Simulation of two DG and their control by Droop strategy

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ABSTRACT

The presence of scattered sources and micro-grids in power systems, despite the economic and environmental advantages, have added new problems to power systems.Among these problems, voltage and frequency fluctuations can be mentioned when possible events occur, such as extreme load changes or errors in the power system. In the island mode, due to the lack of backup power, the intensity and range of these fluctuations and the possibility of instability in the microgrid are much higher. In this paper, we study how to control the voltage, frequency and power supply required by load in a microgrid. Microgrid is a small low voltage power supply grid. It has two work modes:grid-connected mode and islanded mode.The most important challenge in using the microcontroller grid is to provide better control of distributed generations (DG) by connecting it to the microgridwith an inverter interface. Therefore, the main purpose is to control the inverters. In this paper, a drop-down control technique is proposed to control voltage and frequency of the microgrid and the power allocation between microgrids. The advantage of this method is using a single controller in both work modes. Also, there is no need for communication grids between micro components.

Keywords: *microgrid; distributed generation; droop-down control*

1. *INTRODUCTION*

Today, there are very few power plants in many places that can produce electricity in large quantities. Also, distribution networks cannot be done in rural areas due to their high cost. In these situations, small smart microgrids of electricity distribution are a good alternative to provide electricity distribution and proper business in remote rural areas. This network uses various sensors, wireless communications, advanced software, and appropriate facilities to enable electric companies to know how much energy is being consumed and where. And smart actions are taken.[1] In general, distributed energy sources are called DG, which in most cases are replaced by distributed generation in the distribution system. Introducing distributed generation in networks has advantages and disadvantages: the advantages of distributed resources: improvement of power quality, improvement of reliability, reduction of losses, assistance to main generators in peak load, reduction of the need for generators, simultaneous production of electrical energy and Heat with an energy source, creating competition between energy producers.[1] There are different types of distributed production, each of which has advantages and disadvantages. The most important sources of distributed production are: wind power plant, solar power plant, small turbines, energy storage devices, fuel cells. One of the unique features of electric microgrids is their ability to function automatically when the main power grid is interrupted. A microgrid can operate both in connected mode and in island mode. In the state of connection to the main grid, scattered production sources are connected to the main grid. In this situation, due to the high inertia of the national grid, the main role of controlling the voltage and frequency of the grid is the responsibility of the main electricity generation grid.[1-2] In case of an error on the side of the national network, it can cut off its connection with the main network and by going to the island work mode, it can provide higher reliability for subscribers or loads and provide the necessary power for all or part of its loads with appropriate quality. slow down and isolate consumers from the upcoming crisis. The concept of drop control is derived from the theory of power systems, which divides the load between different generators of the power network based on the frequency drop component in terms of active power (w،p) and voltage in terms of reactive power (E،Q). This concept is used for the parallel operation of inverters, as it is clear in Figure 5and figure6,the active power *can be controlled by changing the phase angle, which can result in the angle frequency w, and also the size of the voltage E is effective on the reactive power Q.[1-2]*

With the growth in electronics, the ability to generate electric power has grown significantly. This growth has led to the formation of small grids of power or microgrids. Microgrids are referred to as a set of distributed generations and load sources, which can operate in island-connected and grid-connected modes. Advantages of such grids include high reliability, low losses and costs, and environmental benefits. It is clear that accurate and reliable functioning of a microgrid is achieved by proper control of its power generators. The main purpose of control in a microgrid is to obtain accurate power distribution between its sources and to regulate the voltage and frequency within the allowed range [1]. The most important challenge in using a microgrid is to control it. The main purpose of controlling, is to maintain voltage and frequency of the microgrid within allowed range and providing required load power in the grid.Other goals such as power quality, reliability or proper power allocation may also be considered. To achieve a better control, distributed generations connect to the microgrid with inverter interface. So the main purpose is to control the inverters. Many methods have been used to control the DG using an inverter, such as the master/slave method, PQ drop-down control method and standard deviation of power value method. In this paper, a control scheme based on the drop-down control technique is proposed that meets the control objectives in both modes of the microgrid.

2. Microgrid System

The primary function of droop control is to facilitate power sharing among distributed generation (DG) units during load variations. Furthermore, the selection of droop parameters significantly impacts small-signal stability; thus, for optimal microgrid operation, these parameters should be integrated into the economic dispatch strategies managed by the tertiary control layer. This study focuses on implementing a comprehensive control framework to manage power flow and distribute active power among subsystems. To achieve this, the droop control method—a conventional technique for autonomous microgrids—is employed.The proposed control strategy consists of three key components: active and reactive power control, voltage and frequency regulation, and inverter gate signal generation. Notably, the proposed controller operates effectively in both grid-connected and islanded modes, eliminating the requirement for master units, centralized controllers, or communication links between generation units. Additionally, the control structure remains robust, requiring no reconfiguration during islanding transitions. To mitigate network resonance and attenuate high-frequency harmonics stemming from high-speed power electronic switching, an output filter is incorporated at the inverter stage. The microgrid is coupled to the main utility grid via a circuit breaker at the Point of Common Coupling (PCC). In the event of grid disturbances where stability cannot be maintained, the PCC breaker is opened, allowing the microgrid to transition seamlessly into islanded operation. To ensure a sinusoidal output, the inverter's voltage amplitude, frequency, and phase must be precisely regulated. Assuming a constant DC-link voltage, the output voltage is modulated using Pulse Width Modulation (PWM). In this implementation, a carrier-based PWM strategy is adopted, avoiding triangular wave carriers to prevent excessive switching noise—a phenomenon caused by simultaneous switching of all three inverter legs.Fig. 1 illustrates the microgrid architecture, comprising two inverter-based DG units and sensitive loads. Under grid-connected conditions, the main distribution system maintains voltage and frequency at nominal values; thus, the inverter control objective is to regulate active and reactive power injection. Upon detecting a fault in the distribution grid, the PCC breaker is tripped, and the microgrid switches to islanded mode, thereby enhancing system reliability [2, 3, 4].In grid-connected mode, the inverter controller must ensure that the microgrid's voltage and frequency are maintained within acceptable tolerances around their nominal values, while simultaneously supplying the requisite power to the connected loads. Transitioning to islanded operation introduces a critical challenge: the equitable allocation of power demand among the available generation units. Consequently, the primary control objective in this mode shifts to preserving the voltage and frequency stability of the distributed generators while ensuring appropriate power-sharing among them. Droop control stands out as a highly effective methodology for coordinating power generation across multiple distributed generators operating in parallel. A significant advantage of this approach is its inherent ability to facilitate parallel inverter configurations without necessitating a dedicated communication infrastructure between the DG units.

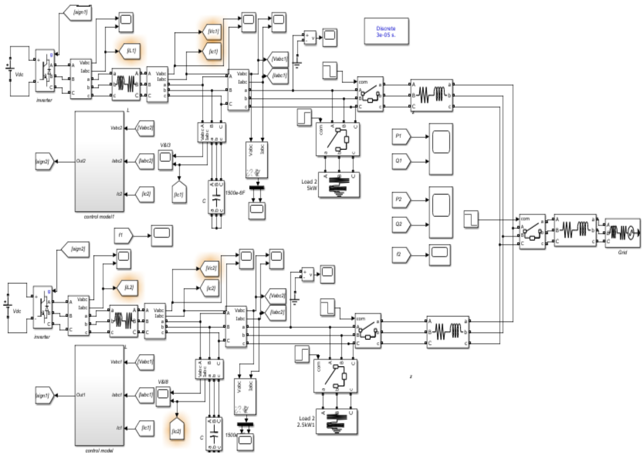

Fig. 1. *Structure of a microgridwith inverter interface*

3. Designing the power part of the inverter

The power part of the inverter comprises the voltage source inverter (VSI), a filter, and a local load. A brief explanation of each of these components will be provided.

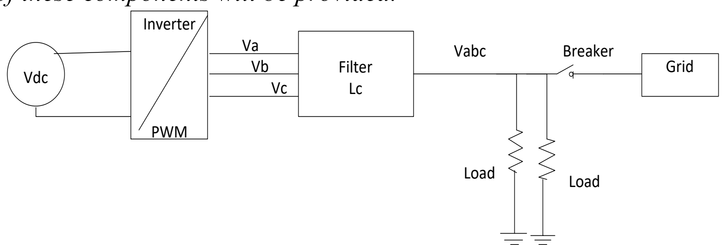

Fig.2.*General Overview of a Microgrid*

Figure 2 illustrates the components of a Distributed Generator (DG) and its network interconnection. The DG is modeled as a DC voltage source coupled with an inverter, which interfaces with the network via an LC filter. Electronic power converters, such as inverters, are commonly employed as grid interfaces for distributed generation sources like photovoltaics, fuel cells, and wind turbines. To mitigate resonance effects on the network and reduce high-frequency harmonics generated by the power electronics' switching, an output filter has been designed for the inverter. This LC filter is crucial for maintaining power quality, particularly when connected to weak networks. The microgrid under consideration connects to the main power grid through a circuit breaker at the Point of Common Coupling (PCC). In the event of a system disturbance that compromises stability during grid-connected operation, the circuit breaker opens, allowing the microgrid to operate independently from the main power system [5].

4. inverter

The primary function of a power inverter is to convert a DC input voltage into a symmetrical AC output voltage with regulated magnitude and frequency. In this study, a triangular signal is utilized as the carrier wave for the Pulse Width Modulation (PWM) technique. The selection of the carrier signal is critical; using a standard triangular wave for a three-phase inverter may necessitate simultaneous switching of all three inverter legs in specific operation modes, potentially introducing significant electromagnetic interference (EMI) and noise into the control circuitry. Although inverters are generally categorized into Voltage Source Inverters (VSI) and Current Source Inverters (CSI), the term 'inverter' conventionally refers to the VSI configuration due to its prevalence in medium- to high-power applications. The main objective of this topology is to generate a three-phase voltage with controllable amplitude and frequency. The standard configuration of a three-phase VSI is illustrated in Fig. 3, where six power switches (S_1 to S_6) are modulated to synthesize the desired output voltage [5-6]. The resulting three-phase output voltages are denoted as V_a , V_b , and V_c . The choice of power semiconductor switches depends on the power rating: for low-power applications, devices such as

MOSFETs or ETOs are typically employed, whereas high-power implementations predominantly utilize SCRs, GTOs, or GTCs.

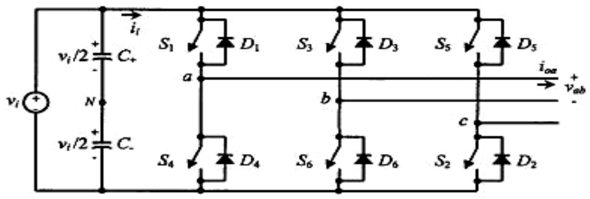

Fig.3.*Internal View of Inverter*

5.Droop control technique

Figure 2 illustrates a microgrid comprising two inverters and sensitive loads, connected to the main distribution grid via an isolating switch. During normal grid-connected operation, the microgrid functions as a subservient part of the distribution network, wherein the utility grid dictates the voltage and frequency. Consequently, the inverter control objective in this mode is primarily to regulate the injection of a constant amount of reactive power and active power. However, in the event of a fault within the distribution network, the common connection point switch is opened, enabling the microgrid to operate autonomously in islanded mode, thereby enhancing system reliability. In this islanded configuration, the inverter controller must actively maintain the system frequency and voltage within acceptable nominal ranges while ensuring the supply of required power to the microgrid loads [5-6]. Acritical aspect of independent operation is the equitable distribution of the microgrid's load power demand among the distributed generation (DG) units. Essentially, the control strategy in this mode aims to achieve load power sharing among DGs while simultaneously regulating system voltage and frequency. Droop control has been identified through extensive research as a highly effective method for coordinating power generation among multiple DGs. Its key advantages include rapid adjustment of power outputs to ensure system stability and the elimination of the need for inter-unit communication systems, facilitating decentralized operation. The droop control technique applied to parallel inverters is analogous to the droop control method employed for a single DG unit interfacing through an inverter, as well as for synchronous generators in conventional power systems. Leveraging this technique, for a transmission line with negligible resistance, the active and reactive power equations can be derived from the primary side, as presented in Equations 1 and 2.

6 Frequency and Voltage Droop-Down Control

System voltage and frequency regulation are achieved through the implementation of active power-frequency droop control and reactive power-voltage droop control mechanisms. It is assumed that the network inductance is self-sufficient, and the inputs to this control subsystem comprise the nominal and measured voltage and frequency at the point of common coupling. The default power outputs are sourced from the Distributed Generators (DGs). In the grid-connected mode, the system sources derive their reference voltage and frequency values from the main grid. Conversely, in islanded mode, these sources utilize their internally set desired values and obtain feedback from their respective output terminals. Should the voltage and frequency deviate beyond their permissible ranges, a suitable load shedding strategy must be employed, typically involving the disconnection of non-sensitive loads to ensure the power supply to critical loads. A control loop is imperative for maintaining frequency stabilityThis is typically addressed via a hierarchical control structure consisting of a primary frequency control loop and a secondary frequency control loop. Upon the occurrence of a system disturbance, such as a load increase, the actual output power is affected, leading to a deviation of the system frequency from its nominal value. This transient frequency drop is inherently limited by the primary control loop, which provides immediate response. A secondary control loop is subsequently engaged to restore the system frequency to its nominal setpoint and compensate for any steady-state error. This secondary loop commonly employs a conventional Proportional-Integral (PI) controller to eliminate steady-state deviations. While in grid-connected operation, all available sources and inverters synchronize to the electrical signals of the main grid frequency, this synchronization reference is lost in islanded mode. The droop control technique, as applied to parallel inverters, mirrors the droop control methodology utilized for synchronous generators *within a power system. Based on this principle, for a low-resistance transmission line, the equations governing the active and reactive powers injected by the primary side are presented as follows [3].*

$$p = \frac{V_1 V_2}{x} \sin\delta \qquad (1)$$

$$Q = \frac{V_1^2}{x} - \frac{V_1 V_2}{x} \cos\delta \qquad (2)$$

Where P represents the active power, Q denotes the injected reactive power into the line, δ is the power angle, V1 and V2 are the voltage magnitudes at the two ends of the line, and X is the reactance of the transmission line. Equations (1) and (2) can be reformulated in terms of the power angle as follows:"

$$\delta = \frac{x_p}{V_1 V_2} \qquad (3)$$

$$V_1 V_2 = \frac{x_q}{V_1} \qquad (4)$$

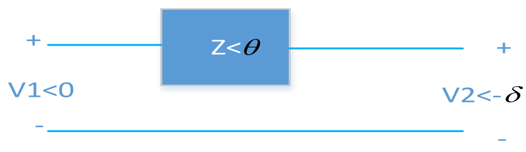

Figure.4. *Power transmission in a transmission line*

Equations (3) and (4) reveal a direct dependency of the power angle on active power, and similarly, a dependency of the voltage difference on reactive power. In essence, the power angle can be regulated by controlling the active power, while voltage control is achieved analogously through reactive power management. Given that the generation units do not treat the initial phase values of other units as independent entities within the system, each generation unit employs frequency as a substitute for power angle when implementing the droop control method for transmitted active power. Consequently, dynamic frequency control effectively governs the power angle [4]. These findings lead to the following control equations for frequency and voltage:"

$$f = f_o - k_{pf}\left(p - p_o\right) \qquad (5)$$

$$v_1 = v_o - k_{qv}\left(Q - Q_o\right) \qquad (6)$$

Where k_{qv} and k_{pf} represent the positive droop control coefficients. V_o and f_o denote the nominal voltage and frequency, respectively, while P_o and Q_o serve as the setpoints for the generator's active and reactive power. Equation (5) can be reformulated in terms of the power angle. The results derived from the droop method represent the reference voltage, frequency, or power angle expected to be generated by the inverter. The characteristic curves of the droop control strategy are illustrated in Figures 3 and 4 [5][6]. Equations (5) and (7) demonstrate that if the active power injected into the transmission line by the generator deviates from its designated setpoint P_o, the droop control mechanism adjusts the generator's frequency or power angle to mitigate this deviation. Similarly, as indicated by Equation (6), if the injected reactive power deviates from its setpoint Q_o, the droop control compensates for this deviation by adjusting the generator voltage accordingly."

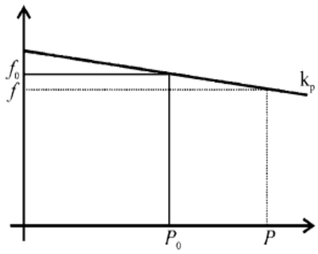

Figure.5. *Frequency-active power drop-down characteristics*

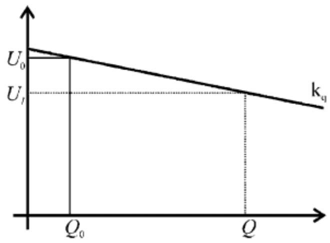

Figure.6. *Voltage-reactive power drop-down characteristics*

7. Controlling Microgrids with Inverter Interface

Figure 5 illustrates the proposed control scheme for an inverter. As previously established, the primary objective of the inverter controller is to maintain the micro-grid's voltage and frequency, particularly for sensitive loads, within permissible limits. A secondary objective involves allocating load power variations among the micro-grid's Distributed Generators (DGs) [6]. These objectives are addressed irrespective of the micro-grid's operational mode, encompassing both grid-connected and islanded configurations. The control methodology presented in this paper comprises three distinct components: voltage and frequency control, output active and reactive power control, and the inverter gate signal generator. Critically, the controller operates effectively in both micro-grid modes. Consequently, this approach obviates the necessity for a master unit, a central micro-grid controller, or inter-unit communication systems, unlike conventional methods. Furthermore, it eliminates the need for controller switching or reconfiguration during transitions to islanded operation [7].

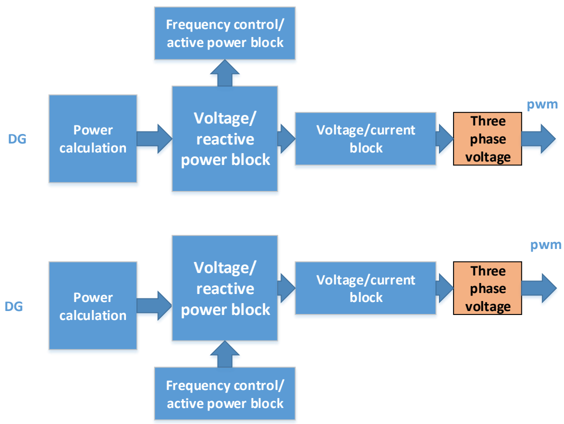

Figure.7. *Diagram of proposed inverter control scheme*

8. Controlling Voltage and Frequency

The primary function of the voltage controller is to regulate the inverter's output voltage in response to variations in its reference setpoints. To achieve a robust stability state, an integral-proportional (PI) controller is designed. Figure 8 illustrates the considered voltage control structure. Within this architecture, the voltage is initially decomposed into its d-q components. Subsequently, these components are compared against their respective reference values, and the resultant error signals are minimized by the aforementioned PI controller [6-7].Following the voltage control loop, an internal current control loop is implemented. For both the current and voltage control loops, the utilization of a PI controller is deemed adequate. This is because a purely proportional controller would introduce a significant phase shift; consequently, employing a large gain factor within the control loop becomes imperative to compensate for this time shift and attain steady-state operation. Therefore, the inner current control loop plays a critical role in mitigating resonant oscillations induced by the output filter. Finally, the d-q voltage components are transformed back into the ABC frame. A Pulse Width Modulation (PWM) generator block then synthesizes the requisite signals for inverter commutation.

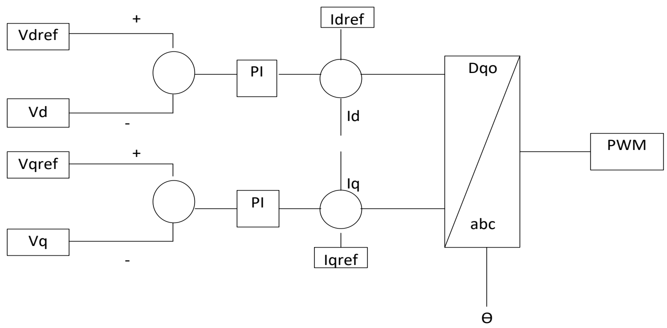

Figure.8. *Voltage control loop*

To regulate the system's load voltage and frequency, droop control strategies for frequency/active power and voltage/reactive power are employed. Consequently, it is assumed that the inductance of the transmission lines significantly exceeds their resistance. The inputs to these control units comprise locally measured nominal voltage and frequency, along with the default output powers of the Distributed Generators (DGs). Equations (7) and (8) mathematically define how these frequency and voltage droop characteristics are utilized to generate the reference active and reactive output powers for each DG unit:

$$Q_{ref} = Q_o + k_{qv}\left(v_o - v\right) \qquad (7)$$

$$P_{ref} = p_o + k_{fp}\left(f_o - f\right) \qquad (8)$$

Here, F_o and V_o denote the default frequency and voltage values, respectively. P_o and Q_o represent the default values of the output active and reactive powers for each DG unit, which are selected based on the microgrid's operational state. f and v correspond to the actual measured frequency and effective voltage at the output bus. All control-required output quantities are acquired through direct measurement of three-phase current and voltage at the inverter's output bus, as depicted in Figure 1. k_{fp} and k_{vq} are the droop coefficients defining the slopes of the respective droop characteristics. $Pref$ and $Qref$ signify the corrected reference values for active and reactive powers. In the grid-connected mode, the distribution grid inherently maintains the load bus voltage and system frequency at their nominal values. Consequently, the generators operate by producing their default power outputs. In essence, the inverter's voltage and frequency control unit remains inactive under these conditions. According to Equations (7) and (8)

$$v = v_o \Rightarrow Q_{ref} = Q_o \quad (9)$$

$$f = f_o \Rightarrow p_{ref} = p_o \quad (10)$$

Should the distribution grid, for any reason, fail to maintain the load bus voltage and system frequency, the voltage and frequency control unit then assumes responsibility for determining the reference values of active and reactive powers. Such a scenario may arise from the microgrid's disconnection from the main distribution grid or due to fluctuations in the microgrid's load demand. The droop coefficients quantitatively represent the extent to which each unit compensates for voltage and frequency variations. A higher droop coefficient signifies that a DG injects a greater amount of reactive power, consequently playing a more significant role in voltage stabilization. For instance, consider a microgrid comprising two DGs where the voltage deviation at the load bus is Δ V. In this situation, the droop coefficients are selected as follows:

$$\Delta v \times kvq_1 + \Delta v \times kvq_2 = \Delta Q_{tot} \quad (11)$$

ΔQ represents the total reactive power output variation of the DGs. Frequency and active power follow a similar control paradigm. The frequency and voltage control unit exclusively utilizes locally measured quantities—specifically, the effective load bus voltage and frequency—to compute the inverter's requisite output power. Consequently, there is no necessity for inter-unit communication or interaction with the microgrid's central control system [8-9].

9. Controlling Active and Reactive Powers

This section effectively represents the active power control component of the reactive power regulation, tasked with generating the desired output power. This control module also relies solely on locally measured power quantities. A simplified model of a micro-generator illustrates this principle. Considering the proposed microgrid configuration, when operating in an islanded (standalone) mode, the active power must be regulated to control the frequency, while the reactive power is adjusted to manage the voltage. This control is primarily achieved through active power manipulation.Such a control structure is conventionally referred to as P/f-Q/V control. As depicted in the figure below, to calculate the active and reactive powers, the DG's output voltage and current are initially transformed into the dqo reference frame, yielding $v\ d\ q$ *and* $i\ d\ q$ *respectively. Subsequently, these transformed values are fed into the power calculation block of the main component, where the powers are computed based on the instantaneous reactive power theory. The instantaneous values of reactive and active powers are determined using the following relations:*

$$P = Vd*Id + Vq*Iq \quad (12)$$

$$Q = Vq*Iq - Vd*Id \quad (13)$$

This is, in fact, the PQ (Active/Reactive Power) control unit, responsible for generating the required output power. This control unit also utilizes solely local measured power values. Figure 9 illustrates a simplified model of a micro-generator.

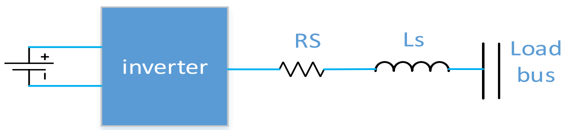

Figure.9. *Simplified model of a micro generator*

The subsequent equations exhibit a similar form to Equations (6) and (7).

$$E_{ref} = E_0 + k_{QE}(Q_{ref} - Q_{out}) \quad (14)$$

$$\delta_{ref} = \delta_0 + k_{p\delta}(p_{ref} - p_{out}) \quad (15)$$

$Q\ ref$ and $Pref$ represent the reference power values, computed within the voltage and frequency control section. $Qout$ and $Pout$ denote the measured output power values of the inverter. $kp\delta$ and kqE are the control coefficients for active power/power angle and reactive power/voltage magnitude, respectively. $E0$ and $\delta 0$ are the default values for voltage magnitude and angle. These parameters are selected such that, in grid-connected mode, the inverter's output active and reactive powers closely approximate the default setpoints P P and Q. By determining $\delta\delta$ and E, the output active and reactive powers can be effectively controlled [8].

DG1		DG2	
Parameter	*Value*	*Parameter*	*Value*
Vdc(v)	800	*Pref(Kw)*	6
Pref(Kw)	8	*Qref(Kar)*	2
Qref(Kvar)	2	*Vn(v)*	311
F0(Hz)	50	*F0(Hz)*	50

TABLE I:*Parameters for simulation*

10.Frequency and voltage drop control

The droop control technique applied to parallel inverters bears resemblance to the droop control method employed for distributed generation sources, individual inverters, and synchronous generators within a power system. As discussed in this article, the power angle exhibits a direct dependency on active power, while voltage deviation is contingent upon reactive power. In essence, controlling active power allows for the regulation of the power angle, and similarly, adjusting reactive power enables voltage control. Given that the generation unit does not account for the initial phase values of other units in an islanded system, the droop method utilizes frequency, rather than the power angle, for controlling the transmitted active power.In essence, controlling active power allows for the regulation of the power angle, and similarly, adjusting reactive power enables voltage control. Given that the generation unit does not account for the initial phase values of other units in an islanded system, the droop method utilizes frequency, rather than the power angle, for controlling the transmitted active power. Frequency dynamically regulates the power angle, consequently leading to the derivation of frequency and voltage droop control equations. To manage the system's load voltage and frequency, the droop control strategy is implemented for frequency/active power and voltage/reactive power. In the simulation of this segment of the thesis, where the inductance of the transmission lines significantly exceeds their resistance, the frequency and voltage droop characteristics, as follows, are leveraged to generate the reference active and reactive power outputs for each unit [9].

11. Simulation

This article investigates the control of Distributed Generators (DGs) via inverters in a microgrid, considering both grid-connected and islanded modes. The droop control technique has been employed in the inverter controller design for managing voltage, frequency, and load power sharing. Figure 1 illustrates the proposed design, comprising two inverters and sensitive loads. The microgrid is interconnected with the distribution network via an isolation switch. During normal grid operation, the microgrid functions as a segment of the distribution network, where the main grid actively maintains system voltage and frequency. Consequently, the inverter's control objective in this mode is to generate a constant amount of reactive and active power. Upon a distribution network fault, the switch at the Point of Common Coupling (PCC) is opened, enabling the microgrid to operate in island mode, thereby enhancing reliability [10]. In this islanded mode, the inverter controller must ensure that system frequency and voltage are maintained within an acceptable range around their nominal values, while also supplying the required power. Another critical aspect of *independent control is the equitable distribution of the microgrid's load power demand among the generation units.Essentially, the control's purpose in this operational mode is to manage load power variations among the DGs while preserving voltage and frequency stability. Based on conducted research, droop control is recognized as one of the most effective methods for coordinating power generation among multiple distributed generators due to its capability for rapid adjustment of power outputs, contributing to system stability without the necessity of a communication system between units, unlike centralized control schemes [9-10]. Conventional droop control methods suffer from drawbacks such as low system damping against disturbances, reduced power-sharing accuracy in networks with significant resistive impedance, inability to effectively manage load power division, and deviations of the microgrid's frequency and voltage from nominal values The advantages of the proposed control method over existing ones lie in its attractiveness for controlling parallel inverters, particularly in scenarios with significant distances between inverters, which impede the utilization of communication lines [11]. The paramount challenge in Microgrids resides in their control, primarily aimed at maintaining voltage and frequency. Other objectives include power quality, reliability, and appropriate power allocation. The proposed droop control method effectively addresses issues such as deviations of microgrid voltage and frequency from nominal values and limitations in load power sharing. For enhanced control of distributed sources, they are connected to the grid through inverters. This section details a simulation method for a microgrid featuring two DGs, each interfaced via an inverter.The microgrid comprises two DGs, loads, and possesses the capability to connect to the main grid or operate in island mode, with the interconnection point being the PCC [11-12]. Prior to the microgrid transitioning from island mode to grid-connected mode, one of the DGs (designated as DG1 in this context) assumes the responsibility of synchronizing the magnitude and phase angle of the main grid voltage with that of the microgrid. In this network configuration, loads are connected via switches, allowing for online connection and disconnection. To assess the performance of the proposed controller, a sample microgrid is simulated using MATLAB-Simulink. Certain parameters have been adjusted for a more comprehensive evaluation. The two DGs are assumed to be identical, a simplification adopted solely for computational ease. The microgrid is analyzed under both grid-connected and islanded operating conditions. The base values for reactive power and grid voltage are 2 kVAR and 311 V, respectively, with a grid frequency of 50 Hz. The default active and reactive power setpoints for each unit are 6 kW and 2 kVAR, respectively.*

The simulation is conducted over four distinct periods:

1. 0-0.8 seconds: Setup. The grid operates in grid-connected mode. During this interval, the distributed generator is interfaced with the main grid, contributing to the provision of reactive and active power. The main grid bears the responsibility for maintaining voltage and frequency. Consequently, the load power supply is managed by the main grid within this period.

2. 0.8-0.9 seconds: Grid transitions to islanded mode. The microgrid disconnects from the main grid upon the opening of the PCC switch. In this configuration, the microgrid undertakes the responsibility of supplying the load power. The microgrid is tasked with maintaining the system's voltage and frequency within the permissible range..

3. 0.9-1.8 seconds: The microgrid reconnects to the main grid by closing the PCC switch. The microgrid assumes the roles of maintaining system voltage and frequency, as well as supplying the load power.

4. 2 seconds: End of simulation.

Figure 10a: Voltage and current of the proposed design. Figure 10b: Frequency of DG 1. Figures 10c, 10d, 10e, and 10f: Illustrate the generated active and reactive powers by the two DGs, respectively.

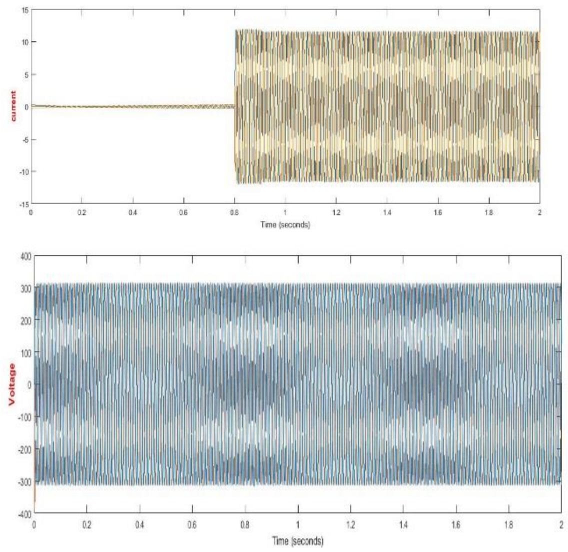

Figure.10a. *Voltage and current of DG 1*

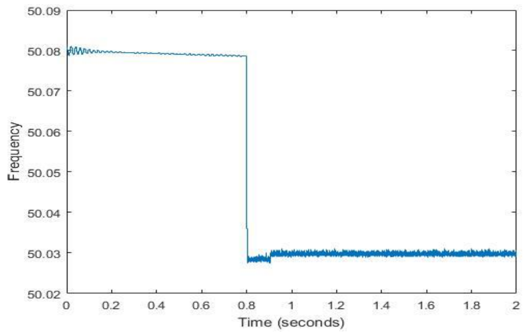

Figure.10b. Frequency of DG 1

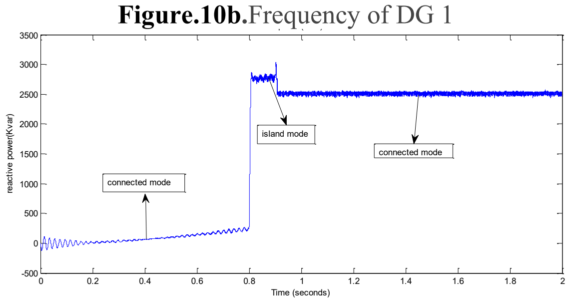

Figure.10c. *reactive power generated by DG1*

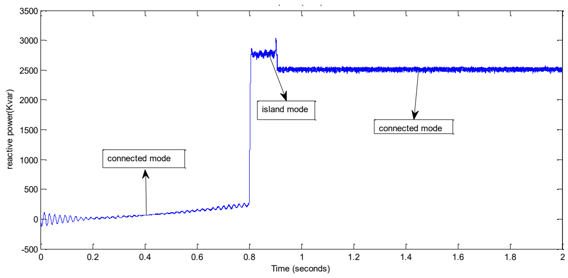

Figure.10d. *reactive power generated by DG2*

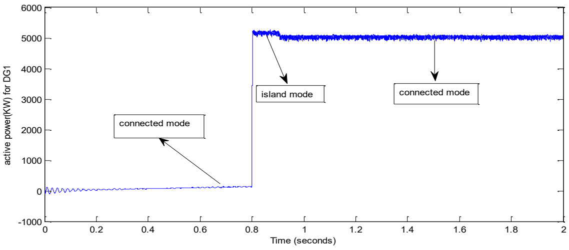

Figure.10f.*Active power generated by DG1*

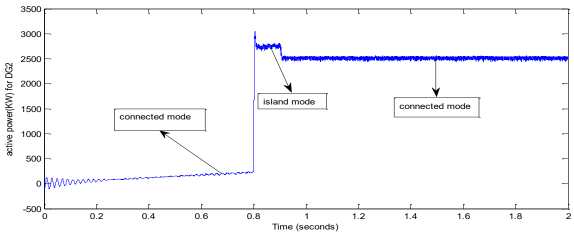

Figure.10e. *Active power generated by DG2*

12. Conclusion

In this paper, two distributed generators (DGs) with parallel-interfaced inverters have been designed for both grid-connected and islanded modes of operation. Furthermore, a droop control strategy is employed to regulate the DGs. The droop control method is primarily utilized for parallel-connected inverters and serves as one of the most effective techniques for coordinating power generation among DGs, as it enables rapid adjustment of power output to enhance system stability. The proposed controller relies exclusively on locally measured quantities, thereby eliminating the need for inter-unit communication or a centralized microgrid control system. The primary advantage of this approach lies in the utilization of a unified control scheme for both microgrid operating modes, which, unlike conventional master/slave control strategies, obviates the necessity for switching between multiple controllers during the transition to islanded mode.

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