# POWER COMPENSATION AND VOLTAGE FREQUENCY FLICKER CONTROL OF SOLAR USING V-F DROOP CONTROL TECHNIQUE

by

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# CERTIFICATE OF APPROVAL

The thesis entitled as “Power compensation and voltage frequency flicker control of solar using v-f droop control Technique” submitted by **Mohammad Mainul Hassan**, bearing Matric **ID. ET 171076** and **Md. Shafiul Alam** bearing Matric **ID. ET 171084** of session Autumn 2021, to the Department of Electrical and Electronic Engineering (EEE), International Islamic University Chittagong (IIUC), has been accepted as satisfactory in partial fulfilment of the requirements for the degree of Bachelor of Science in Engineering and approved for the examination held on 16th April, 2022.

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# DECLARATION

It is hereby declared that this work has been done by us and no portion of the work contained in this thesis/project has been submitted elsewhere for the award of any degree or diploma.

Mohammad Mainul Hassan

Md. Shafiul Alam

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In the name of Allah, the Most Gracious and the Most Merciful.

First of all, we are grateful to almighty Allah for giving us strength and wisdom throughout all our life. We thank our family for their love, their moral and financial support they had given us. This helped us a lot. We would like to give our gratitude for our supervisor Engr. Sk. Md. Golam Mostafa, Associate Professor, Dept. of EEE, IIUC who has given us significant suggestions and inspections during the whole process of the work. His invaluable help of constructive comments and suggestions throughout the thesis work have contributed to the success of this thesis.

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Authors

# ABSTRACT

Nanogrid is now an advanced concept which is under the frame of microgrid aiming at providing a smart power supply structure for future personal house or single building. It arises for the need to enable “plug-and-play” integration of generated renewable energy. It is a version of smart grid which have the ability to function as separate power generator. A key challenge associated with the nanogrid control is how to maintain voltage and frequency stability in nanogrid islanded and grid connected operation. For Power Quality (PQ) disturbances to be compensated, an alternative techniques of power technology is required. This study has been proposed a new V–F droop control technique to achieve Power Quality disturbances compensation of 10KW nanogrid system. By reducing Power Quality fluctuations, the functionality of droop controller must be optimized. This research reveals a Solar PV Integrated nanogrid framework and explores an improvement in the system's stable operating limit in the event of implementation of V-F Droop controller. The crucial effects of Distributed Generation (DG) grid interaction and the function of controller in mitigating unexpected results and improving the reliability of the nanogrid. In addition, the result demonstrate the reliability of transient voltage 4.2%, and reduce grid harmonic by 6.58%.

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| | |
|---|---|
| NG | Nano grid |
| PEVs | Plug-in Electric Vehicle |
| DSO | Distribution System Operator |
| PQ | Power Quality |
| PV | Photovoltaic |
| THD | Total Harmonic Distortion |
| THDi | Total Harmonic Distortion of current |
| THDv | Total Harmonic Distortion of voltage |
| RMS | Root mean Square |
| PLL | Phase Lock Loop |
| DG | Distributed Generation |
| DSS | Distribution System Simulator |
| RES | Renewable Energy Sources |
| PWM | Pulse Width Modulation |
| PCU | Power Control Unit |

# CHAPTER 1
# INTRODUCTION

## 1.1 Introduction

A Nano-grid is a power distribution system for a single house/ small building, with the ability to connect or disconnect from other power entities via a gateway. It consists of local power production powering local loads, with the option of utilizing energy storage and/or a control system. The concept of Nanogrid has become a new hotspot when it comes to future smart power supply on single buildings and personal homes [1-4]. A nanogrid often contained in microgrid. Nanogrid is capable of both grid-connected and islanding operation. A nanogrid typically supplies 2 to 20 kW of power for load, depending on the power rating [5]. For nanogrid, DC buses are more efficient and dependable than AC buses [6-9]. Although the initial concept of nanogrid was first described in 2004, there are few corresponding publications about it. The microgrid control mechanism cannot offer the plug-and-play flexibility required for nanogrid. J. Bryan and John Schonberger described two types of islanding DBS control approaches [10,11]. It cannot, however, interchange power with the upper level grid without a grid-connected module, [12] describes a control mechanism for a DC-Bus microgrid, but the lack of modularity prevents plug-and-play implementation. The master-slave control approach described in is incompatible with the decentralized control structure [13,14]. The droop control approach is described in however it cannot accommodate a team working on many modules [15,16].

## 1.2 Background Of the Research

Existing electricity infrastructures are being faced with a variety of challenges that they are implicitly unprepared to address. These issues are increased by the usage of long-distance transmission lines to transport electricity from large central generators to consumers[17,18]. This technique of power distribution results in significant line losses, also lowering grid efficiency [19]. It also exposes the grid to costly power outages caused by natural (e.g., severe rain or wind) and man-made (e.g., equipment failure due to age) occurrences [20,21]. These massive central power plants are mainly fossil fuel-based, which leading to the annual release of 30.8 billion tons of carbon dioxide into the environment [22]. Another significant concern is the estimated 1.2 billion people who do not have access to energy around the world [23]. The vast majority of these people reside in rural or remote areas, where extending the grid is usually regarded uneconomical [24,25].

These weaknesses must be solved for social, environmental, and financial reasons, and one solution under research is distributed generation (DG) [26,27]. By producing power close to the point of use, DG hopes to address the difficulties that affect the current power system [28]. This decreases the need for long-distance transmission, resulting in increased efficiency and a more reliable system (reducing outages) [29]. Distributed generation, especially renewable energy, suffers from two fundamental problems that limit widespread adoption in residential and commercial buildings [30]. These weaknesses can be solved by the use of a control system to balance supply and demand [31]. The microgrid is one such control system that is now popular in this sector of research [32]. Microgrids integrate different types of DG and optimize their utilization to serve the power needs of local villages, hospitals, and university campuses, among other places [33]. This then develops into a programmable, flexible power subsystem that may connect to or disconnect from the main power grid [34]. After that a microgrid concept can be scaled down and further it define a new name, “Nanogrid”. Despite the fact that nanogrids are a relatively new research topic within the area of power systems, they are attracting international interest from both small and major research groups [35]. Nanogrid research is currently divided into four categories: works summarizing the nanogrid concept, including future advancements [36-44] nanogrid control [45-61], nanogrid hardware [60,62-92], and nanogrid networks [ 93, 39-41,55,94-97].

The majority of nanogrid research focuses on control and hardware, with a wide range of algorithms and power converter topologies being considered. The concept of using the modular nature of nanogrids to create a network of interconnected nanogrids has also been proposed in the literature, but most of it is still conceptual. The difficulty with current literature is that it leaves the concept of a nanogrid vague, implying numerous qualities and/or bounds to distinguish the nanogrid as its own power structure.

### 1.3 Nanogrid Model

A nanogrid is a single domain for voltage, quality, reliability, price, and administration. . It must have at least one load or sink of power—which could be electricity storage—and at least one gateway to the outside. Electricity sources aren’t part of the nanogrid, but a source often will be connected only to a single nanogrid.

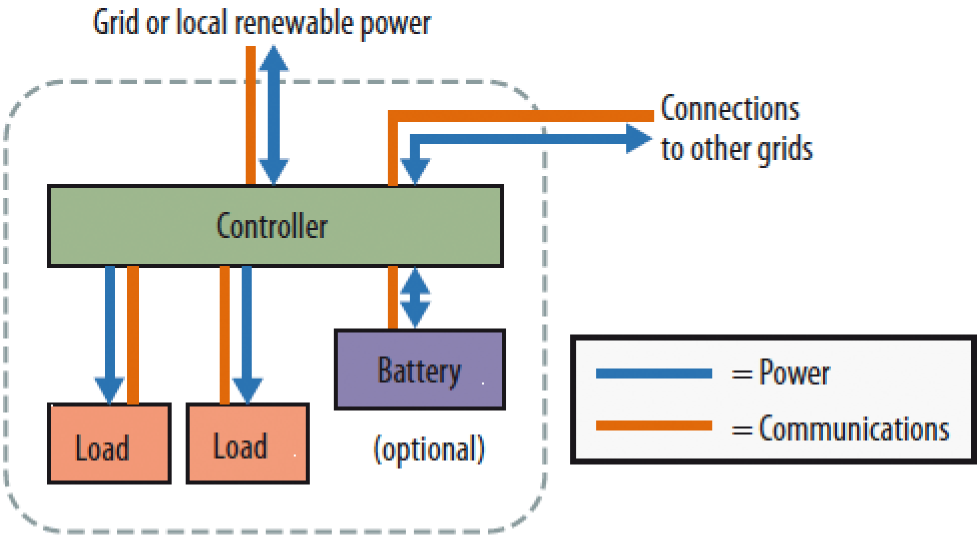


**Fig 1.1** : Ideal Nanogrid Model[123].

In **Fig. 1.1** illustrates a simple nanogrid structure. All power flows are accompanied by communications— either wired or wireless. Interfaces to other power entities are through gateways within the nanogrid controller. Each nanogrid manages the power distributed to its loads.

The controller uses price to mediate local electricity supply and demand, both within the nanogrid and in exchanges across gateways. The nanogrid controller receives requests for power, grants or revokes such requests, measures or estimates power, and sets the local price. Nanogrids implement power distribution only—they perform no functional control of the devices that connect to them.

Nanogrids are already quite common—a notebook computer includes all of these elements: it can provide power to attached USB devices, has an internal battery, and can operate either connected to grid power or off-grid. Nanogrid loads take the local electricity price into account in deciding how to operate, along with functional considerations. High prices will tend to reduce or delay energy services; low prices increase or advance them over time. Controllers negotiate with each other across gateways to buy or sell power. Battery storage is optional, but it can increase reliability and stability.

## 1.4 Aims and Objective of The Research

The most important requirement for these systems is to have enough control specifications capable of achieving exact transient/steadystate functioning, allowing effective active and reactive power sharing across the DGs, bus, and load. This must be accomplished without fluctuations while maintaining precise voltage and frequency management of the load. A good damping of system oscillatory modes, precise regulation of frequency and voltage magnitude by the voltage source inverter (VSI), coordination between distributed energy resources (DERs), and voltages total harmonic distortion reduction are all requirements for NGs operating in autonomous mode [98,99].

To met this requirement we design a V-F Droop controller which can fulfill our requirements. The higher level we use as a droop controller, which should be able to generate suitable voltage references for low-level control while meeting the following requirements [98,100]: provide plug-and-play capacities for DERs and proportionally share active and reactive power among them; reduce circulating currents to prevent over-current in switching devices and dc-link capacitor damage; improve active power oscillation through proper design of active power oscillators. Droop control not only provides redundancy and dependability in addition to simplicity and expandability [98,99].

In our project we use V-F and P-Q droop control method that can be applied with to achieve better voltage and frequency in islanded NG. The droop controller is a common control mechanism for managing the system voltage and frequency in islanded NG systems. It can supply voltage and frequency references for voltage and current regulation according on the NG's power requirements. In the islanded functioning of NG, the P – F and Q – V droops are used to maintain the system voltage and frequency. However, in order to gain better control performance, various parameters in the traditional droop controller must be improved. But Controlling the voltage and frequency in NG's islanded mode of operation is not an easy task. Any fluctuations in generation or load power will result in changes in system voltage and frequency, in this time NG demanding the use of an intelligent mechanism to regulate the system in this situation. V-F is a method of controlling DC-AC converters in NGs in a repeating manner to ensure that the controller can cope with fluctuations in generation and load. better stabilization. It has the benefit of being able to solve and optimize multidimensional and multiobjective systems. We conducted self-adjusting droop mechanism in the droop controller also use proportional-integral (PI) controller in droop control to eliminate the frequency divergence. PI controller can calculate the new droop position to eliminate the frequency divergence.

## 1.4 Objectives

The main objectives of this project are**:**

a) To design a 10KW Nanogrid by using Matlab software.

b) And control voltage and frequency by using V-F Droop control to improve system performance and stability.

c) And the main objectives is to stable the whole Nanogrid system.

## 1.5 Thesis Outlines

In this thesis, we described and discussed about our thesis in 5 chapter. The outlines of our thesis are as follows **:**

- **Chapter-1:** In chapter 1 I have discussed merely about the Nanogrid, and Nanogrid problem. Also described about our research objective.
- **Chapter-2:** In chapter 2 I have done literature review. In this section several kind of controller and different nanogrid technology, types are discussed. Also there advantage and disadvantage was discussed.
- **Chapter-3:** In this chapter I have done methodology. Methodology about the nanogrid design also V-F droop controller design which can stable our nanogrid system stable. Also, the procedure of getting output in the Matlab software and also discuss the mechanism of droop control. Describe the components which we use in this research.
- **Chapter-4:** This chapter we draw result and analysis this result with relevent way. And we design a model which is so much stable and suitable for use.
- **Chapter-5:** In this chapter I have come to a conclusion with the scope of the future work.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 Introduction

In this chapter we overview on Nanogrid and other kinds of instrument which are very essential for NG. We will explain about smartgrid, Microgrid and Nanogrid. Also we discuss about classification of Nanogrid, NG technologies, and how many controller we can use in NG and their advantage and disadvantage and controller types.

## 2.2 Types of Nanogrid Technology

Alternating current(AC) and direct current (DC) power debate are the old debate. As we know that, AC prevailed out for the national grid, owing to technical limitations at the time the grid was constructed [101]. The benefits of a DC grid are still frequently addressed, especially with increased research into the benefits of distributed generation, where the supply and storage are often DC. This is also a concept that commonly appears in microgrid and nanogrid literature, with the goal of increasing DC power distribution efficiency. A basic diagram of the AC and DC nanogrid shows in **Fig. 2.1** and **Fig. 2.2** respectively. There are so many similarities between this diagram.

## 2.3 AC Nanogrid

When comparing to the DC nanogrid, the AC nanogrid requires more conversions to ensure that the correct power is delivered to the load. Because of additional convertion AC nanogrid loses efficiency, which take place in [102].

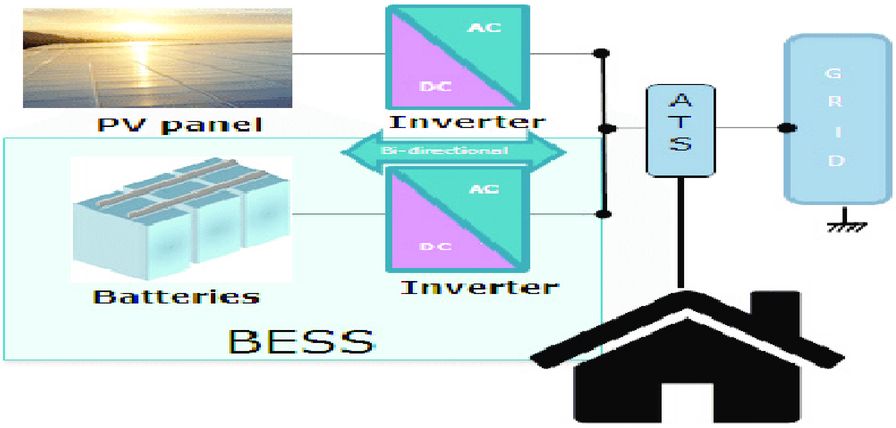


**Fig 2.1:** AC Nanogrid[102].

- **DC-AC Converter:** It takes the voltage from the source converter and the output of dc-ac converter are 230V AC(or 120V AC depending on origin) which is very much popular in nowadays for consumer load sight. This converter also help to supplied voltage level to a nanogrid from the national grid. That means using this converter that can synchronize the grid's frequency of 50 Hz (60 Hz depending on origin), for that povwer can easily shared between the power entities. In [89] they discuss about the invenrter conversion which can bring efficiency 90%.

- **Load AC-DC Converter:** The Power adapter( also known as a wall wart) within this adapter AC voltage converterd to DC. The DC-DC conversion is frequently performed using a "linear power supply" for AC loads that require less than 15 W of power (e.g. cell phones). And the efficiency of these device varies from 20% to 75%. But in switch mode power conversion it draw a high power conversion which is more efficient and range is 50% to 90% [103].

## 2.4 DC Nanogrid

**2.4.1 DC Source :** Although there are no restrictions on whether renewable or non-renewable resources can be used to create electricity,( (hydro isn't commonly utilized in nanogrids because it requires access to a body of water, which most residents and businesses do not have). And the resources are solar( PV), wind ( small scale wind turbines(SSWT), are the commonly used resources, which generate AC but usually output DC as the AC frequency varies and battery storage which will be plug in electric vehical in the near future [59,65]. Diesel generators and fuel cells are referenced in the nanogrid literature, but not nearly often as SSWT, PV, and batteries [75,104]. And the output voltage of SSWT or PV is less than 50 V). In **Fig. 2.2** we show a DC Nanogrid ideal structure.

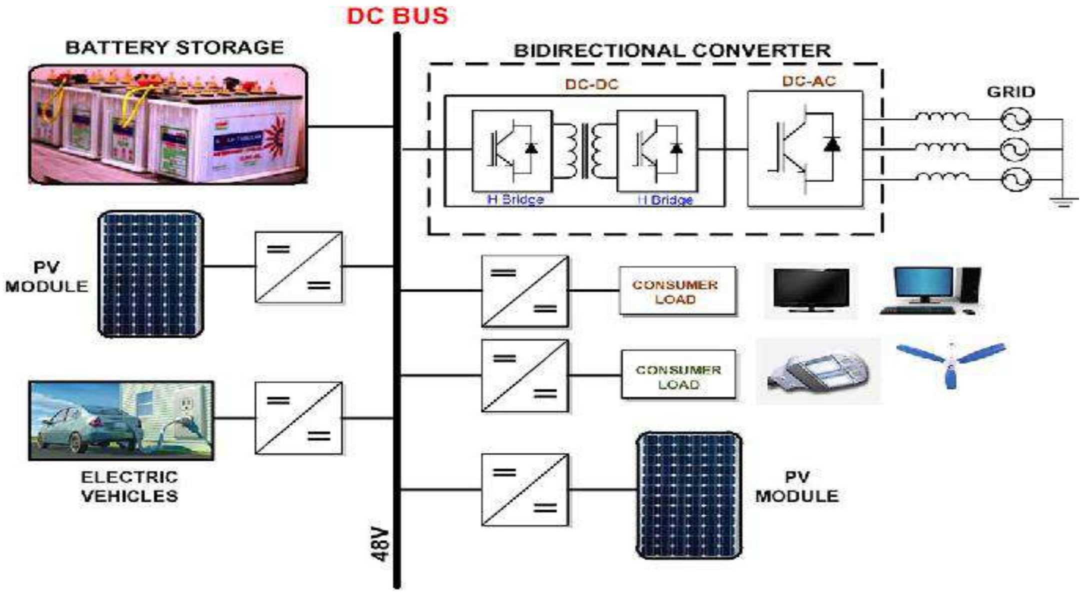


**Fig 2.2 :** DC Nanogrid[65].

**2.4.2 DC-DC Converter Source:** This kind of converter it takes an input voltage and then voltage either increase or decrease depending on the required output voltage. Different kind of functions can be used to fulfil source DC-DC converter below we explain their information:

- **Multiple Source Interface**
  At any given time, nanogrids can be powered by a variety of sources. For example, a hybrid system could include a PV array, SSWT, and storage giving power to the nanogrid. Each source has its own operational characteristics. Each source requires a DC-DC converter in order to be integrated into the nanogrid. The converter maintains supply management and protects the system [65].

- **Bus Voltage**
  The Source DC-DC converter may also convert the source voltage to a 380 V DC bus voltage [69,90]. This level of voltage become industry-standard intermediate level [59]. The voltage can then be rectified in the case of the AC topology. The DC bus voltage has the further benefit of simplifying nanogrid control, which is covered in the "Nanogrid Control" chapter [105].

- **Maximum Power Point Tracking**
  SSWT and PV are the two nonlinear behavior. There is just one operating point that ensures maximum power output under particular environmental conditions. This maximum power point is dynamic, and it may be followed using sensor to monitor the

behavior of the renewable source and this point can be traced. This maximum power point is dynamic, and it may be followed using sensors to monitor the behavior of the renewable source and ambient circumstances. This is accomplished by changing the duty cycle of the source DC-DC converter, effectively putting a variable load on the source. If the perfect load for environmental condition is created the source will be forced to run at its maximum power point [106].

## 2.5 Nanogrid Control Types and Techniques

The nanogrid controller performs nanogrid control, which allows the system to coordinate numerous sources and optimize power production and consumption. It is the "brains" of systems, and if applied effectively, it can improve the nanogrid's efficiency. There are two types of control in a nanogrid structure: supply side management (SSM) and demand side management (DSM). Photovoltaic modules, small-scale wind turbines, the grid and so on are the nanogrid’s power source which are supply power to nanogrid. The demand is the amount of energy consumed by household loads such as refrigerators, televisions, and heaters [107,108]. Unfortunately, in an high demand and production times rarely coincide in an unregulated nanogrid. That’s why in NG controller supply and demand side management is an integral part. SSM and DSM can be implemented using a variety of control topologies with different levels of success. The implementation of supply side management is demonstrated using nanogrid control topologies [46,52]. The pros and cons of each system are explained below, along with how each topology is set up for both supply and demand side management.

### 2.5.1 Control Types

#### 2.5.1.1 Central control

The central control system consists of a main controller that operates on data from sensors that measure the system's power generation and consumption (as well as other variables such as temperature in some circumstances). In **Fig. 2.3** the communication lines are indicated in red, and the power is indicated in black, in this block diagram of the central control topology. The central controller monitors parameters in real time, allowing the system to respond quickly to commands.

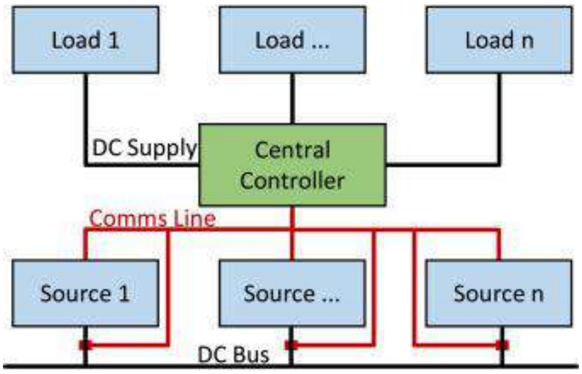


**Fig 2.3:** Central Controller[46].

One drawback of this design is that it relies on a high-bandwidth communications line to receive data from its sensors and execute control in a timely manner. Another drawback is that by concentrating control on a single controller, the system becomes more likely to fail. The system will no longer be able to apply control if a communication line or the central controller itself is damaged.

### 2.5.1.2 Decentralized control

A collection of control nodes working independently perceive the state of each local source or load in decentralized control**.** The node's collected data is subsequently used to control the local source/load (as shown in **Fig. 2.4**). In central control there is a long communication line but in decentralized control it does not require a long communication line, eliminating this reliance. This topology is also more robust and stable than a central control because it has numerous separate controllers. As a result, the decentralized topology is quick and reliable.

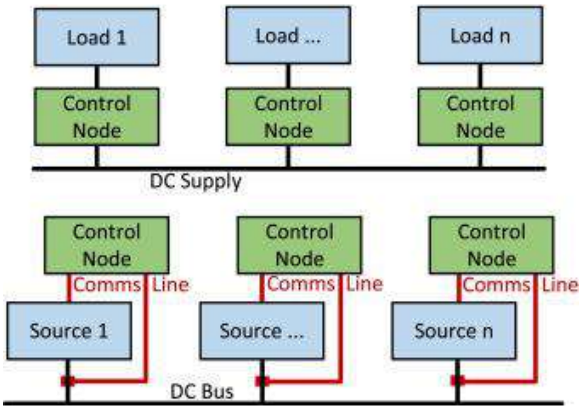


**Fig 2.4**: Decentralized Control[46]

Beside this, control scheme’s usefulness as a control topology is limited. It’s happened because there is lack of communication with different system’s nodes. The capacity to force a reaction within a power system to an event that may only be noticed by a single node is at the heart of most control systems. This can only be done if communication between nodes is possible, which it isn't in this situation [46].

### 2.5.1.3 Distributed control

Distributed control, like central control, utilizes a decentralized topology and adds communication between two via a communication line [109]. This means that certain properties of both systems are adopted by the distributed system. It corrects the decentralized scheme's flaws by allowing each node to broadcast its power status. The network as a whole forms a coherent control strategy by storing portions of an overlying control strategy (relating to its own relationship to the system) in each control node. Distributed control, like decentralized control, benefits from several controllers, which reduces the risk of complete system failure. Distributed control also dependent on the communication line.

### 2.5.1.4 Hybrid Distributed control

Hybrid Distributed Control is a combination of distributed and decentralized control, as the names suggest. Nodes in a dispersed topology can communicate, resulting in an united control approach. The hybrid system, on the other hand, appears to increase on the distributed control topology by eliminating the need for a communication line, as shown in **Fig.2.5**. It accomplishes this by communicating between nodes using DC bus/supply lines, similar to the popular "droop control" [110]. As a result, the hybrid distributed control scheme does not require a communications link, enhancing the system's reliability.

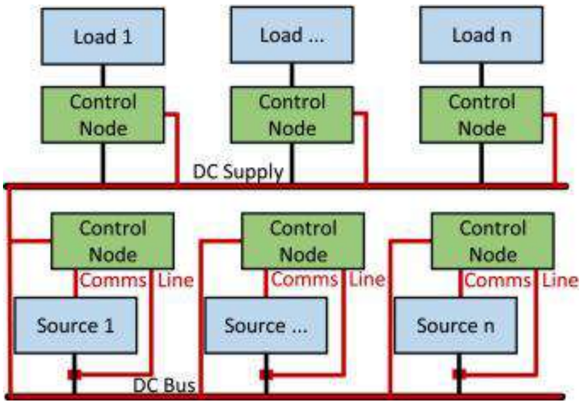


**Fig 2.5 :** Hybrid Distributed Control Block Diagram[110]

### 2.5.1.5 Hybrid Central control

Hybrid central control is the control system which is the combine of central control system and decentralized control system. In this system central control and decentralized control creates a communication line by nodes as shown in **Fig. 2.6.**

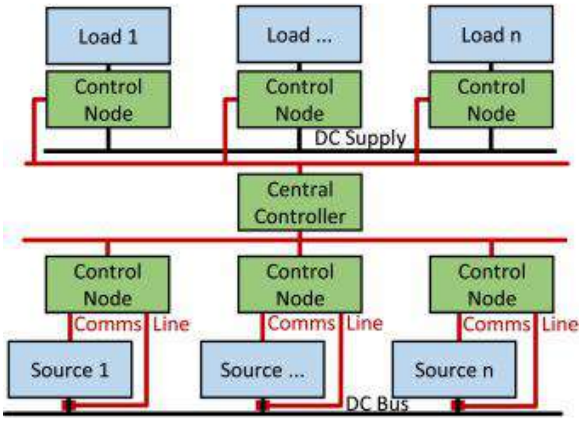


**Fig 2.6:** Hybrid Central Control Block Diagram[110].

The source/load level control is implemented by the control nodes, whereas the central controller supervises every node. The hybrid central control system provides a powerful and quick control system with greater fault tolerance. However, because the system depends on communication lines, it is susceptible to failure.

### 2.5.2 Nanogrid Control Techniques

There are several proposed nanogrid control strategies in the nanogrid literature. The main purpose of nanogrid control is to produce a more efficient system by optimizing supply and demand patterns. This is usually measured in terms of the financial savings a controlled nanogrid generates over a nanogrid with no control measures in place. Below we listed a number of nanogrid control techniques, along with explanation of how they work.

### 2.5.2.1 Ad Hoc Nanogrid

The distributed control mechanism is implemented in the Ad Hoc Nanogrid. It looks to make sure that loads get the power as they need, that sources aren't overwhelmed, and that power is transported in the most efficient way possible. For cases when the nanogrid does not have access to a national grid (islanded mode), such as isolated rural areas, the ad hoc control technique was created. The system's purpose is to produce a power structure that can be scaled, flexible in dynamic settings, and dependable, where limited infrastructure planning and no central control. During a number of phases, the nodes connect wirelessly while the control algorithm (contained in each node) picks the path for power flow.

During the first phase, a node attached to a load seeks power from local sources first, then increases its search until it finds an available source. When a suitable source is identified, the request is met with a proposal. The loading node then enters a holding mode, where it waits for responses from the other nodes many sources, at which time the cost of each is weighed to determine the best path. To allow power to flow from the source to the load, a confirmation notification is provided via the selected path. The last phase involves the nodes attempting to improve the power flow by seeking out less expensive alternate channels. This makes sure that power flows from source to load across the nanogrid in the most efficient way [54].

#### 2.5.2.2 Cost Function Control Technique

The Cost Function is a control tool described in [56], which take advantage of electricity price changes on the national grid to put in place implementing demand-side management. The system employs a central control system that collects data from the nanogrid's hardware, it can collects two way communication system one is smart grid connection and other is internet connection. This data is utilized to create the control algorithm and send control signals to the converters that connect the nanogrid to the national grid, photovoltaic systems, and battery storage. When power prices fluctuate, this rule-based algorithm shifts or reduces loads. It also decides whether to sell or utilize photovoltaic energy based on the grid's buyback price. Moreover, while such systems exist, they are sometimes too complex to install in home-based systems or do not utilize grid connectivity [111]. There are three algorithm states of operation automatic response, load curtailment and islanding mode. In Automatic response mode it can pricing information (from the smart grid) and weather information( from the internet) also control charging and discharging of the batteries. Load curtailment is the mode that can be requested by the utility grid. During this mode, a consumption limit is established depending on available resources, and an agreement is reached with the utility to keep the nanogrid's grid usage to a bare minimum.  In islanding mode, generation and consumption are tracked, and power is rationed to guarantee that critical loads are kept running during a blackout. The system's purpose is to shorten the time it takes for a nanogrid to pay for itself.

### 2.5.2.3 Predictive Control Technique

Within the nanogrid, predictive control makes judgments based on cumulative load knowledge from the previous day's power consumption. This method is used to create a demand side management algorithm in [47], which schedules the charging times of a plug-in electric vehicle (PEV). This technique employs hybrid central control, in which the central controller provides advisory signals to a node, which then allows or disallows PEV charging. This helps to flatten the nanogrid's demand curve by charging the PEV when there is enough power available and deferring the charging process when there is a strong demand for electricity. Three separate zones are created by calculating an upper and lower border around this average consumption figure (less than lower bound, between bounds and greater than upper bound). It then compares real-time usage data to the three locations and transmits one of three instructions based on the result. The PEV is urged to charge if its real-time power consumption is less than the lower bound. If the consumption is between the bounds, the system issues a delay charging instruction, and if the consumption is above the upper bound, the system rejects charging if possible. As a result, the consumption curve is flatter, and peak consumption is lower. This has a lot of advantages, including financial savings [112].

### 2.5.2.4 Droop Control Technique

Droop Control is a control approach that may be applied to both demand and supply side management. Droop control also refers to voltage level control (in DC and AC systems) and frequency control (in AC systems) in AC and DC microgrid control [34,113,114-116]. The control technique is utilized in nanogrids to regulate supply and loads in the same way. The DC bus signaling (voltage level) approach to droop control is provided [49,50] and [53]as a supply side management strategy in [117]. A DC transmission network (DC bus) with a fixed voltage level between source DC-DC converters and load DC-DC converters is used to create DC bus signaling. The DC bus voltage is permitted to droop or diminish in magnitude as loading occurs to control the nanogrid's sources. The controller connects alternate sources to the system when the DC bus voltage hits specific predetermined voltage levels. For example, If a nanogrid consists of photovoltaics, batteries, and a grid connection, the system may be powered solely by photovoltaic modules. This may be sufficient under mild load conditions, but as the load increases, the DC bus will begin to droop. To meet the load demands, batteries will be added after the first voltage threshold is achieved. This control technique can also be applied to demand side management. In [45,51] AC system, droop is the main reason of frequency difference between basic nanogrid and other frequency.

## 2.6 Nanogrid Hardware

There are a number of technologies employed with nanogrids, but converter topologies are the subject that dominates the nanogrid literature. Within the nanogrid, converters are in charge of adjusting voltages to fit the needs of a particular activity. As shown in **Fig.2.7** [91], this normally entails connecting the nanogrid's sources to the systems bus, the national grid, and the nanogrid's loads to the bus. DC to DC, DC to AC, and AC to DC are the most common categories of converter used in Nanogrid [105].

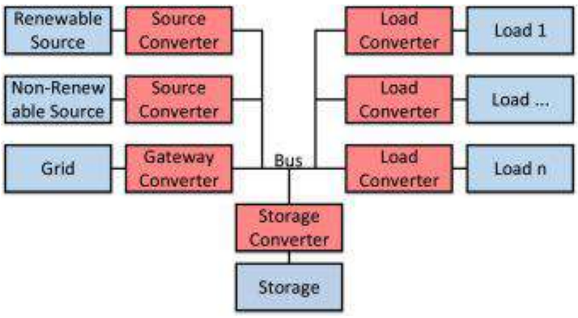


**Fig 2.7:** Hardware Structure of Nanogrid[105]

There are so many converter we explain below which we find from different renowned research.

- Dual-active-bridge based bidirectional micro-inverter which is Bidirectional DC to AC type converter. This dc to ac type converter makes with Lithium-ion-Ultra-Capacitors (LICs). LIC battery use for short term storage in a synchronous boost converter, by reducing the dp/dt factors of PV modules it increases nanogrid’s power quality also increases fuel economy of the diesel generators [64].
- Multi-port power converter architecture which is DC to DC type converter. In this system converter replaces conventional boost converter control switch with a full-bridge network which consists four switches and create isolated and non-isolated device. This kind of device that require galvanically isolation [66].
- Single-stage multistring PV inverter which is DC to AC converter. This is a grid-tied multistring converter featuring a high-frequency AC link, soft-switching operation, and high-frequency galvanic isolation. This means that any number of photovoltaic modules can be connected to the converter, and the converter will extract the greatest

amount of power from each. This converter has a high efficiency, a large power density, and a high level of reliability [89].

- Boost-derived hybrid converter [72] is a DC to DC and DC to AC converter. A bidirectional single-phase bridge network replaces the control switch of a traditional boost converter. This gives both an AC and a DC output at the same time, which is useful when running a nanogrid with both AC and DC loads.
- Isolated bidirectional AC-DC converter which is Bidirectional AC to DC converter. Multiple switching technologies, such as insulated-gate bipolar transistors (IGBTs) without an antiparallel diode, MOSFETs, and silicon carbide (SiC) diodes, are suggested for use in this converter. A frequency detection approach based on an advanced filter compensator, a rapid quad cycle detector, and a finite impulse response (FIR) filter is included with this.

# CHAPTER 3
# METHODOLOGY

## 3.1 Introduction

First of all we design a Nanogrid model in Matlab simulink model. Below here the simulation process then how we analysed this system has been done. First of all, we show our model then describe how it works and which instrument we use in our model. Then we describe our components describtion. Also we describe the droop control characteristics and its opeartion also V-F and P-Q controller mechanism. In model design and controller design we constructed the value in the way where we can get the Nanogrid power quality at efficiently.

## 3.2 Experimental Setup in Matlab

The proposed method is applied to a test system to evaluate its applicability and prove its effectiveness. In this case study, we will apply both droop control and the proposed method are connected with islanded MG test system then we compared the result. The two control methods are applied to a hypothetical NG running in islanded mode in this case study. This NG consists one DG and two loads, to switch between grid linked and islanded mode, the grid is connected using a grid breaker. **Fig. 3.1** shows the Simulink representation of this test system.

The system parameters used in simulation is given in table1. To calculate voltage and frequency droop controller we use equation (1) and (2). Under this droop control system in islanded mode the voltage and frequency of the system are diverged from their nominal levels, which has an impact on the system's operation and stability. So, in microgrid and nanogrid, system voltage and frequency control is important. In the following subsections, we will apply our proposed method for the droop control to this test system and then we analysis this result. The complete control system for the proposed method is shown in **Fig. 3.3 and Fig. 3.4.**

In our simulink model we use different kinds of semiconductor device and instrument which is very much essential to stable and improve our Nanogrid system. Here we use V-F droop controller, PWM IGBT Inverter, one storage battery, LC filter, Circuit breaker, Bus bar, resistive load, inductive load.

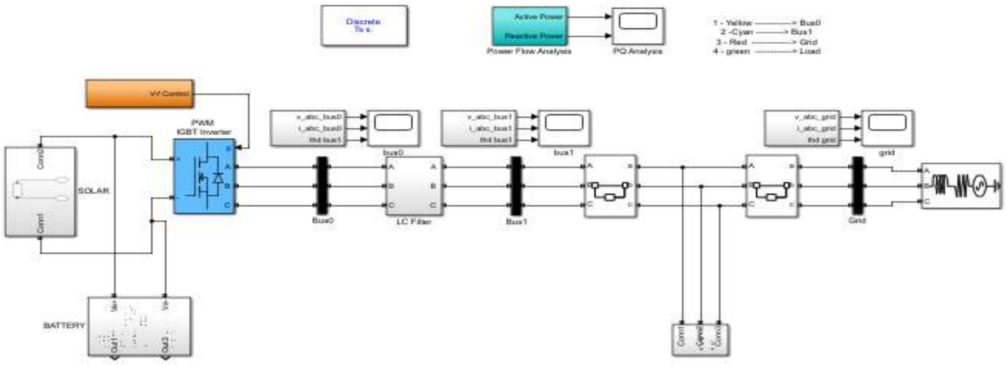


**Fig 3.1:** Simulink model of a Nanogrid with single converter and virtual grid

In this Nanogrid we use one DG which is based on solar and this solar source applied voltage is 80V. Here we use IGBT Inverter, Inverter converts DC to AC that means our 80V DC become convert AC power. But sometimes in conversion output AC voltage and frequency are not fixed. To fixed this voltage and frequency we use turn on and off semiconductor device IGBT. Usually IGBT use for high voltage and high current. And from PWM frequency and voltage are controlled by V-F droop control. How droop control voltage frequency it will be discuss in section 3.6. When our nanogrid model voltage amplitude are smaller or larger than the input volatge. To achieve this change amplitude, we use reactive components (capacitor and inductors) and switching components such as diodes, metal-oxide-semiconductors, field-effect transistors(MOSFETs) and insulated-gate bipolar transistors( IGBTs) [74,63]. By rapidly switching the model we use pulse width modulation (PWM), the necessary output voltage can be attained. Although, by measuring the output ( or input) voltage (or current) the PWM can be altered to ensure the output voltage remains stable even when the input voltage varies. Here we use highly inductive low pass filter. Low pass filter are the circuit that pass DC and low frequency signal but cut high frequency signal. LC filter become cut high frequency which was pass from the PWM IGBT Inverter. This LC filter cut noise and other distorted signal and specific signal can be identified. When LC filter cut high frequency it will be increase reactive power in system. We use load bus which connects three phase components and contain multiple amount of source and generators. In our model we use four bus to know how many power flow in our line and load. It can show voltage magnitude current magnitude and active reactive power which is very important for us to know that our system become stable or not. Breaker blocks connected between input and output of the blocks. We connect it in series because we want it to use as a switch. Usually three phase breaker uses where opeaning and closing times controlled by external controller. If we set it a external control mode one input icon attend to the block icon then control signal must input 0 in the block as a result breaker switch will be open or if the input are the positive value then breaker will be closed. We use two load one is resistive load other is inductive load. In nature, resistive loads are highly consistent. Because the resistive load obstructs the passage of electrical energy in the circuit and transforms it to thermal energy, the circuit faces an energy dropout. There are some example of resistive load they are- electrical heaters, soldering iron, and incandescent lighthing etc. On the other hand Inductive loads, among others, are the more power-hungry or heavy loads since they can also drive mechanical loads. In nature, inductive load are not consistent. That means their charateristics changes with the change in nature of the power supply. Here in **Table 3.1** we show all the input data of our simulink system. Some examples of Inductive Loads are Electric Motor, Induction cookers, etc. And we use battery for as a storage device which is optional for this system. When our system is overloaded we can store some power in our battery bank it can supply power when our system need power.

**Table 3.1: SYSTEM PARAMETERS**

| Components | Parameter | Symbols | Quantity |
|---|---|---|---|
| DGs system | Nominal Frequency | f | 50 Hz |
| | Nominal Voltage | v | 400v |
| LC Filter | Inductance | L | 2mH |
| | Capacitance | C | 0.000008F |
| PWM IGBT Inverter | Snubber Resistance | R | 5000ohm |
| | Capacitance | C | Inf |
| | Ron | R | 0.001 ohm |
| Three phase Breaker 2 | Breaker Resistance | R | 0.000000000001 ohm |
| | Snubber Resistance | R | 1000000 ohm |
| | Snubber capacitance | C | Inf |
| Three phase breaker | Breaker Resistance | R | 0.001 ohm |
| | Snubber Resistance | R | 1000000 ohm |
| | Snubber Capacitance | C | Inf |
| Three phase breaker1 | Breaker Resistance | R | 0.001 ohm |
| | Snubber Resistance | R | 1000000 ohm |
| | Snubber Capacitance | C | Inf |
| Load 1 | Resistive | R | 3 ohm |
| | Inductive | L | 3/100/pi |
| Load 2 | Resistive | R | 3 ohm |

## 3.3 Input Data

For input we apply our DC solar source which is 80V. And we use 50kw solar source.

## 3.4 Output Data

From output we find active, reactive power graph and voltage, current graph for Nanogrid simulation model. From droop control we find frequency and voltage graph how they control voltage and frequency by droop control menthod. And we found THD graph which is important for a power system.

## 3.5 Components Description Battery

In a nanogrid construction, the usage of a storage system is considered optional, but it is often used in nanogrid. In fact, it improves stability and provides a power buffer that may be utilized to appropriately manage energy according to set goals, such as lowering electric bills or increasing efficiency. Due to capacity limits and the residential context, a battery bank is the best energy storage device for nanogrids, and its proper integration in a DC grid-based laboratory testbed demands special attention.

### 3.5.1 PWM IGBT Inverter

A PWM IGBT Inverter capable of switching 20kHz. An inverter is a circuit which converts a DC power into an AC power at desired output voltage and frequency. The AC output voltage could be fixed or variable voltage and frequency. This conversion can be achieved either by controlled turn on and turnoff devices (e.g. BJT, MOSFET , IGBT , and MCT etc.) or by forced commutated thyristors, depending on application. The output voltage waveform of an ideal inverter should be sinusoidal. The voltage waveforms of practical inverter are however, non-sinusoidal and contain certain harmonics. Square wave or quasi-square wave voltage maybe acceptable for low and medium power application and for high power application low distorted, sinusoidal waveform are required. The output frequency of an inverter is determined by the rate at which the semiconductor devices are switched on and off by the inverter control circuitry and consequently, an adjustable frequency AC output is readily provided. The harmonics content of output voltage can be minimized or reduced significantly by switching technique of variable high speed power semiconductor devices.

The DC power input to the inverter maybe battery, fuel cell, solar cell or other DC source. But in most industrial applications, it is fed by a rectifier. This configuration of AC to DC converter and DC to AC inverter is called a DC link at network frequency is rectified and then filtered in the DC link before being inverter to AC at adjustable frequency. Rectification is achieved by standard diode or thyristors converter circuits and inversion is achieved by the circuit techniques.[118].

### 3.5.2 LC Filter

LC filters refer to circuits consisting of a combination of inductors (L) and capacitors (C) to cut or pass specific frequency bands of an electric signal**.** Capacitors block DC currents but pass AC more easily at higher frequencies. Conversely, inductors pass DC currents as they are, but pass AC less easily at higher frequencies. In other words, capacitors and inductors are passive components with completely opposite properties. By combining these components with opposite properties, noise can be cut and specific signals can be identified. There are three types of LC filter 1. Low pass filter 2. High pass filter 3. Band pass filter. But here we used highly inductive low pass filter.

#### 1. Low-pass Filter (LPF)

Low-pass filters are filter circuits that pass DC and low-frequency signals and cut high-frequency signals. They are the most widely used filter circuits and are mainly used to cut high-frequency noise.

#### 2. High-pass Filters (HPF)

High-pass filters are filter circuits that cut DC and low-frequency signals and pass high-frequency signals. They are used to cut low-frequency noise in the audible range, cut mid-range/bass sound components of treble speakers, etc.

#### 3. Band-pass Filters (BPF)

Band-pass filters are filter circuits that pass only signals at a specific frequency and cut signals at other frequencies. They are used for radio tuning (frequency adjustment) or for cutting the bass/treble sound components of mid-range speakers, etc.[119]

### 3.5.3 BUS

In a power grid, a bus is a node that connects one or more lines and can also contain multiple components like loads and generators. In simple words: a bus is a set of three nodes at which

three-phase elements are tied together. Each bus or node is correlated with one of four quantities: (1), magnitude of voltage, (2) phase angle of voltage, (3) active power or true power, and (4) reactive power.
According to the specified numbers, buses in the load flow study are classified as generation buses, load buses, or slack buses.

1) The generation bus, alternatively referred to as the photovoltaic bus, voltage-controlled bus, or generator bus, is a term that refers to the generator stations in a power grid. The magnitude of the voltage and the actual power are defined for this type of bus. This suggests that the generation bus's unknown variables are the phase angle of the voltage and reactive power.

2) The load bus, or PQ bus as it is often referred to, is a type of node that incorporates both reactive and active power into the network. This indicates that the step angle and magnitude of the voltage are unknown and must be determined using the load flow equation.

3) The term "slack bus" is sometimes used interchangeably with "swing bus" or "reference bus." It does not bear any load but is believed to do so in order to account for transmission losses. Although the generator bus provides active control, it also means that it will be used entirely by the load bus. This results in a discrepancy or power loss that can be measured only after the load flow solution is applied. The slack bus supplies the complex's losses and is still equipped with a generator to meet unmet demand from other buses.[120]

### 3.5.4 Three phase Breaker

The Three-Phase Breaker cause potential a three-phase circuit breaker where closing and opening times that can be controlled by an external Simulink signal (outer control mode) or an internal control mechanism (internal control mode).

The Three-Phase Breaker block uses three Breaker blocks which interconnected between both the inputs and the outputs of the unit. You can connect this block to the three-phase element if you want to switch in series. The Three-Phase Fault block has the same arc extinction method as the Breaker block. Details on the modeling of single-phase breakers can be obtained in the Breaker block reference pages.

A control input appears in the block icon if the Three-Phase Breaker block is set to external control mode. The control signal attached to the Simulink input must be 0 to open the breakers, or any positive value to close them. A 1 signal is frequently used to close the breakers for clarity. The switching timings are provided in the Three-Phase Breaker block's dialog box if the block is set to internal control mode. The signal that controls the three individual breakers is the same. The model includes a series Rs-Cs snubber circuit. They can be attached to the three independent breakers if desired. You must utilize the snubbers if the Three-Phase Breaker block is in series with an inductive circuit, an open circuit, or a current source.

**Parameter- Initial status**

The breakers' initial condition. The three breakers have the same initial status. The indicator displays a closed or open contact depending on the original status. There are two options: open (default) or closed.

**Switching of: Phase A**

Phase A switching is enabled if this option is selected. If the Original status parameter is not set, the phase A breaker will remain in its initial state. Default is selected.

**Switching of: Phase B**

Phase B switching is enabled if this option is selected. If the Original status parameter is not set, the phase B breaker will remain in its initial state. The default option has been chosen.

**Switching of: Phase C**

Phase C switching is enabled if this option is selected. If the Original status parameter is not set, the phase C breaker will remain in its initial state. The default option has been chosen.

**Switching times (s)**

Only if the External check box is checked is this parameter available. When utilizing the Three-Phase Breaker block in internal control mode, specify the switching time vector. Depending on their initial state, the specified breakers open or close at each transition moment. Default is [1/60 5/60]. [121].

## 3.6 Droop Control Characteristics

In power system based on rotating generators, frequency and active power are strongly connected. A load increase implies that the load torque rises without a corresponding rise in prime mover torque, implying that the rotational speed, and hence the frequency become reduces. When frequency decrease and increase the load droop control try to achieve stable manner. The units in the stand-alone system do not know the initial phase values of the other units, to control active power flow droop method uses frequency instead of power angle or phase angle. The voltage and frequency of a power system can be determined by controlling the real and reactive power flows through it. From equations we observed that as the real power load on the system increase, the droop control scheme will allow the system frequency decrease. The common droop control formulae are derived from this two equations.

$$U_{d,ref} = (Q - Q_0)\left(\frac{U_{max} - U_0}{Q_{max} - Q_0}\right) + U_0 \ldots\ldots\ldots(1)$$

$$f_{ref} = (P - P_0)\left(\frac{f_{max} - f_0}{P_{max} - P_0}\right) + f_0 \ldots\ldots\ldots\ldots(2)$$

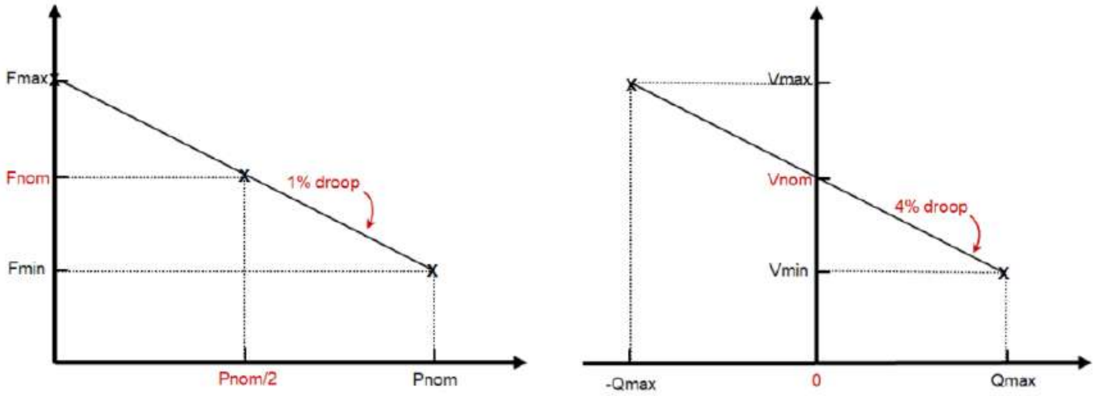


**Fig 3.2:** Droop characteristics (a) P-f droop (b) Q-V droop[122].

The controller P/F is set to 1%, that means the microgrid frequency allowed to vary the range between 60.3 Hz (no active power produced by the inverter) to 59.7 Hz (inverter produces its nominal active power). The droop controller Q/V is adjusted to 4%, allowing the microgrid voltage at the PCC bus to range between 612 Vrms (full inductive power produced by the inverter) to 588 Vrms (inverter produces its full capacitive power). Here we see that Qmax is the half of the Pnom( nominal active power). There are some characteristics of the droop control.

**Measurements**: Inverter generated active and reactive power of the measurement subsystem based on the frequency value of droop control. The d-q components of the three-phase voltages and currents of the microgrid PCC are also calculated.

**Voltage Regulators:** Droop controller reference voltage Vref is fed to the voltage regulators. The reference currents Id ref and Iq ref are generated by the regulators using the measured d-q voltages and the reference voltage Vref.

**Current Regulators: Id ref and Iq ref reference current are fed to the Current Regulators.** The regulators use the measured and reference currents to generate the required inverter's d-q voltages (VdVq conv). We have to note that the regulators dynamic benefits from a feed-forward computations.

**Vref Generation:** The scaled and transformed VdVq conv to three phase signals are fed into the PWM modulator, which generates pulses for the inverter. [122].

**The Method Control Proposed:**

Droop control, which is employed in this study, is a decentralized method that is based on locally measured quantities, allowing for more dependable and flexible operation. It also has a simple structure that allows for plug-and-play operation. The droop control approach is modeled after the behavior of an AC synchronous generator, in which the frequency and active power are inversely proportional, and the voltage and reactive power are similarly inversely proportional.

### A.VF droop controlled Inverters

In **Fig. 3.3** VF droop controller there is two regulators one is voltage regulators other are current regulators. And 230*sqrt(2) are the nominal output voltage of controller. To control voltage and frequency we have to required to control the voltage at the point of the connection then it sends the error signal to PI controller in order to produce reference current. Proportional Integral controller use here to improves the stability of the system, which can dampening in the rapid load change time. And also in critical time PI controller can prevent the synchronism loss. And the reference current are id_ref and iq_ref. It can also be used to adjust MG's voltage by injecting or absorbing a specific quantity of active and reactive power.

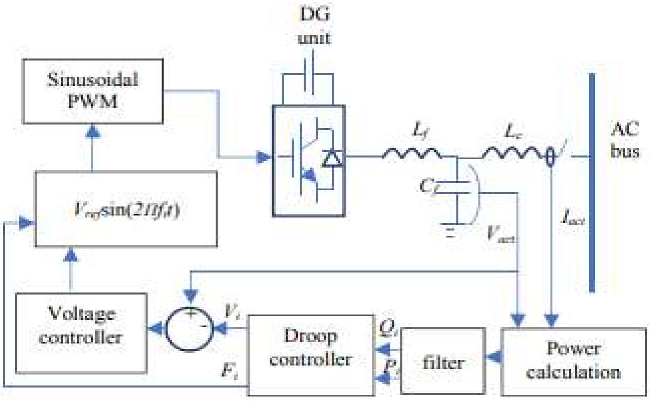


**Fig 3.3:** VF droop control Inverter

VF controller compares reference and measured frequency where F_ref=50 Hz and then sends the error signal ‘df’ to the PI controller, and it generates active reference current (id_ref). Moreover it compares reference and measured voltages at a certain bus and sends error signal ‘dU’ to the PI controller which is responsible for the voltage control loop. This PI controller regulates the injection or absorption of reactive power and generates the reactive current reference (iq ref). The trial and error method is used to tune PI controllers for the various controllers utilized in the network. The varied values were tried in order to properly tune the controller, and an overshoot between the measured and reference current values was noted. The appropriate values have been chosen for the control parameters where there are no substantial issues of signal overshoot in the measured and reference values.

The inverters share active and reactive power (i.e. injection/absorption) based on the current references' levels. These values are fed into the current controller, which is in charge of determining the duty cycle for the inverter's switches.

### B. PQ droop control Inverter

In this **Fig.3.4** we see that case inverter opearates as a current source and it supports the NG by producing certain active and reactive powers according to the locally measured volatge and frequency.

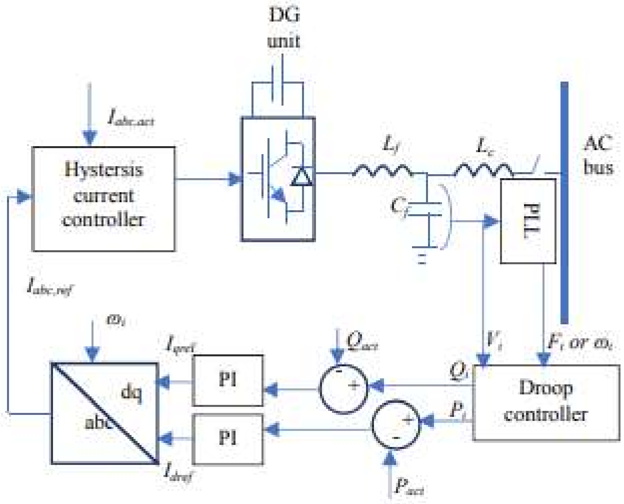


**Fig 3.4:** PQ droop control Inverter

We see that in VF droop control transform into dq0 to abc but in PQ control we have to transform abc to dq0. Here reference voltage and current are neutralize in the PI controller. The switch block in Figure 4 receives signals (id ref** and iq ref**) and (id ref* and iq ref*) from the PQ and VF controllers, respectively, and delivers suitable current references to the current controller based on the PI controller. The current controller receives signals from the PQ or VF controllers and transmits them to the inverter's PWM block, which determines the duty cycle [25]. This neutralize abc then transform into dq0. In frame abc transform into dq0 to choose a reference voltage and current. After that this reference dq0 enter into PWM generator which makes it pulse signal. PQ suffers from being load frequency variation. Load connections and disconnections of system occurred because of frequency deviations. Also there is a tradeoff between frequency regulation and accurate sharing.

# CHAPTER 4
# RESULT & ANALYSIS

## 4.1 Introduction

In this chapter we will discuss about the model results obtain by modal solution. . After performing analysis procedure described in chapter 3, we have obtained different kinds of figure.

A 50 Hz, 400V islanded NG is simulated using MATLAB software to verify the effectiveness of the proposed technique. One DG units make up the NG under investigation. Our simulation model is the highly inductive low pass filter where we use a specific time constant. The first inverter is set to VF control, while the other two are set to PQ control. A common ac bus connects a base load with switching loads. The loads are represented as RL branches in a parallel. Each unit's of droop characteristics are tweaked to deliver rated active power at rated frequency while delivering zero reactive power at nominal voltage.

## 4.2 Simulation Result of with droop control

Because all units are the same and have the same droop coefficients, load will be distributed evenly among them. For that reason we evaluate this system as with and without droop control.

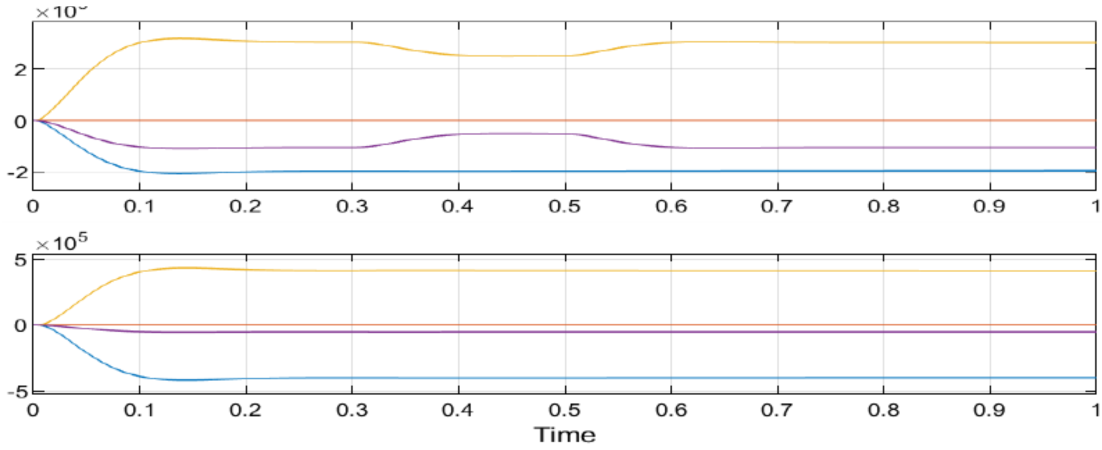


**Fig 4.1:** Active and Reactive power

Here in **Fig.4.1** yellow is for before filter, purple is for load, red is for grid, cyan is for after filter. From **Fig.4.1** we observed that all real and reactive power which was supplied by converter is not absorbed by the load. Because we use two types of load resistive and inductive.

Also we see that after filtering reactive power supply by converter become increased because capacitor inside the low pass filter added to the converter supply. During this simulation, we used 2 types of load at the same time. Firstly, our proposed controller is deactivated and the NG is loaded by the base load which is equal to the sum if the nominal active power of the DG and utility grid, 10KW. In addition, the active power when we connected a resistive load at t=0.3s we see that our active power become decrease because connecting a new load system become unstable this time. From figure we see that NG frequency become increase to 50.005 Hz. At t=0.4s, the proposed controller are activated. In this time droop controller will control the frequency our estimated system frequency 50Hz and droop controller reference frequency also 50 Hz. Then sincos collected frequency transformed into abc to dq0 frame. That means collected frequency filter output in dq0 reference frame then it transformed into abc reference frame for comparing the reference one. Then comparing value apply in PWM generator. PWM generator generates carrier based pulses which sent controller then controller makes decision to control the system which will stable the active power. The controllers succeed in bringing back the frequency to its desired value, 50 Hz with fast response and accurate tracking. This method can respond to any change in system load as fast as possible because when any disturbance occurred in the system controller response it within 0.1s.Three bus active powers output have increased in the same percentage and equal load sharing is not disturbed.

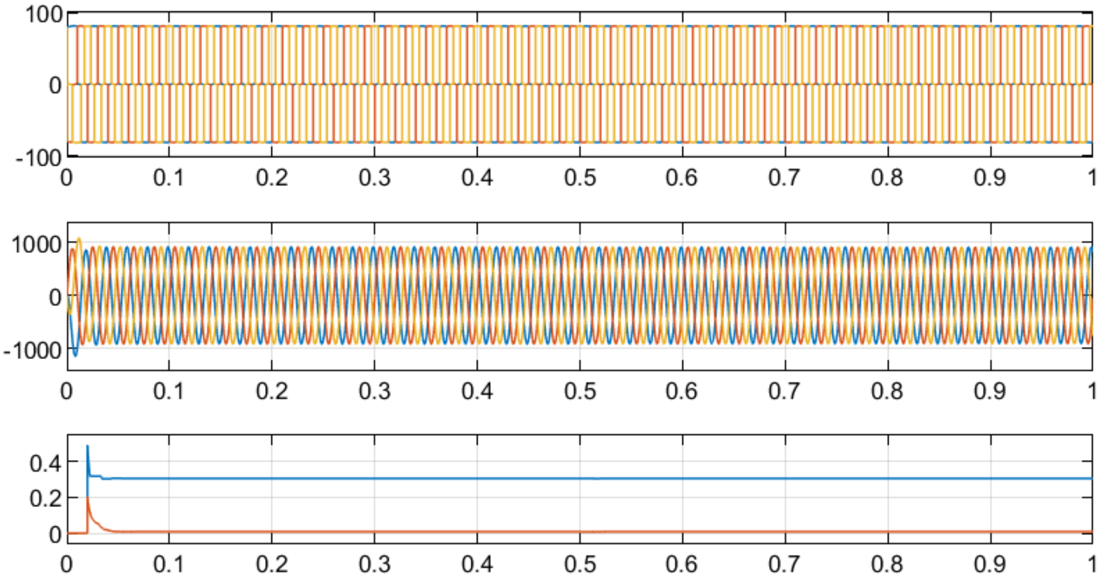


**Fig 4.2:** (a) Voltage curve of the bus 0. (b) Current curve of the bus0. (c) Frequency spectrum of the bus 0.

From **Fig.4.2** we see that before filter in bus0 there is low voltage also low frequency for that reason we didn’t find our estimated output. And in this time our current are 0.13a which is very small current flow. But voltage frequency are stable because voltage frequency become stable by V-F droop control. Without filtering this bus our voltage harmonic distortion become increase. We see that in voltage side graph it’s become square that means it’s not sinusoidal for that our power factor of the bus0 become decrease also power expenditure will be increase. In third graph at initial time there is slightly distortion for current fluctuation for that some THD we found, but there is huge fluctuation in voltage because we doesn’t filter this bus as a result a huge THD we found in this time.

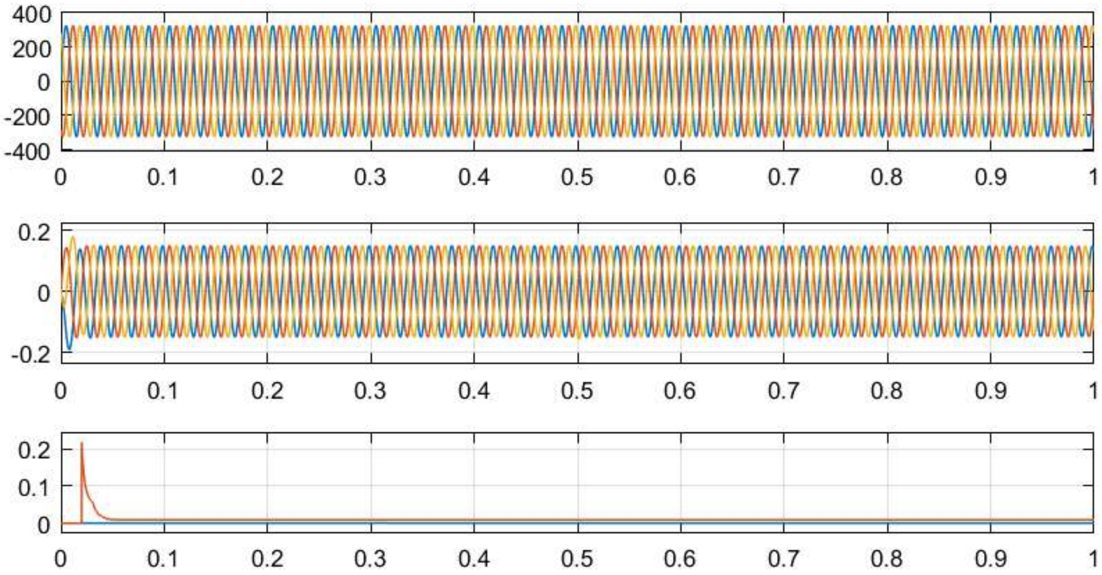


**Fig 4.3:** (a) Voltage curve of the BUS1. (b) Current curve of the BUS 1. (c) Frequency spectrum curve of BUS1.

From **Fig. 4.3** After filtering our voltage and frequency become suitable for our system. For this system we use LC filter which is highly inductive low pass filter, this filter pass DC and low-frequency signals and cut high frequency signals. As a result we find a purely sinusoidal voltage, current in BUS1. So that in Bus1 our power factor become suitable for our system. In third graph we see that at initial time current slightly distorted this time some THD found but it was negligible.

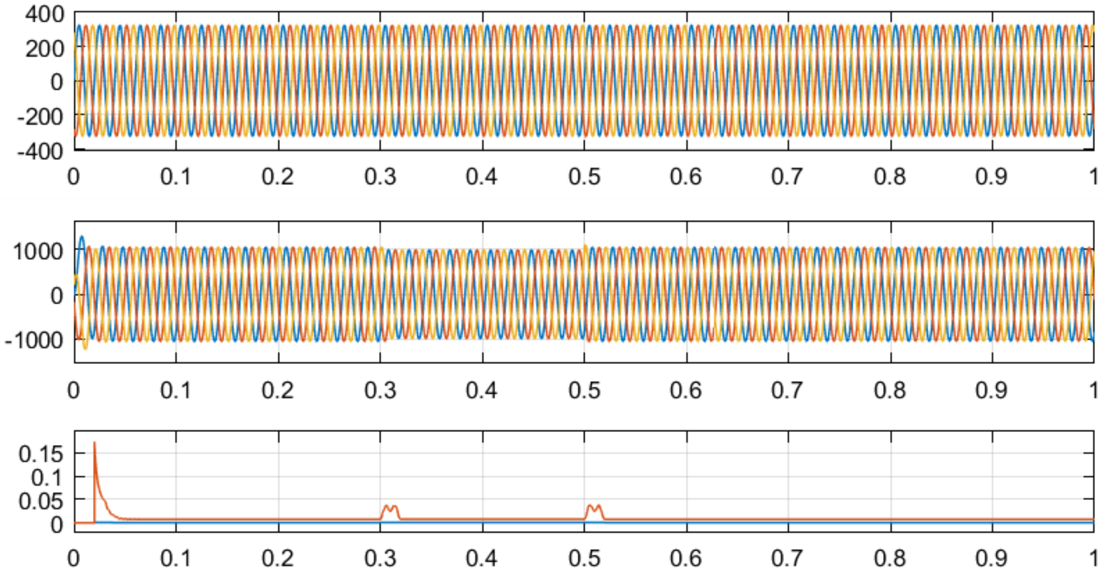


**Fig 4.4:** (a) Voltage curve of Grid (b) Current curve of the Grid (c) Frequency Spectrum of the Grid.

In **Fig. 4.4** grid there is no fluctuation in voltage and current. Also we observed that voltage is fixed in grid. Here some current are losses because adding a load in the system increase voltage demand also increase power demand of the system as a result we know that P=VI where if P and V increase It will be automatically decrease at that time. In current initial position have a slightly distortion because of sub-transient effect and there are a big spike of THD.

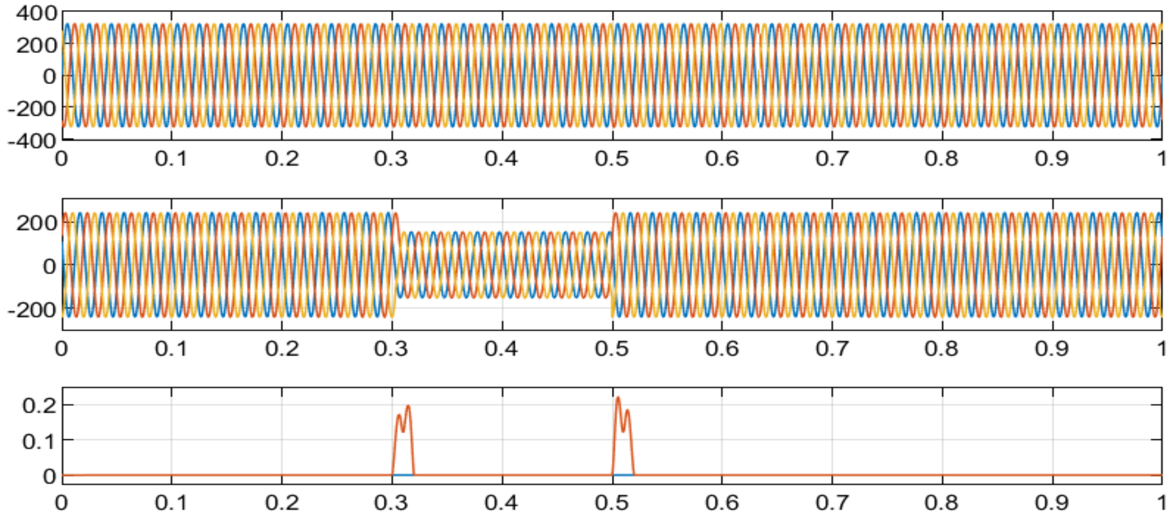


**Fig 4.5:** (a) Voltage curve of the Load. (b) Current curve of the Load (c) Frequency spectrum of the Load

In **Fig. 4.5** we observed that voltage is fixed because of our droop control but the magnitude of current is decreased, because at time 0.3s we disconnected one load from grid. After at time

0.5s we reconnect the load again current increased. We see that load consume 243.17A current. Here suddenly at mid-point current magnitude decrease when we connect inductive load because inductive load consume more current then resistive load. During this period current increase and decrease we see that there is a high THD, at the switching time of the load we see that THD become increase.

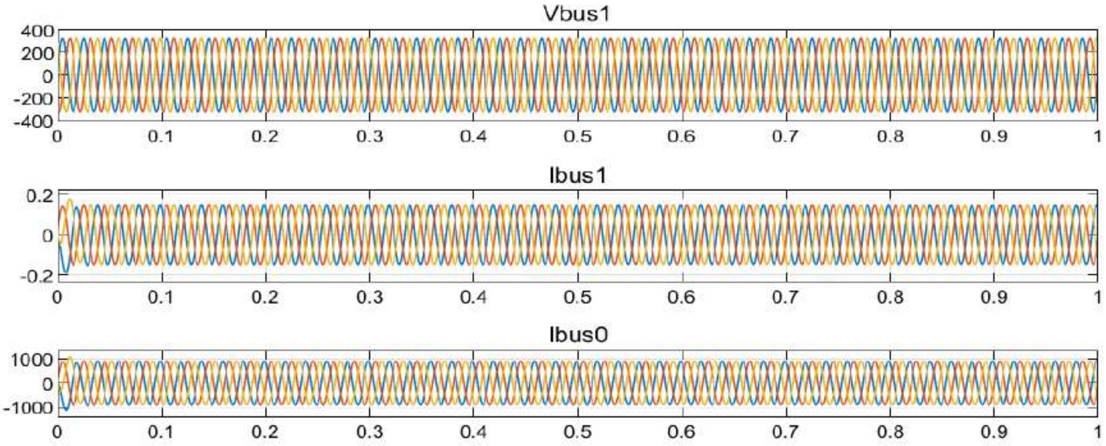


**Fig 4.6:** (a) Reference voltage of bus1 Vabc for droop control.(b) Reference current of bus1 Iabc for droop control. (c) Reference current of bus 0 for droop control.

In this **Fig.4.6** shows the abc reference that means that this voltage and current collected from filter the abc reference frame. Then this voltage and current output transformed into dq reference frame to comparing the reference one. This process help to calculate active and reactive power.

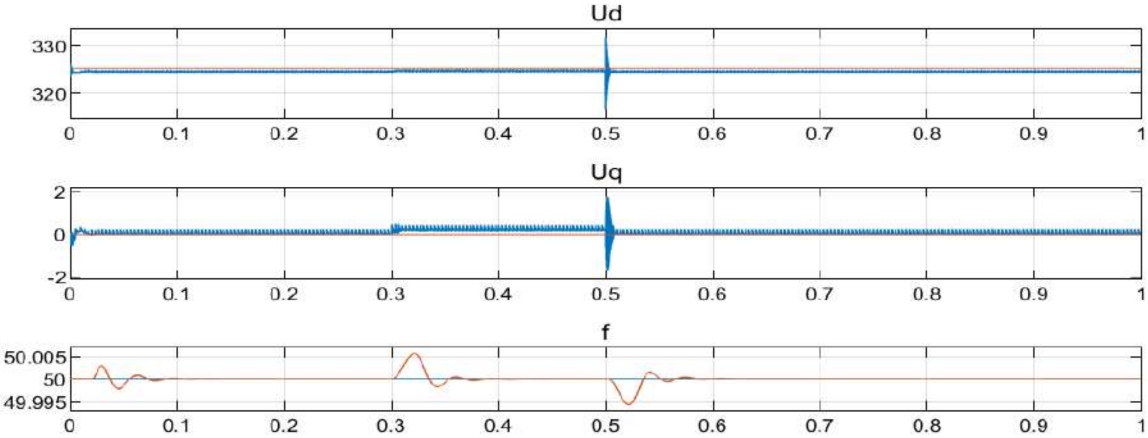


**Fig 4.7**: Representation of dq component of voltage and frequency. (a) Active power control by droop controller (b) Reactive power control by droop control (c) frequency controller by droop control

From **Fig. 4.7** we see that how droop controller maintains voltage and frequency. Ud define active power nominal voltage of the system and Uq define the reactive power nominal voltage of the system. And the constant value of Uq is 0. When load increase active and reactive power also increase on the other hand our voltage and frequency decrease. We see that in 0.3s when we connect a load our voltage are unstable that means decrease but in 0.5s within 0.2s droop control become stable this system. Here we see frequency vary from 49.995Hz to 50.005Hz which is very silly variations because our droop controller control this frequency.

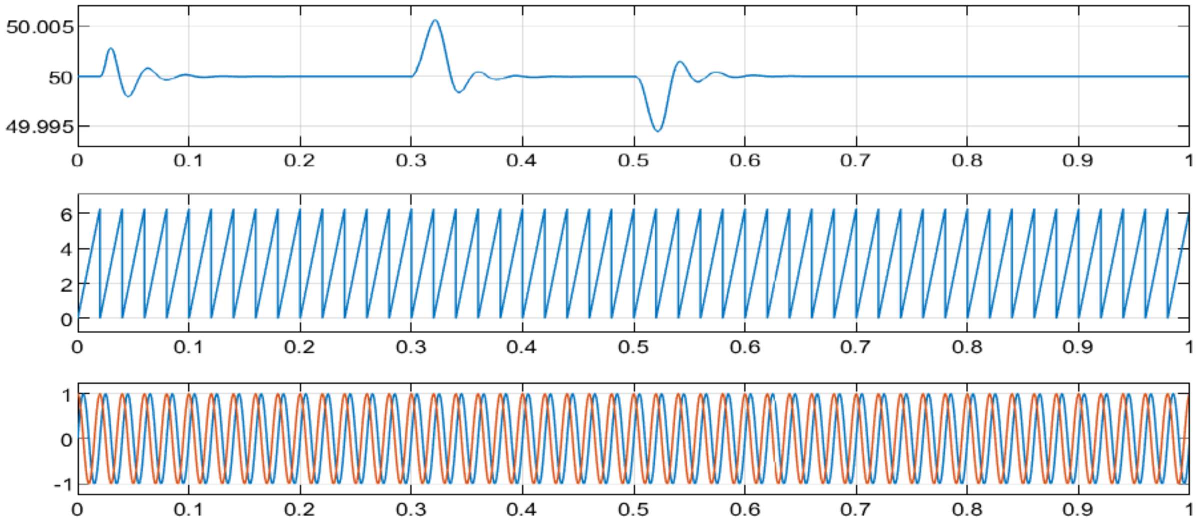


**Fig 4.8**: PV con Vabc, Iabc1 a) measured frequency of PLL system. b) measured Ramp w.t. c) vector output of the system.

From **Fig. 4.8** This Phase Locked Loop (PLL) system can be used to synchronize on a set of variable frequency, three-phase sinusoidal signals. If the Automatic Gain Control is enabled, the input (phase error) of the PLL regulator is scaled according to the input signals magnitude. In this system we apply Kp, Ki, Kd for regulator gains and 50Hz frequency.

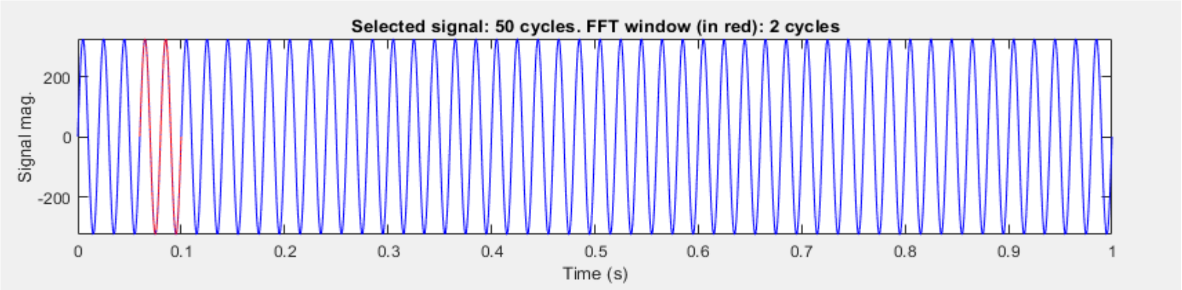


**Fig 4.9:** Signal magnitude of output current**.**

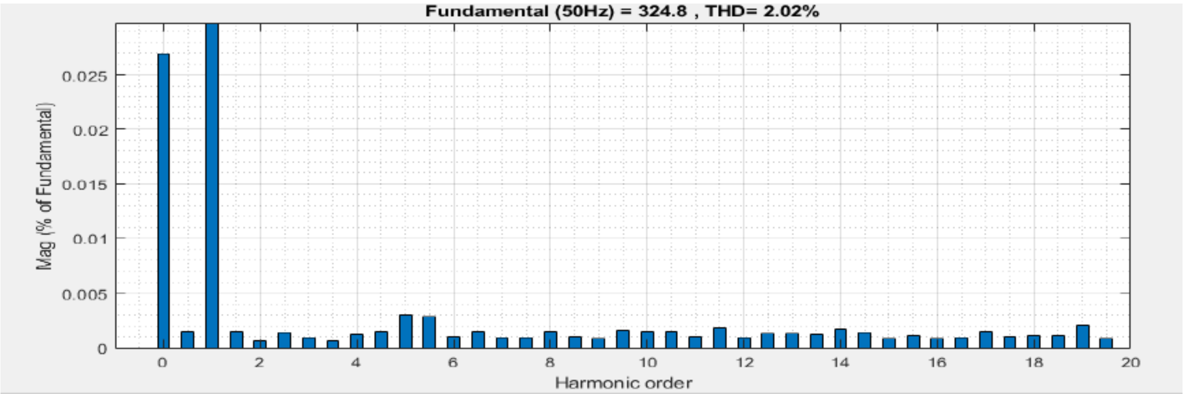
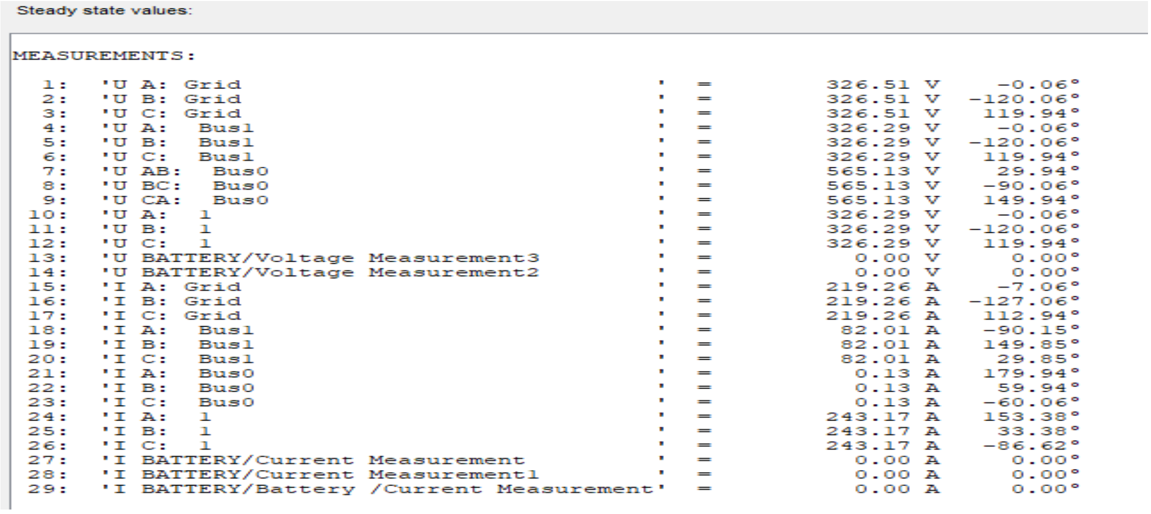


**Fig 4.10**: Frequency spectrum of output current.

### 4.2.1 THD analysis using FFT analyzer

The FFT analyzer is used to do the THD analysis. As we all know, total harmonic distortion has become a critical issue in power systems, as it must be kept to a minimum in order to meet international standards. Lowering THD in the power system results in a greater power factor and lower electricity expenditures, resulting in increased efficiency. The goal of this analysis is to figure out how much harmonic distortion is present in these systems. In **Fig. 4.9** we see that it shows signal magnitude of output current where total 50 cycles present in FFT window but 2 cycles are red because in this time current become distorted. In **Fig. 4.10** we see that our system THD become 2.02% which is very small amount of THD and also we see that fundamental output voltage is 324.9V. We use IGBT in our system which is a power electronic device this kind of device create some harmonic distortion. Because this power electronic is known as non-linear load [6,7,8]. To reduce this THD we use V-F droop control which is very effective to reduce this harmful THD. As a result we achieve our desire value of THD. In this work, we found less than 5% THD which is the standard value.

### 4.2.2 Steady State Values:



Steady state values:

```
MEASUREMENTS:

  1:   'U A: Grid                             '   =        326.51 V     -0.06°
  2:   'U B: Grid                             '   =        326.51 V   -120.06°
  3:   'U C: Grid                             '   =        326.51 V    119.94°
  4:   'U A:  Bus1                            '   =        326.29 V     -0.06°
  5:   'U B:  Bus1                            '   =        326.29 V   -120.06°
  6:   'U C:  Bus1                            '   =        326.29 V    119.94°
  7:   'U AB:  Bus0                           '   =        565.13 V     29.94°
  8:   'U BC:  Bus0                           '   =        565.13 V    -90.06°
  9:   'U CA:  Bus0                           '   =        565.13 V    149.94°
 10:   'U A:  1                               '   =        326.29 V     -0.06°
 11:   'U B:  1                               '   =        326.29 V   -120.06°
 12:   'U C:  1                               '   =        326.29 V    119.94°
 13:   'U BATTERY/Voltage Measurement3        '   =          0.00 V      0.00°
 14:   'U BATTERY/Voltage Measurement2        '   =          0.00 V      0.00°
 15:   'I A: Grid                             '   =        219.26 A     -7.06°
 16:   'I B: Grid                             '   =        219.26 A   -127.06°
 17:   'I C: Grid                             '   =        219.26 A    112.94°
 18:   'I A:  Bus1                            '   =         82.01 A    -90.15°
 19:   'I B:  Bus1                            '   =         82.01 A    149.85°
 20:   'I C:  Bus1                            '   =         82.01 A     29.85°
 21:   'I A:  Bus0                            '   =          0.13 A    179.94°
 22:   'I B:  Bus0                            '   =          0.13 A     59.94°
 23:   'I C:  Bus0                            '   =          0.13 A    -60.06°
 24:   'I A:  1                               '   =        243.17 A    153.38°
 25:   'I B:  1                               '   =        243.17 A     33.38°
 26:   'I C:  1                               '   =        243.17 A    -86.62°
 27:   'I BATTERY/Current Measurement         '   =          0.00 A      0.00°
 28:   'I BATTERY/Current Measurement1        '   =          0.00 A      0.00°
 29:   'I BATTERY/Battery /Current Measurement'   =          0.00 A      0.00°
```

**Fig 4.11**: Steady state values from MATLAB

In **Fig. 4.11** show steady state values from MATLAB simulink. Here it shows bus0, bus1, grid and load voltage and current flow. In bus0, bus1, grid and load voltage are same but current are different because from graph we see that when any load connect there produce current sag which is very harmful for system.

### 4.3 Simulation Result for Without Droop control

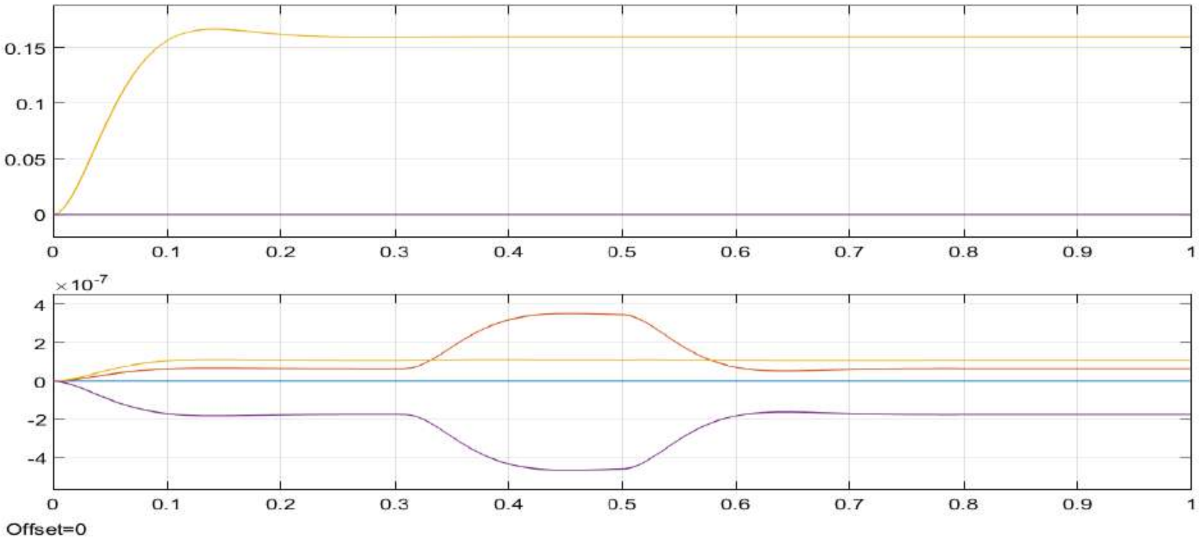


**Fig 4.12:** Active and Reactive power without droop control

From **Fig.4.12** we observed that all real and reactive power which was supplied by converter is not absorbed by the load. Because we use two types of load resistive and inductive. Also we see that after filtering reactive power supply by converter become increased because capacitor inside the low pass filter added to the converter supply. During this simulation, we used 2 types of load at the same time. During this time our proposed controller is deactivated and the NG is loaded by the base load which is equal to the sum if the nominal active power of the DG and utility grid, 10KW.

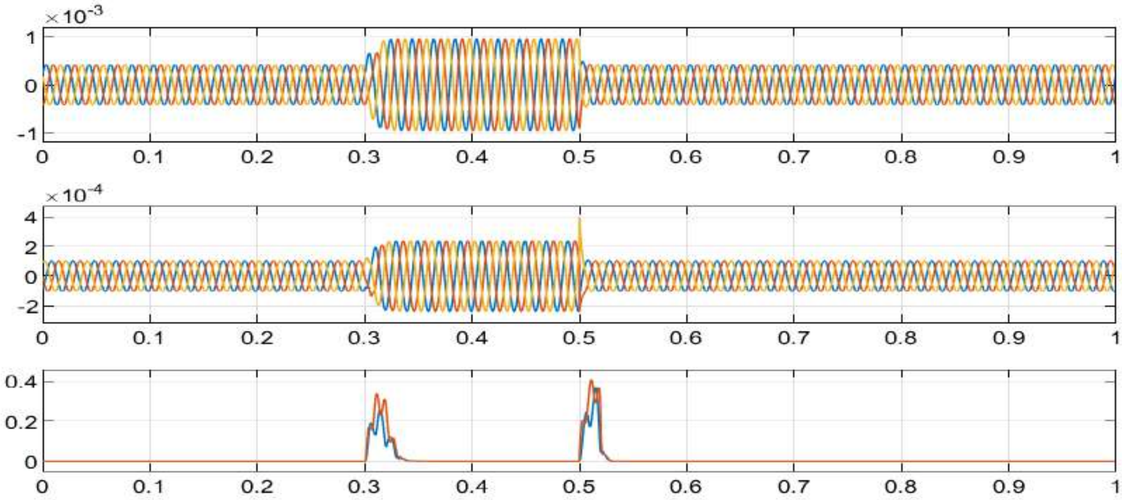


**Fig 4.13:** (a) Voltage curve of the bus 1. (b) Current curve of the bus1. (c) Frequency spectrum of the Bus 1

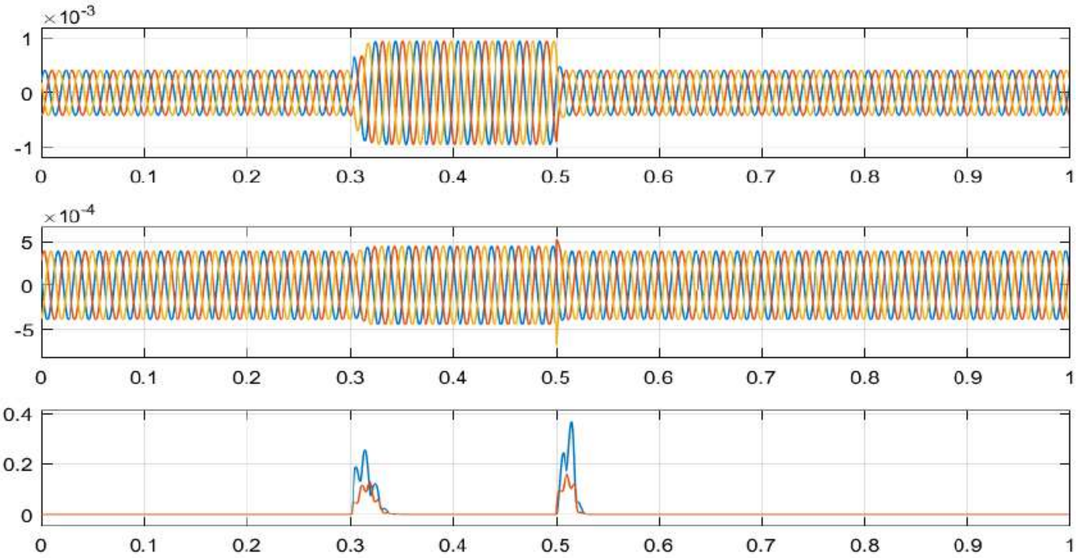


**Fig 4.14:** (a) Voltage curve of the load. (b) Current curve of the load. (c) Frequency spectrum of the load.

From **Fig. 4.13** After filtering our voltage and frequency are not suitable for our system because there produce some voltage swell in this time. For this system we use LC filter which is highly inductive low pass filter, this filter pass DC and low-frequency signals and cut high frequency signals. As a result we find a purely sinusoidal voltage, current in BUS1 but voltage swell create some problem. So that in Bus1 our power factor are not suitable for our system. In third graph we see that at initial time current slightly distorted this time some THD found but it was negligible. In **Fig. 4.14** we observed that voltage not there produced voltage swell but the magnitude of current is slightly produced current swell, because at time 0.3s we disconnected one load from grid. After at time 0.5s we reconnect the load again current increased. We see that load consume 243.17A current. Here suddenly at mid-point current magnitude decrease when we connect inductive load because inductive load consume more current then resistive load. During this period current increase and decrease we see that there is a high THD, at the switching time of the load we see that THD become increase.

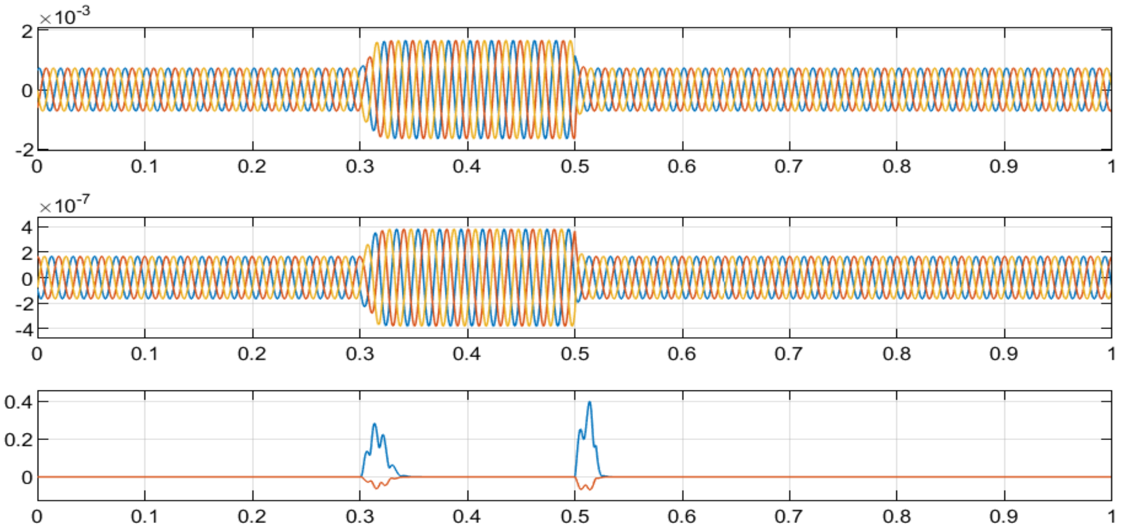


**Fig 4.15:** (a) Voltage curve of the bus 0. (b) Current curve of the bus0. (c) Frequency spectrum of the bus 0

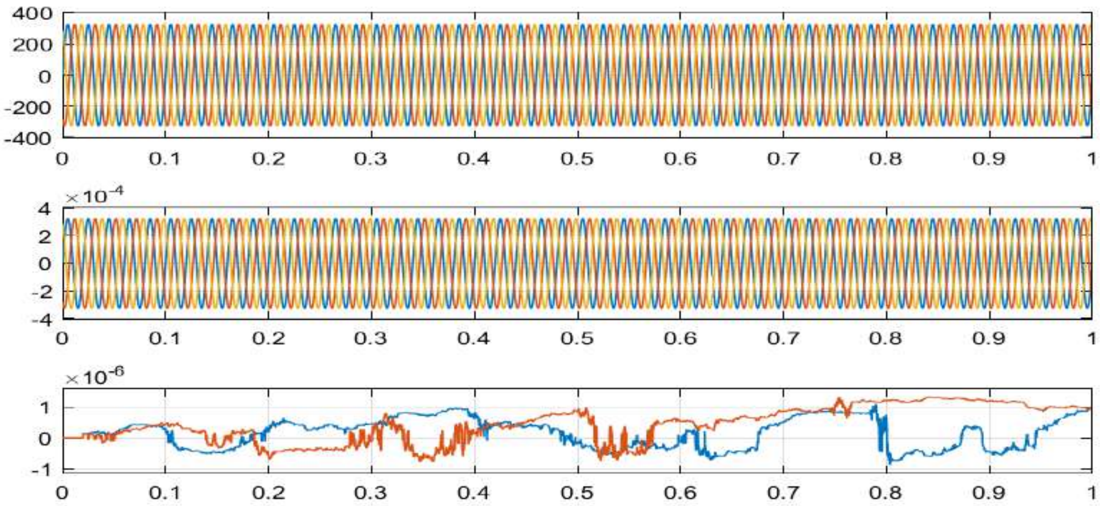


**Fig 4.16:** (a) Voltage curve of the Grid. (b) Current curve of the Grid. (c) Frequency spectrum of the Grid

From **Fig.4.15** we see that before filter in bus0 there is low voltage also low frequency for that reason we didn't find our estimated output. And in this time our current are 0.13a which is very small current flow. Also voltage frequency are not stable because voltage frequency didn't stable by V-F droop control. Without filtering this bus our voltage harmonic distortion become increase. We see that in voltage side graph it's become square that means it's not sinusoidal for that our power factor of the bus0 become decrease also power expenditure will be increase. In **Fig. 4.16** grid there is no fluctuation in voltage and current. Also we observed that voltage is fixed in grid. Here some current are losses because adding a load in the system increase voltage demand also increase power demand of the system as a result we know that P=VI where if P and V increase It will be automatically decrease at that time. But THD are fluctuate at the whole time in grid.

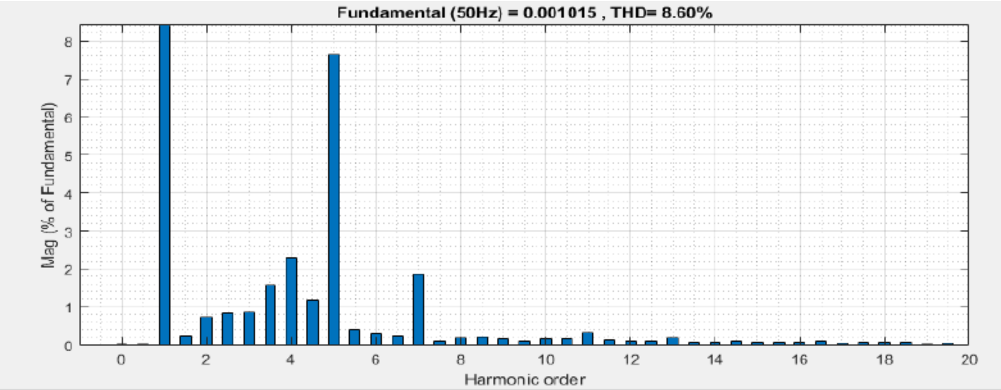


**Fig 4.17**: THD without droop control

In **Fig. 4.17** we see that our system THD become 8.60% which is very high amount of THD and also we see that fundamental output voltage is 324.9V. We use IGBT in our system which is a power electronic device this kind of device create some harmonic distortion. Because this power electronic is known as non-linear load [6,7,8]. To reduce this THD we use V-F droop control which is very effective to reduce this harmful THD. As a result we achieve our desire value of THD. In this work, we found less than 5% THD which is the standard value.

### 4.4 Result Analysis

From simulation result we see that we become control voltage and frequency and find our desired output that means our proposed model are standard. In result section we see that we show two profile at first for with droop control then without droop control. From this two profile we see that our output voltage, current and THD value are stable. But without droop control when we connect any load in system we see that there is a lot of voltage swell occurred in system which decrease the system efficiency. Also in THD section we see that there a lot of harmonics when we doesn’t use droop control. But after all when we use droop control our THD percentage we bring from 8.60% to 2.20%. In any system which maintain THD less than 5% that’s call standard THD. So we can say our proposed method are standard THD maintain model. And when we use droop control our voltage become control when any load connected in a system. We see from result within 0.2s our controller become control voltage and frequency which is very much impressive result for Nano grid system.

# CHAPTER 6
# Conclusions

## 5.1 Conclusion

This research proposed a new controller which is control the NG and increase power quality and stable the whole system. In this research we proposed a V-F droop control which control voltage and frequency and adjusts to their acceptable values. The proposed approach was used to modify the system voltage and frequency by controlling the output of the DGs in an NG system using the droop controller coefficients. The frequency reference signal is changed for VF units. PQ units, on the other hand, use frequency error to change their active power references. To compensate for the frequency deviation, identical PI controllers are used to locally analyze the frequency error at each unit and estimate the associated change in the droop line location.

Our proposed method and NG model verified by applying it to a test system simulated in Matlab/Simulink environment. To make this model we use different kind of electronic device and also battery which is the optional device for Nanogrid. From result we see that our active and reactive power are clearly share in different bus and load and when we connect load, controller become control within a few second and stable the system. Which denotes that our method are more robust, efficient, more reliable and it can response fast in controlling NG parameter.

## 5.2 Future Work

1. Nanogrid Testbeds system which can control nanogrid and nanogrid network which will be very beneficial for consumer. This will allow for long-term monitoring of power flows as well as advancement of control techniques.

2. The characteristics of the nanogrid network, as well as its connectivity to the national grid, will need to be investigated using a testbed.

3. The nanogrid network also introduces a variety of societal implications that will need to be investigated more in the future. More research into the advantages of a nanogrid/nanogrid network to power providers in terms of national DSM and disaster response should be performed.

### 5.3 Limitation

In the literature additional limits were found. First, the limited purpose of MATLAB Simulink is to model practical grid circumstances, since the situation in the real world has a lot of implications for the grid. But Simulink must have been known in MATLAB as the ideal grid. Second, we do not find any lab support from any university, lab, or any other organization. Thirdly, history of Nano grid research are small essential parts of NG are controller, gateway, DGs, are the promising research field. Also the instrument of NG are too expensive as a result funding barrier and other shortage of standard lab facility hampered the research of Nano grid.

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