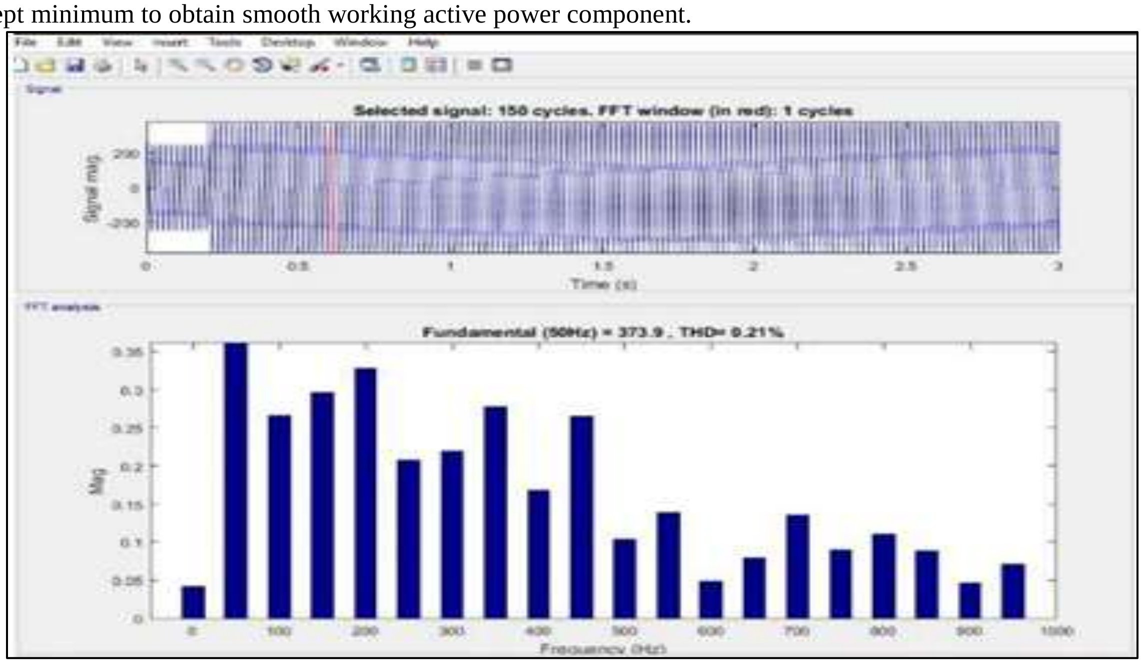

Fig. 11: Showing the harmonics level in reactive power control technique

In this method we are able to provide a proper power stability analysis to the system. This analysis shows the proper active power and reactive power consumption. Also, the other finding is that the THD is also minimum to 0.2 percent.

III. CONCLUSION AND FUTURE SCOPE

A. Conclusion

In this project we represent islanding operation of the AC micro grids .This mainly works on the comparison among the THD levels of all the control techniques mentioned. Our research is important in the sense because it helps to provide the additional or the alternative energy sources in the cases of grid maintenance or during the cases of faulty conditions. Reactive Power control strategy adopted is the most efficient strategy with less losses in DG. This is one of the best method compared with other methods of control techniques. By applying this method we can obtain a minimum harmonics and THD levels. Also, this method properly shows the power consumption in a power system. This technique shows that appropriate level of reactive power to be consumed to the corresponding active power component. Hence keeping these points in mind we came to conclusion that Reactive Power Control method is the best.

B. Future Scope

1) Future Plan for the Existing System is by providing a New Strategy:

The stability of micro grid has been studied for long years. However, the stability of the micro grid has never been studied perfectly when it supplies some complex loads such as the dynamic loads, the constant loads, inductor motor, the pulsed loads, and the electric vehicles. So it is necessary to propose the special models and control methods to solve the voltage, frequency, and the power angle stabilities for these composite loads.

The traditional bulk power system consists of many synchronous generators with a relatively large inertia. But micro grids do not have the kinetic energy to and spinning reserve, which consist of many inverter based distributed resources with a low inertia. Then the low inertia may lead to the severe voltage or frequency deviations in some big disturbances and sudden changes. So the system should show a large inertia when the frequency will deviate, and allow inertia when to recover the frequency. The objective of variable inertia is always to keep the normal frequency.

The fault tolerant control is a key technology area which should not only manage supply and demand of electricity more efficiently, but also apply appropriate corrective actions to eliminate, mitigate, and prevent various emergency situations such as faults, outages, disturbances to power quality or changes in the user needs. Moreover, the fault tolerant control also can be implemented for self-heating and anti-islanding which enhances the capability of fault-ride through and ensures the reliability and security of the systems.

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