COMPARATIVE STUDY OF MICROGRID CONNECTED IN ISLANDED MODE USING DROOP CONTROL & ADVANCED DYNAMIC DROOP CONTROL TECHNIQUES

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Abstract - *Recent climatic changes have led to the increase in utilization of sustainable Distributed Generation (DG) resources such as fuel cells using natural or biogas, wind, solar etc. To meet the ever increasing energy requirement, society is moving to renewable sources like solar energy, wind energy etc, as it is pollution free, clean and available in plenty. In this paper , a micro grid model is designed using PV cell by using two different control strategies have been analysed. Droop control and advanced dynamic droop control methods have been explained in this paper In both these techniques, there is no need of communication line and maximum power is extracted from solar panel using Perturb and Observe method. The LC filters are designed to eliminate harmonic current. The conventional droop control has poor voltage regulation at heavy load condition and poor power sharing performance at light load condition. The conventional P-Q droop methods shares the active power based on fixed droop coefficient irrespective of available energy from non conventional energy source. The disadvantages of the conventional droop control can be reduced with the use of advanced dynamic droop control. PV models with droop control and advanced dynamic droop control have been designed and compared using matlab/simulink models*

Key words :DG, MPPT, PV, PO,PWM

1 INTRODCTION

The interest in distributed generation (DG) systems is rapidly increasing because large power
plants are becoming less feasible in many regions due to increasing fuel costs and high heating
DG based on renewable energy source (such as solar and wind) integration contributes to reducing CO_2 emissions from fossil fuel based sources, reducing transmission losses, mitigating voltage variation, relieving peak loading, and enhancing supply reliability. Microgrid is defined as integrated system consisting of conventional and non conventional energy sources. In this paper work, PV is used as primary energy source since it does not require fuel and also the energy loss is on the lower side. Photovoltaic system is used as distributed generation system. When PV is connected to microgrid, it may face many problems like voltage and frequency deviation, power unbalance, overloading, circulating current etc. The droop control methods employs active power versus frequency (P-ω) and reactive power versus voltage (Q-V) relation for active and reactive power sharing amongst the DG of the microgrid. There is no communication link between microgrid. Power sharing control is classified in two ways -Conventional droop control and advanced dynamic droop control. Conventional droop control has less efficiency when compared to advanced dynamic droop control. As PV voltage continuously varies, for effective operation of PV system,Perturb and observe method to track maximum voltage. LC filters are used to reduce harmonics in voltage and current waveform. LC filters reduce maximum ripples, has lower cost compared to other filters and are simple design and implement. For the power system to be stable, during synchronization process we have to regulate frequency, voltage, active power, reactive power and improve settling time.

1.1 MICROGRID CONTROL ISSUES

1.1.1 STABILITY ISSUE

Microgrid stability issues may arise from various causes, such as islanding and reconnection to the grid, different types of faults, changes in network parameters, mismatch in the power generation-demand, and sudden connection or disconnection of DGs or loads in the system.

1.1.2 UNBALANCED VOLTAGE

In a three-phase system, the phase voltages are not perfectly sinusoidal in nature and have some degree of unbalance. Therefore, a microgrid needs to be designed to operate under unbalanced conditions. The voltage unbalance occurs because of various reasons such as the

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spacing of the overhead transmission lines, three-phase loads with unbalanced impedances, and a fault in the power system. Voltage unbalance can be defined as unequal voltage magnitudes at fundamental system frequency (under voltages and over voltages), fundamental phase angle deviation, and unequal levels of harmonic distortion between the phases

2 OBJECTIVE

Due to various constraints, conventional grid is not sufficient to meet our energy requirement feasibly. Microgrid provides solution to this problem and meets our energy needs. Microgrid mainly integrates with renewable energy since it has no fuel cost and no heating loss. For synchronization, we have to regulate active and reactive power. Microgrids can provide better efficiency, continuous supply of electricity without interruption; eliminate harmonic current, maximize utilization of renewable energy resource, reduce CO_2 emission etc.In this paper comparative study has been conducted on amicrogrid with droop and advanced dynamic droop control technique.

3 BLOCK DIAGRAM

Figure 1 shows droop control or advanced droop control strategy of microgrid. AC microgrid consists of PV array as supply. To track maximum power from the panel, perturb and observe method is used. Gate pulse signals are provided to the boost converter. Boost converter output voltage is used as input to the three phase PWM inverter. By using two control strategies, active power, reactive power, voltage and frequency for the synchronization are controlled. Synchronization process is done by providing gate pulse for the PWM inverter switches.

Output obtained from the PV is DC. DC is boost up using boost converter .The output of boost converter is given to the PWM inverter which converts DC to AC. AC output from inverter is filtered using filter circuit to reduce the harmonic content in AC signal. The filtered signal is given to the point of common coupling

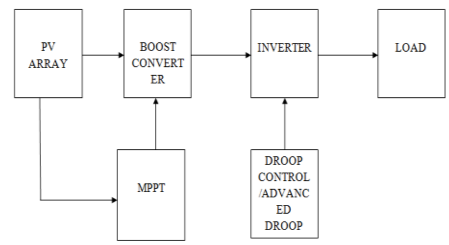

Fig 1 Block diagram of microgrid

4 CONTROL STRATEGIES

The microgrid includes many DG units that are able to work in both modes grid-connected and island mode. It raises many issues that could create technical challenges, particularly during the transfer between the two modes of operation.

1) Grid connected mode

2) Islanded mode

4.1 ISLANDED MODE

Islanding is a condition in which a microgrid is a portion of power grid, consisting of distributed generation (DG) sources, like solar, wind etc. Converter and load get disconnected from the utility grid. There is no interconnection with microgrid.

In this paper an islanded microgrid with solar unit as distributed source has been used

Solar energy is one of the most promising renewable energy source which does not require any fuel cost. There is no moving device in the solar pv system. It is static device that provides direct current which can be converted according to our needs. Communication requirement between the inverters is not needed.

- The voltage and frequency are regulated by regulating the reactive and active power respectively.
- In power grids, active power and reactive power have strong coupling with frequency and voltage, respectively

4.2 DROOP CONTROL

Droop control has got wide acceptance because of the absence of the communication requirements between the inverters. The main idea is to regulate the voltage and the frequency by regulating the reactive and the active power respectively which can be sensed locally.

The Droop control method has many desirable features such as expandability, modularity, redundancy and flexibility. The droop control of parallel inverters facilitates the microgrid to operate in both grid-connected and islanded mode. The microgrid continues to supply power to the local load at times of utility failure. The parameters like regulated voltage, accurate active and reactive power sharing, and stability form the performance indices of the distribution system. Hence the droop strategy is widely preferred to investigate the performance indices, in connection with microgrid. The origin of droop control strategy depends on the principle of synchronous generators in which the voltage and frequency experience a droop with changing the load. The main advantages of conventional droop control are avoided communication, improved power-sharing, high reliability, expandability and modularity, low bandwidth requirement. The main disadvantages of the Droop control strategy are power-sharing attained at an expense of voltage regulation and slow response.

In power grids, active power and reactive power have strong coupling with frequency and voltage, respectively. Accordingly, relationship between active power/ frequency and reactive power/ voltage can be expressed as

$$F = f_0 + K_{pf}(P_0 - P) \quad (1)$$

$$V = V_0 + K_{qf}(Q_0 - Q) \quad (2)$$

Where f_0 rated frequency and V_0 is rated voltage and P_0 and Q_0 are momentary set points of active and reactive power. P and Q are the measured active and reactive power and K_{pf} and K_{qf} obtained symbolize drooping coefficients.

$$K_{pf} = \frac{\Delta f}{P_{max}} \quad (3)$$

$$K_{qf} = \frac{\Delta v}{Q_{max}} \quad (4)$$

Where P_{max} and Q_{max} are the maximum active and reactive power. Δf and Δv are the maximum allowable frequency and voltage. For several DG units connected in parallel constituting a microgrid, the load power sharing depends on the slope of the droop characteristics.

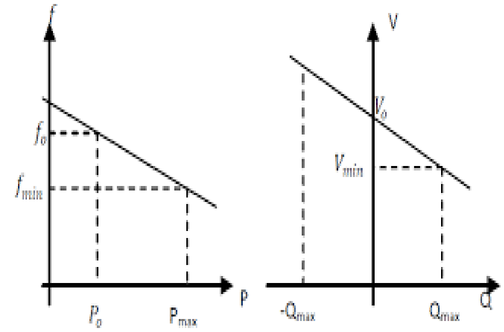

Fig 2 Slope Of Droop Characteristics

When there is an increase in the load, the frequency reference is decreased Reactive power is shared using the droop characteristic of the voltage magnitude. The active and reactive power are predetermined by using different control strategies like MPPT.

4.2.1 PQ CONTROL MODE

The PQ controlled inverter operates by injecting into the grid a pre-specified power defined locally or centrally. Droop based control system for the VF inverter is used to share the load power .

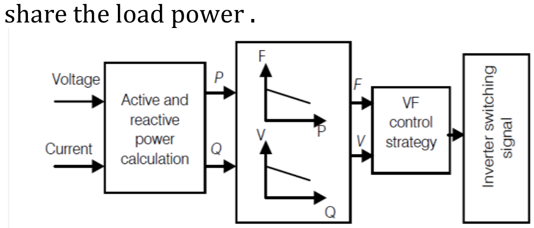

Fig 3 Droop Based Control System For The PQ Inverter

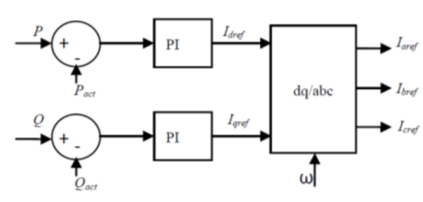

Fig 4 PQ Inverter Control System

- The actual voltage and frequency are passed to droop unit to generate reference signal for the active power and reactive power.
- The reference values are compared with their actual values and the errors are processed to PI controller.

- It generates direct axis and quadrature axis components.
- These 2 components are converted into 3 phase component by Clark's transformation.
- These 3 components are compared with carrier and is used as switching pulse of the inverter thereby regulating voltage and frequency.

4.3 ADVANCED DYNAMIC DROOP CONTROL

The disadvantages of the conventional droop control can be reduced by using advanced dynamic droop control. Conventional droop control has poor voltage regulation at heavy load and poor power sharing performance at light load condition. Conventional P-ω droop methods share the active power based on fixed droop coefficient irrespective of available energy from non conventional energy source like PV.

The inverters output voltage is utilized to achieve desired active and reactive power exchange. The inverters output voltage Eabc and current Iabc are transformed into d-q frame to obtain the active power and reactive power.

$$P_0 = (IdVd + IqVq) \tag{5}$$

$$Q_0 = (IqVd - IdVq) \tag{6}$$

Where Id and Iq are direct axis and quadrature axis components of the inverter output current. Vd and Vq are direct axis and quadrature axis component of the inverter output voltage.

In order to reduce harmonic of the active power and reactive power first order low pass filter is used. The equation is shown below

$$P_{01} = \frac{\omega_c}{S+\omega_c} * \frac{3}{2}\left(I_d V_d + I_q V_q\right) \tag{7}$$

$$Q_{02} = \frac{\omega_c}{S+\omega_c} * \frac{3}{2}\left(I_q V_d - I_d V_q\right) \tag{8}$$

Where ω_c represents cut-off frequency

The error Δp between the maximum power extracted from PV array under given conditions P_{mpp} and the active power supplied through the inverter P is used to derive Δω. The P_{mpp} information is obtained from perturb and observe (P&O) MPPT algorithm implemented with dc to dc boost converter. The desired frequency ω_{ref} of the Modified droop controllers is obtained by adding a components Δω to the frequency W obtained from the conventional droop characteristics.

$$\omega^* = \left(P - P_{mppt}\right)\mathrm{m} \tag{9}$$

$$\omega = \omega_0 + m(P_{rated} - P_0) \tag{10}$$

$$m = \frac{\Delta\omega}{P_{rated}} \tag{11}$$

$$\omega_{ref} = \Delta\omega + \omega. \tag{12}$$

The reactive power droop control is implemented using reactive power v/s voltage (Q -V) droop equation represented by the equation given below, which provide the V_{ref} reference voltage for the voltage droop.

$$Q = n(Q_0 - Q_1) \tag{13}$$

$$V_{ref} = V_0 - n(Q_0 - Q_1) \tag{14}$$

$$n = \frac{\Delta\omega}{Q_1} \tag{15}$$

The voltage and frequency V_{ref} and ω_{ref} respectively are applied to voltage control loop. The voltage control loop generates sinusoidal three phase ac voltage from V_{ref} and ω_{ref} and then further applied abc–dq transformation to derive the reference d-q voltage components. The V_d and V_q voltage regulator loop compares these V_{d*} and V_{q*} with actual inverter output d –q voltage components (V_q and V_d). Output obtained is passed through 3 phase sine wave generator. We get Eabc , this Eabc is compared with carrier and generates gate pulse for the MOSFET of 3 phase PWM inverter.

4.4 PERTURB AND OBSERVE METHOD

Maximum power point tracking (MPPT) is used in the photovoltaic (PV) system to maximize the PV array output power irrespective of temperature and irradiation conditions. The weather and load changes cause the operation of a PV system to vary almost all the time. The dynamic tracking technique is important to ensure maximum power is obtained from the photovoltaic arrays.

The most commonly used MPPT algorithm is P&O method. This algorithm uses simple feedback arrangement and little measured parameters. In this approach, the module voltage is periodically given a perturbation and the corresponding output power is compared with that of the previous value. In this algorithm a slight perturbation is introduce to the system. This perturbation causes the power of the solar module to vary. If the power increases due to the perturbation then the perturbation is continued in the same direction. When the peak power is reached, system tracks maximum power and at this stage the rate of change of power is zero.

5 MATLAB AND SIMULATION

5.1 MICROGRID WITH DROP CONTROL

The circuit diagram shows the Microgrid with droop control. In this paper PV array of 21.35 KW is considered for simulation.The perturb and observe method is used to track maximum voltage and power and it give gate pulse for the MOSFET of the boost converter .The output obtained from the boost is given as input of the inverter. The gate pulse for the MOSFET is given according to droop control strategy and there by regulating active and reactive power for the synchronization purpose

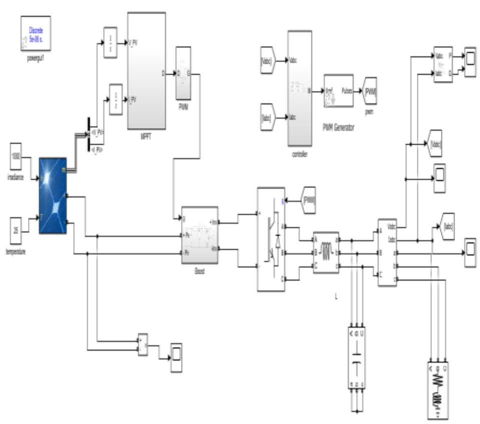

Fig 5 MICROGRID WITH DROOP CONTROL

5.2 CURRENT CONTROL CIRCUIT

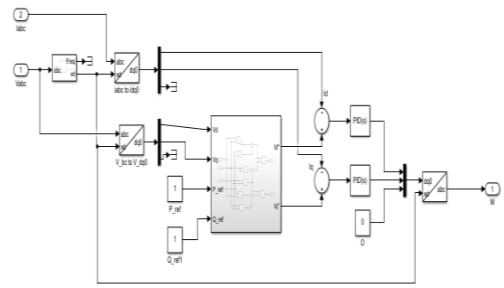

Fig 6 Current control circuit

The load voltage and load current can be converted according to park tarnsformation and compare their actual value with reference value and generate d -q components .Again it is converted in to 3 phase and compare with reference

The reference I_d* and I_q*are can be implemented by using this circuit.The equation as follows

$$I_d * = \frac{V_d * P_{ref} + V_q * Q_{ref}}{V_d^2 + V_q^2}$$

$$I_q * = \frac{V_d * P_{ref} - V_q * Q_{ref}}{V_d^2 + V_q^2}$$

5.3 VOLTAGE CONTROL CIRCUIT

The voltage control circuit consist of 3 separate sine wave with difference in the phase angle. It can be considered as reference wave and this reference wave is compared with load wave form and thereby generating gate pulse for regulating active and reactive power.

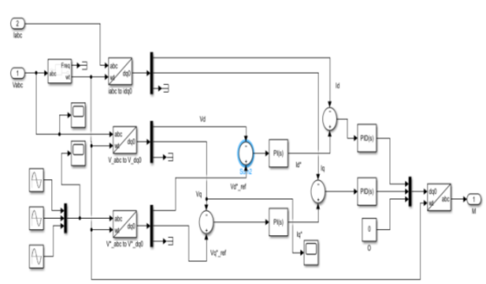

Fig 7 voltage control circuit

5.4 ADVANCED DYNAMIC DROOP CONTROL

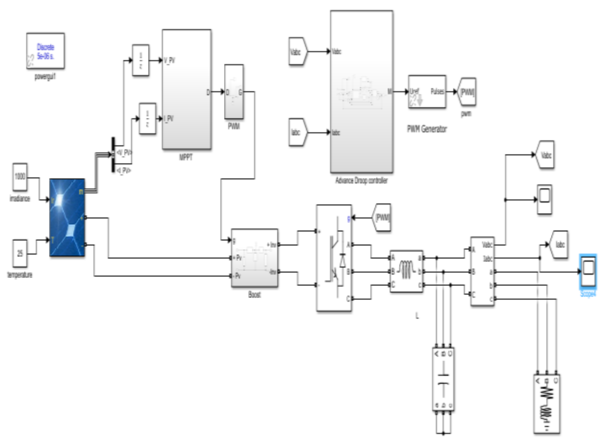

Fig 8 Circuit diagram for advanced dynamic droop control

This circuit show the advanced dynamic control of microgrid.This circuit also consist of PV 21KW.It has only difference control stragey with our conventional droop control method.Power system gave more importance settling time.The settling time is defined as time require to attain stability.So conventional droop control take more time compare with advanced droop control strategy.

5.5 DYNAMIC DROOP CONTROL CIRCUIT

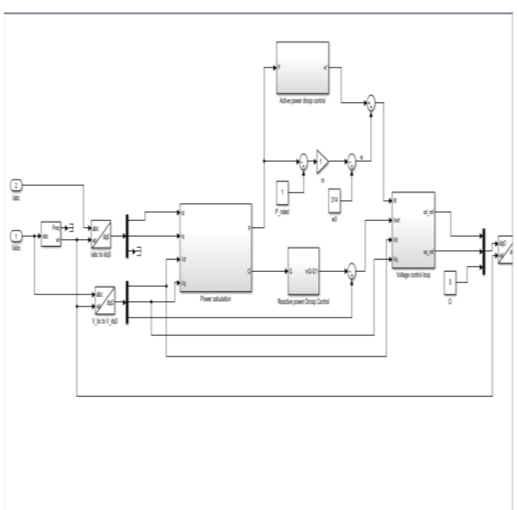

Fig 9 Voltage Control of Advanced Dynamic Droop Control

This circuit shows overall control circuit of advanced dynamic droop control. After active and reactive power calculation we get reference value for both frequency and voltage, which is passed through voltage control loop to generate 3 phase waveform. The reference value is compared with carrier and gate pulse is generated there by regulating active power and reactive power for the synchronization purpose.

6 RESULT AND DISCUSSION

The PV characteristics, boost converter output, load current and load voltage of both advanced dynamic and conventional droop control are discussed based on the simulation results. Also the active power and reactive power of both advanced dynamic and conventional droop control are shown. From these waveforms we clearly understand that advanced droop control method is better for synchronization.

6.1 PV CHARACTRISTICS

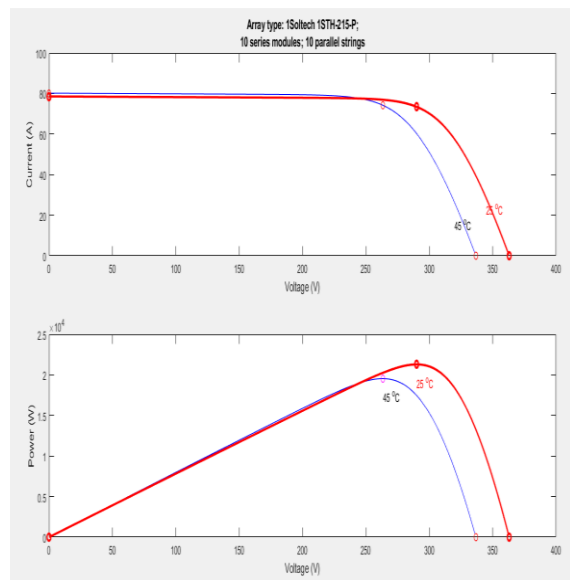

Fig 10 PV OUTPUT VOLTAGE

This is the PV panel output. Maximum power obtained from panel is 21.37 KW. Maximum voltage is 290.7 V. Different irradiance are considered here. Maximum power point is at 1000W/m^2 irradiance level and temperature 25 °C.

6.2 OUTPUT VOLTAGE OF CONVENTIONAL DROOP CONTROL

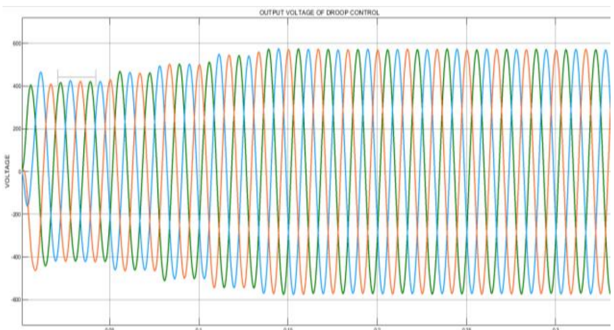

Fig 11 Conventional droop output voltage

This figure 11 shows the output voltage of conventional droop control of about 585.9 V

6.3 OUTPUT CURRENT OF CONVENTIONAL DROOP CONTROL

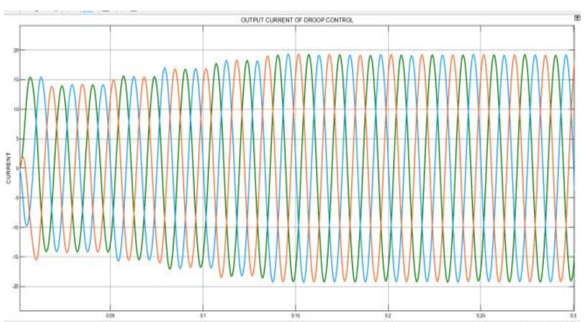

Fig 12 Conventional droop output voltage

This figure 12 shows the output current of conventional droop control of about 19A

6.4 ACTIVE POWER AND REACTIVE POWER OF CONVENTIONAL DROOP CONTROL

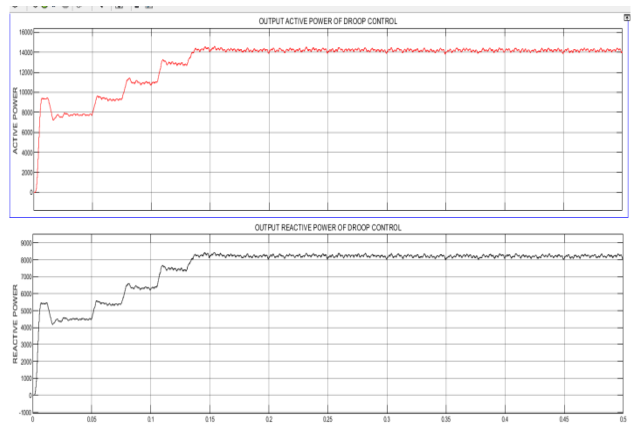

Fig 13 Active Power and Reactive Power Of Conventional Droop Control

This figure 13 shows the output active and reactive power of conventional droop control .Active power of 14000W and reactive Power of About 9000 W

6.5 OUTPUT VOLTAGE OF ADVANCED DYNAMIC DROOP CONTROL

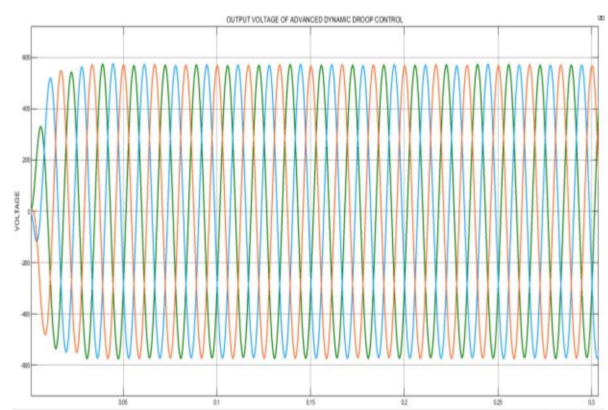

Fig 14 Output Voltage Advanced Dynamic Droop Control

This figure 14 shows the output voltage of Advanced dynamic droop control of about 585.98V

6.6 OUTPUT CURRENT OF ADVANCED DYNAMIC DROOP CONTROL

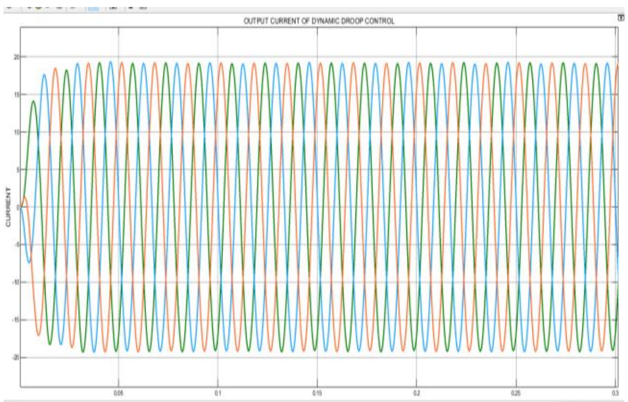

Fig 15 Output Current Advanced Dynamic Droop Control

This figure 15 shows the output current Of advanced dynamic droop control of about 19A

6.7 ACTIVE POWER AND REACTIVE POWER OF ADVANCED DYNAMIC DROOP CONTROL

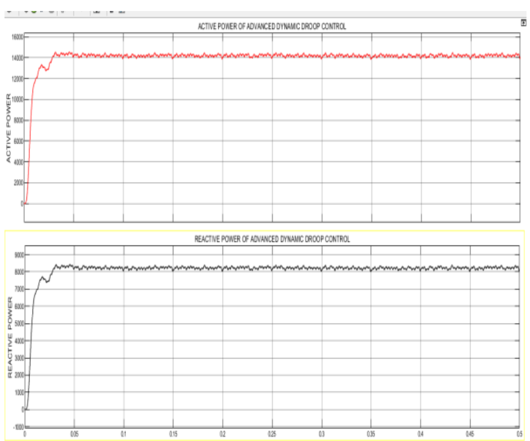

Fig 16 Active Power and Reactive Power of Advanced Dynamic Droop Control

Figure 16 shows active power of about 14000W and reactive power of about 9000W.

7 CONCLUSION

Microgrid has become popular and is considered as one of the best solutions to energy crisis management. Microgrid has various advantages that help to provide uninterrupted electrical energy to meet our energy demand feasibly. As the solar radiation and temperature varies, the output of PV system also varies. In order to track maximum power from the PV arrays, maximum power point tracking (MPPT) is used with perturb and observe algorithm. During synchronization, voltage, frequency, active power and reactive power are to be regulated so that the power system remains stable. Droop control techniques can be used for maintaining power system stability. These techniques have various advantages. In this project a comparative study between conventional droop control and advanced dynamic droop control technique has been conducted using MATLAB simulation tool. One of the main factors to be considered while defining stability of a system is settling time. From the simulation results it can be concluded that the system with conventional droop control technique takes more time to settle when compared to system with advanced dynamic droop control. The response time of system with advanced dynamic droop control is found to be faster compared to conventional droop control. Hence, it can be concluded that advanced dynamic droop control helps to ensure power system stability by improving the system performance.

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