Microgrid Protection using Directional Overcurrent scheme

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(Electrical Power Systems)

By

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CERTIFICATE

This is to certify that the Major Project Report entitled “”Microgrid protection by using directional overcurrent scheme” submitted by Mr. Suchit Soni (15MEEE24) towards the partial fulfillment of the requirements for the award of degree in Master of Technology (Electrical Engineering) in the field of Electrical Power Systems of Nirma University is the record of work carried out by him under our supervision and guidance. The work submitted has in our opinion reached a level required for being accepted for examination. The results embodied in this major project work to the best of our knowledge have not been submitted to any other University or Institution for award of any degree or diploma.

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I would like to express my immense gratitude to my project guide Prof. Shankar Godwal, Department of Electrical Engineering, Institute of Technology, Ahmedabad for his valuable guidance and continual encouragement throughout my preface of project. His constant support and interest equipped me with a great understanding of different aspects. His supervision and direction right from beginning motivate me to complete this period of project.

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Abstract

At distribution level the infiltration of distributed generation increases, managing of these systems effectively becomes an ultimatum. One Recommended way to manage these systems is validation of Micro grids. Micro grids are smaller version of large power systems.

At distribution network side Micro grid can formed with collaboration of several Renewable sources and loads,that utilize as single aggregated load or generation sources.micro grid can either connected to the grid or in case of a grid fault in island-ed mode.Micro grid would be improve system Efficiency and Reliability.Its objective is to deliver reliable and quality energy in both modes. PS-CAD would be used for modelling of small distribution network as if it were micro grid. Renewable sources along with dispatch-able sources could be added;Which supply power at maximum requirement for load more than average load.The type fault would be simulated at buses in both grid connected and island ed mode. At that time the Analyzing of fault current and voltage levels obtained.According to that deciding of protection scheme at distribution network.A protection scheme has been developed which consist of directional over current relays.These relays are coordinated in terms of their operating time.

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Chapter 1

Introduction

1.1 General

The community depends gravelly on a secure supply energy.Generally the concept of power systems are centralized.The main topic currently being mattered by the alert on global warming,pollution and carbon footprint emissions.sometimes it could be major concern of Power grid failure & also high transmission line losses so that distribution side generation by DGs would be appropriate choice as solutions.

throughout departed years, the rise of DGs has been growing.Different micro generation technologies, like PV cells, fuel cells,diesel engines,wind turbines, micro turbine with rated power appropriate 100kW that can be connected at distribution network.As the combination of these units are connected at the consumers side.That gives promising options for consumer in the form of reliability,power quality & good economic,technical,environmental benefits.

At presents, New inventions which makes it easy to utilize power with higher efficiency from the micro sources.Micro grids expanded into two categories: off-grid systems, which operate in isolation, and grid-tied systems, which has a single common coupling with the main grid but still operate self sufficiently.

As micro grid comes in picture, protection scheme of distribution systems and micro grid required and also interconnection of main grid and micro grid.It necessity to change in existing protection system.Relay coordination ensures that relays operate within the time limit,Hence clearing the faults before they originate major harm to the system.

1.2 Defination

At distribution side Micro grid consist of distributed energy resources (DER) like;PV,Micro turbine,Fuel cells etc. together with storage devices (energy capacitors,batteries and fly wheel) and flexible loads. These kind of systems can be operated in non-autonomous way if interconnected to the grid, or in an autonomous way, if disconnected from the main grid.The operation of micro-sources in network can endow distinct benefits to overall system execution, if managed and coordinated efficiently.

In another report from the Congressional Research Service (CRS) a slightly different definition of a Micro grid is provided:

A Micro grid is any small or local electric power system that is self- sufficient from the extended electric power network.
For example, combined heat and power system based on a natural gas combustion engine (which co generates electricity and hot steam or water from water used to cool the natural gas turbine), or diesel generators, renewable energy, or fuel cell.

1.3 Microgrid

MIcrogrid is define as cluster of inter-appended loads and distributed energy resources within distinctly defined electrical ranges that act as single controllable authority with respect to the grid. A Micro grid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode.
These micro sources can be either renewable sources,diesel engine,fuel cells or microturbine.
The micro grid assumes three critical functions for the uniqueness of the Architecture :

- micro source controller
- Energy manager
- Protection

From definition it can be says that:

1. Micro grid is an co-ordination podium for supply-side, storage units and demand resources vested in a local distribution grid.
2. A micro grid should be eligible of handling both normal state (grid-connected) and emergency state (Islanded) operation.
3. The difference between a micro grid and a passive grid penetrated by micro sources recline mainly in-terms of management and adjustment of available resources.

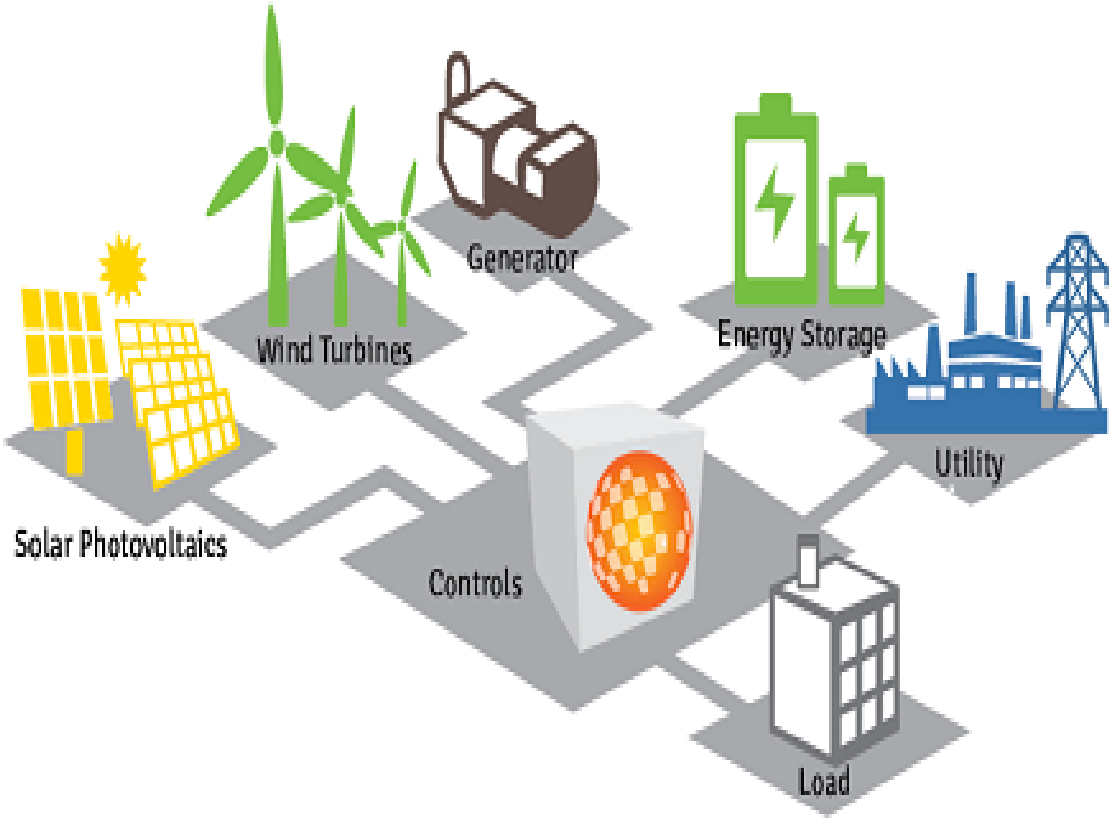

Figure 1.1: Micro grid

However, To operate micro grid in our expected manners - grid connected and islanded; We requires some micro grid technologies:

- Distributed generations
- Bidirectional and is-landed inverters

- Smart-meters
- Distribution Automation
- Sub-station Automation
- Micro grid control systems
- Advanced storage systems

There are certain standards and protocols defined for micro grid.The IEEE P1547.4 guide for design,operations and Integration of distributed resources with power system.IEEE 1547.4 covers the opinion for planning and operating of micro grid. This incorporate Impact of power quality,frequency,voltage,single point of common coupling (PCC),protection schemes and modifications.This contains 1547-2003,1547.1-2005,1547.2-2008,1547.3-2007,1547.4,1547.5 etc. standards,all give guidelines and procedures for relevant performance,operation,testing and maintenance of interconnection.

1.4 Micro grid Value Proposition

- Efficiency
  - Alleviate Fuel consumption
  - Supply near to demand minimize distribution losses
  - Conspire electricity and heat generation

- Reliability
  - Optimally direct on-site energy resources 24/7
  Power quality and reliability at the positional level

- Energy Security
  Secure energy supply for critical loads utilizing on-site generation
  Grid liberation capability

- Economic Savings
  Peak Shaving/Load shifting and supply management with demand response
  Enables hedging against energy cost fluctuation
  Reduction of cost of electricity with on-site generation and effective energy management

- Sustainability
  Reduction of carbon footprint by integrating cleaner fuel resources

1.5 The key features of a Microgrid include:

1. operation in both island mode or grid-connected
2. combination of interconnected loads and co-located power generation sources
3. provision of varied levels of power quality and reliability for end-uses, and
4. designed to accommodate total system energy requirements

1.6 Protection

One of the volumetric challenge is to formation of the protection scheme for micro grid to ensure its appropriate functioning. And this design has to be similar with the national distribution codes.The flow of power in conventional distribution system is fictitiously in unidirectional and hence the protection scheme of systems are designed accordingly.
Protection must replicate to both utility grid and Micro grid faults. If the fault is occur at utility grid, the desired action required to isolate the Micro grid from the main utility as quickly as necessary to protect the Micro grid loads at distribution network side.
If the fault is inside the Micro grid, the protection coordinator isolates the smallest probabilistic section of the Micro grid to discard the fault.
An ideal protection system for a micro grid should possess following features:

- Must replicate to both distribution system and micro grid fault.
- For a fault on main grid, isolate the micro grid as speedily as possible.
- For a fault inside micro grid, isolate the smallest possible section of the radial feeder carrying the fault.
- Effective operation of customers' protection.

1.7 Types of Micro grids

1. Campus Environment/Institutional Micro grids
2. Military Base Micro grids
3. Commercial and Industrial (C & I) Micro grids
4. Community/Utility Micro grids

1.8 Literature Survey

(1) Robert H.Lasseter, "CERTS MICROGRID,", IEEE JOURNAL

- In this Report He presented fundamental information of micro grid, And he discussed about CERTS micro grid, Which has two critical components : micro sources and static switch.
- In this, Static switch has caliber to autonomously island micro grid from faulty section of system and also reconnect after distinctly fault.
- The synchronization obtained by using the frequency difference of islandaed micro grid and utility grid insuring transient free operation without having to match frequency and phase angle at the connection point.
- Micro grid also reliable, the reason defined on the report is that if one source of micro grid is accessible by simple plug n play and it can be used without re engineering the concepts and control (protection schemes also)no need to change.
- Protection schemes for both is-landing and grid connected operations are same. The static switch is designed to open first after the fault occur inside that would be clear by techniques as per zone protection.

(2) Benjamin Kroposki,Thomas Basso & Richard DeBlasio, "Micro grid standards and Technologies,"IEEE International Conference

- This paper addressed about micro grid technology & standards that are gives information about implementing micro grid and benefits to customer & utility .
- They write up about , IEEE 1547.4 key inspection for planning and operating micro grids.
- This links: effects of power quality, frequency, voltage ,protection schemes and modifications, monitoring, information swap and control, knowing the characteristics of the DERs, understanding interactions between machines, surplus equipment requirements, and additional functionality associated with inverters.
- This guide is to assist power system designers, operators, system integrator, and equipment manufacturers to understand & give opinion for implementing micro grid.

(3) Y. Zoka et al.,"An interaction problem of DGs installed in micro grid.

-In this, the author evolved micro grid model implementing of DRs,(micro turbine, fuel cell , diesel engines) Then problem of interaction is slacken by using numerical solution.

(4) Niraj Kumar Chaudharyl, Saumya Ranjan Mahantj & Ravindra Kumar Singh, "A Review on microgrid Protection.," International Electrical Engineering Congress 2014

- Reviewed on the conventional protection scheme of the distribution system and the challenges regarding to the MG protection system along with the discussion of alternate protection strategies.
- Observed that the conventional over current protection Schemes are no longer substantial for the is-landed mode of Operations.
- Due to Incorporation of Distributed Generation (DG) into the distribution system it has increased the complication of protection.The short circuit current magnitudes and directions are not same and therefore the existing protection schemes may not be able to execute its coordination function correctly and that's why directional over current protection going to use.

(5) Aushiq Ali Memon, Kimmo Kauhaniemi , " A critical review of AC Micro grid protection issues and available solutions," Journal homepage:www.elsevier.com

- Observed the protection schemes for three main categories:

  - the schemes for only grid-connected mode
  - the schemes for only is-landed mode
  - the schemes for both grid-connected and is-landed mode

Also,Briefs the convenience and limitations of each schemes is well describe.Most of the offered adaptive protection schemes that are able to work in both grid connected and is-landed mode of micro grid required communication links.
Therefore, Reformation of communication system reliability or provide alternate schemes to cope with communication inaccuracy & protection against cyber-attacks & secure operation of future micro grid.

(6) Alias Khamis et al.," Modelling and simulation of small scale Micro grid System", Australian Journal of Basic and Applied Sciences.

- This paper exhibits basic modelling of micro grid in PS CAD.They have also cited the parameters to set for different DG sources.
- They used PV,Wind and storage batteries in micro grid. Major focus is on parameters and effectiveness of inverter.

(7) Qiang Fu ,"Modelling analysis and assessment of microgrids considering renewable energy penetration",University of wisconsin-Milwaukee Author addressed about the different DG sources basic modelling and their characteristics in PS CAD.In this he mentioned about different parameters of Diesel generator ,storage batteries and PV etc.

(8)E. Muljadi, M. Singh, and V. Gevorgian," PSCAD Modules Representing PV Generator", National Renewable Energy Laboratory did detailed analyses of PV generators.They described about PV inverter modelling using PSCAD.

(9)Islam Ali and Bekir Zihni Yuksek,"Grid connected wind turbines- A Simulation study",
This paper guided about grid connection complications for wind turbines and gave appropriate solutions. They described the comparison for modelling of wind turbines in PS CAD and MAT LAB.

(10) Nikos Hatziargyriou ," MICROGRIDS: ARCHITECTURES AND CONTROL", wiley IEEE ebook

- In this author addresses the concepts of micro grid from various forms of implementation to potential economic,environmental and technical benefits.

- He addresses two great challenges of micro grids: control and protection and also describes devious methods for providing befitting protection functions such as adaptive protection schemes.

- He also elaborates on the technical,economic,environmental and social benefits of micro grids.

(11) M.G. Simes, B. Palle, S. Chakraborty, and C. Uriarte "Electrical Model Development and validation for distributed Resources"

- This was guided about the Diesel generator and also the development of the simulation in PSCAD.

(12)Amit Kumar Jindal, Aniruddha M. Gole and Dharshana Muthumuni "Modeling and Performance Analysis of an Integrated Wind/Diesel Power System for Off-Grid Locations"

-This paper presents the modeling and performance analysis of wind/diesel hybrid generating system.

1.9 Problem Identification

This project expected simulation of micro grid, cluster of micro sources, main grid. Micro grid can be knitted and synchronization to main grid. When fault take place at any point of the power system than whole system should not be affected.If fault occur at the main grid than micro grid should isolate from the main grid and intercept itself from any spoilage. Same as in case the fault occur in micro grid ,it should separate from main grid to prevent fault in it. For these kind of situation a good protective scheme should executed to prevent system from damages.

1.10 Objective

The solution of the above discussed problem would be to use distribution side generation. By applying distributed energy resources so that transmission line losses and environmental issues can be solved easily.

To improve power system reliability and quality micro grid can help. Micro grid could be applied to the main grid as backup during the heavy fault occurs on system.According to load-shedding in peak hours Micro grid configuration may change as per various control.

For project accomplishing, simulation of power system that consisting of main grid, micro grid and protection schemes should required. PS CAD/EM TDC software found suitable for this purpose. The photo voltaic Array , Wind turbine, diesel generation system,battery system simply formulate in PS-CAD and it take times to synchronized it. In software individual micro sources has been simulated first and run to obtain essential output.Once these individual systems were calibrated then they were connected together to load in order to make Micro grid. Then after micro grid connected to main grid,that is WSCC nine bus system in this case. both grids were synchronized for proper functioning and after that protective scheme was designed and implemented.

Chapter 2

Modelling of micro grid

Micro grid modelling involves modelling of micro sources with storage also. micro sources are not only AC sources (PV) therefor inverter modelling also required. Similarly for wind farm , diesel generator it requires frequency to be maintained for synchronization with grid. The software being used for modelling is PS CAD/EMT-DC 4.5 student version.

2.1 Distributed Generation Sources

The IEEE interpret distributed generation as the generation of electricity which facilitate that are miniature than central generating plants so that to permit interconnection at nearly any point of power system.The DG source varies from country to country,because of the standards also varies according to different criteria of different Institutes. DG sources that constitute the micro-grid for the given project are PV , Wind and Diesel.

2.2 PV system

The fig. 2.1 exhibits the model of Photo voltaic.The modelling system includes PV module,resistor,inductor,circuit breaker,inverter,storage capacitor and voltage collapse limiter.

Solar irradiates and temperature are input of the PV module.As the slider varies input also varies accordingly that output of inverter also commute.

In PS CAD, there has been selections in PV module that can be change as the number of solar cells, solar cell strings, and arrays,in series and parallel both connection. Which maintains the change in output of system. PV system gives an output approx 375kW.

2.3 Wind farm

The wind farm model shown in figure 2.2 formations of wind source,wind turbine,Governer and synchronous generator.This module is then connected to a converter circuit,coherent of power and frequency converter and other components for voltage regulation.

There are different types of wind turbines acquirable and used practically. The ultimate way of classification is horizontal and vertical axes. In the model Horizontal Axis wind turbine is considered with three blades.Similarly,the generators can be selected from two options,viz. Permanent Magnet Synchronous Generator and Doubly fed induction generator.

In the model, PMSG was used.The combined model is shown in figure 2.3 This model is build according to the PS CAD road book.That gives detail description of components used and the reason for their use.The given model is for 3MW rating, although the output is not as high as the rating of generator.

2.4 Battery system

When renewable sources are used for power generation.For suitable reliable supply of power,a storage device can be used. Battery is also designed for emergency purposes for the micro grid.Battery is DC source, so inversion circuit required to connect DC to AC of desired frequency of 60 Hz.The figure 2.4 shows the battery system in PS CAD.

2.5 Diesel generator system

The Diesel generator shows in figure 2.5. In that synchronous generator managed by diesel engine. synchronous generator connect with exciter and timer.The control system consists of PI controller whose input is the offset of actual speed and reference speed that control the actual diesel engine and outcome controlled torque that is send to the synchronous generator.

2.6 main grid

A standard WSCC nine bus system is simulate to consist main grid.This system has three generator machines and those are interconnected through nine buses.The nine bus data taken from some online sources. Micro grid is connected to this main grid.The main grid system is shown in figure 2.6. The output from micro grid is to stepped up to connect it to main grid.micro grid output has to link with one of the bus of main grid and than synchronization requires then after analysis requires.

2.7 Micro grid system

As per the definition micro grid is the cluster of the distributed resources and loads within some electrical boundaries. which function as single entity with respect to grid.So in previous simulations we have seen the isolated systems of the distributed resources.The Micro grid was synchronized so we get the desired wave forms of power,current and voltage.Initially wind system, PV system and diesel system simulated were connected together to form a micro grid.But due to synchronization issues,two wind systems and one diesel system are connected together to form desired micro grid system.The wave form thus procured in next chapter.The micro grid output is stepped up to 230kV in order to connect it to main grid's bus 7.

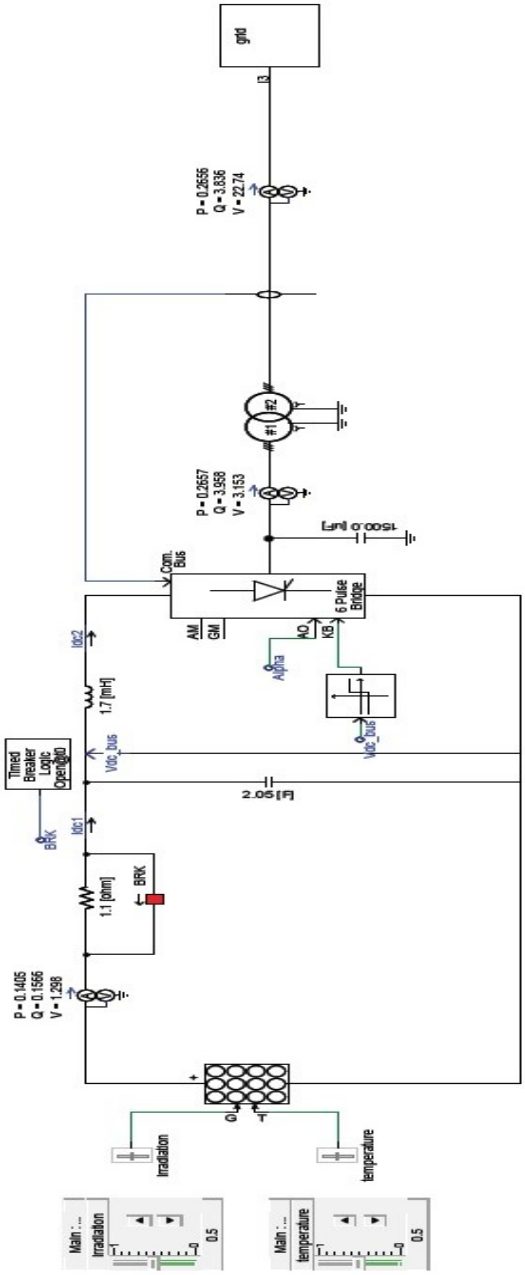

Figure 2.1: PV system

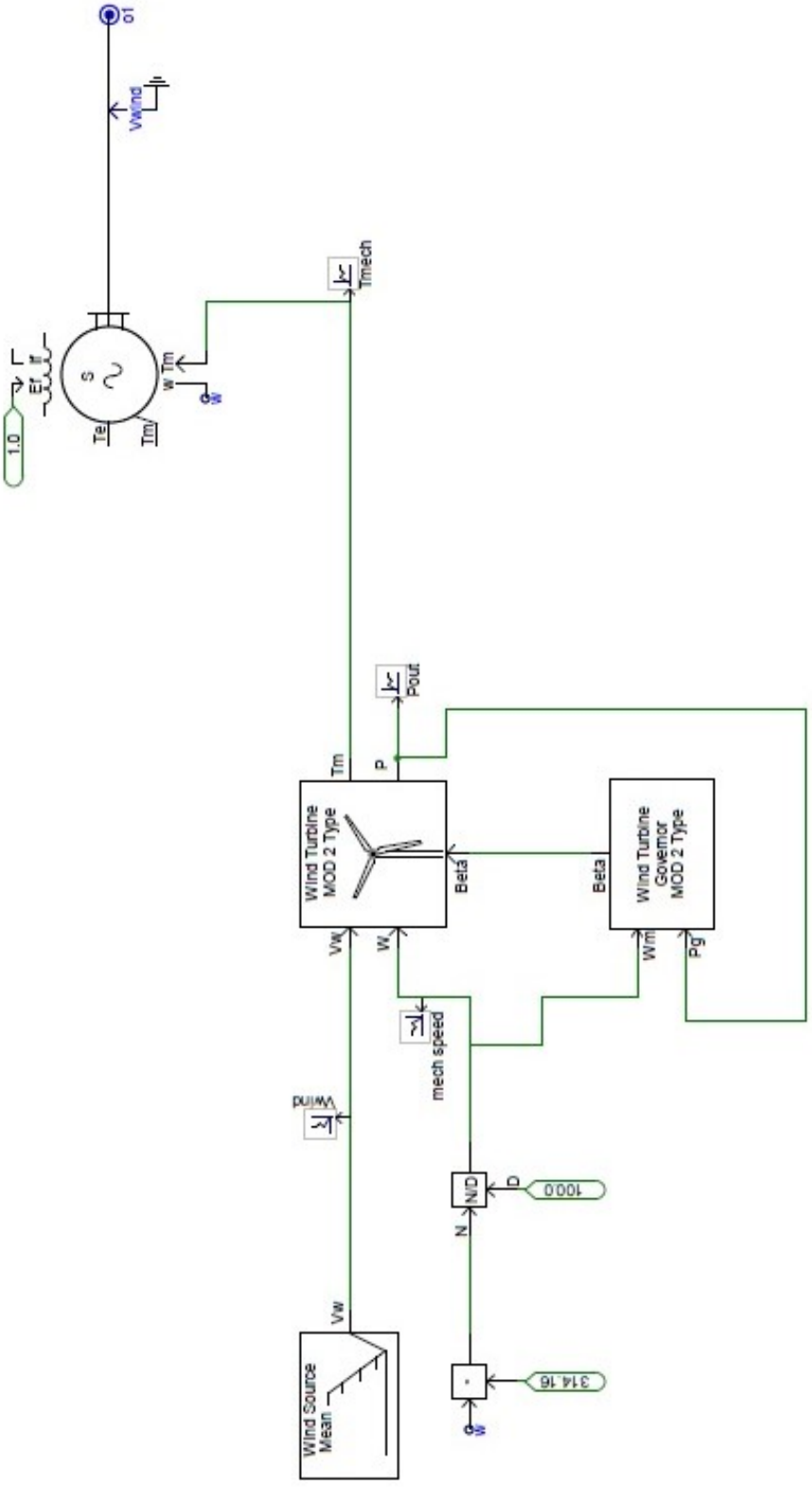

Figure 2.2: Wind System

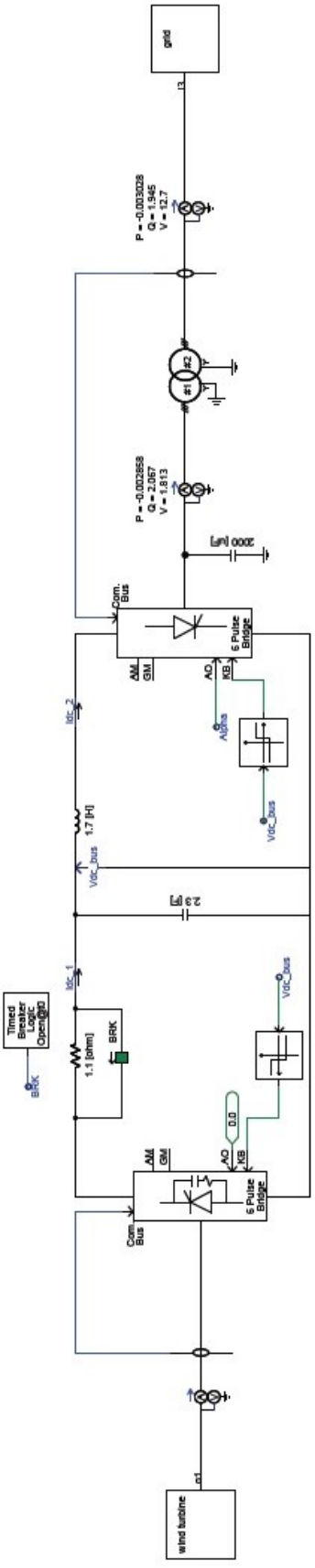

Figure 2.3: Wind system with converter circuit

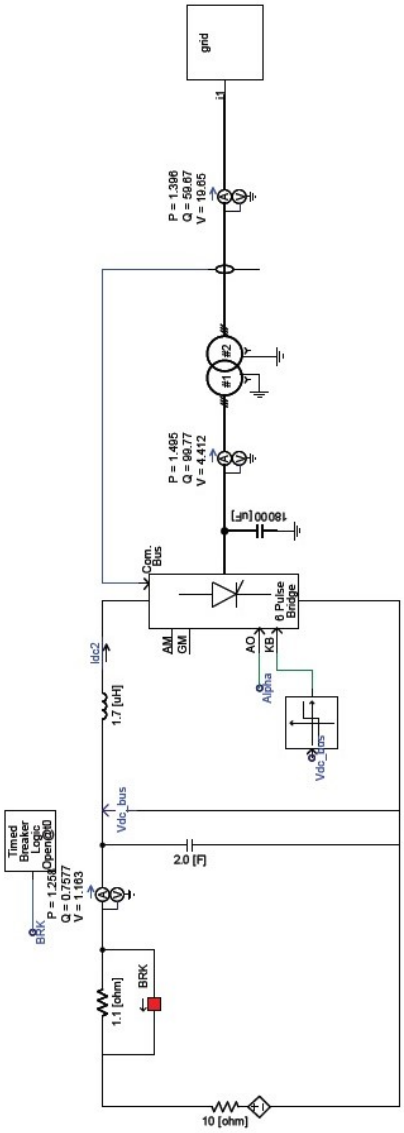

Figure 2.4: Battery system

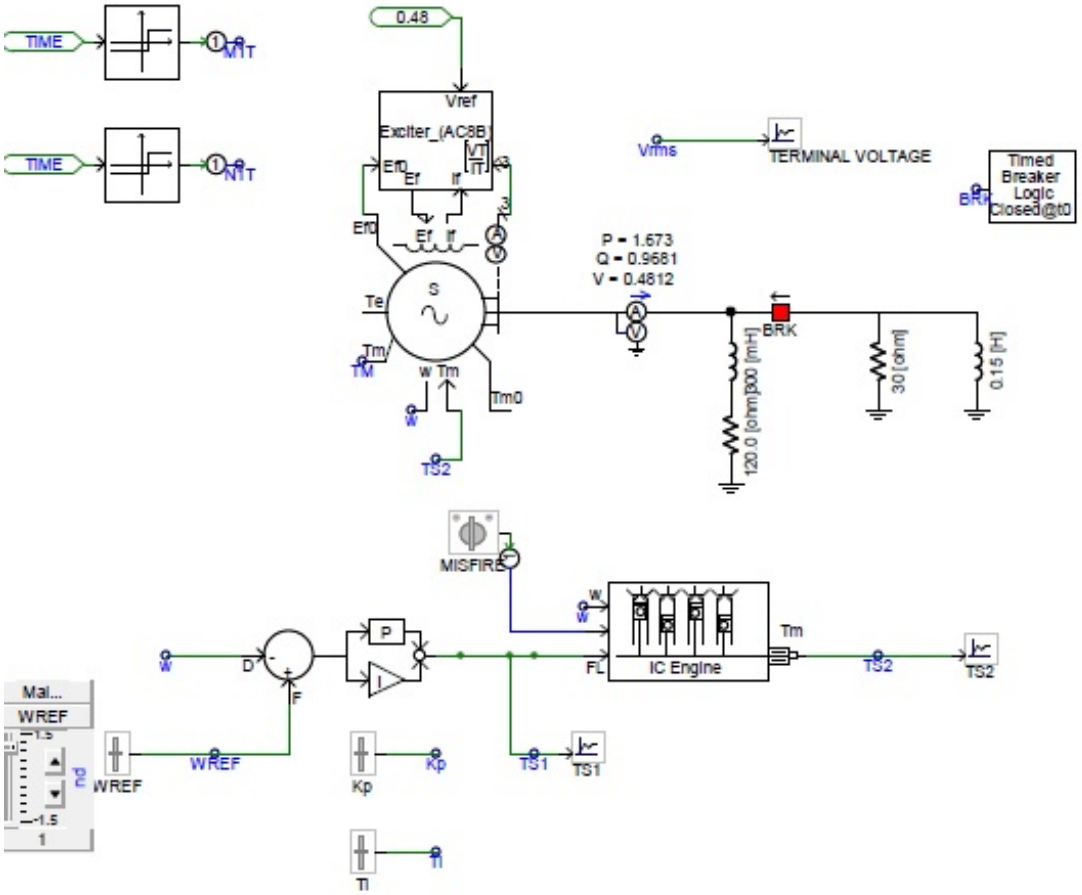

Figure 2.5: Diesel generator system

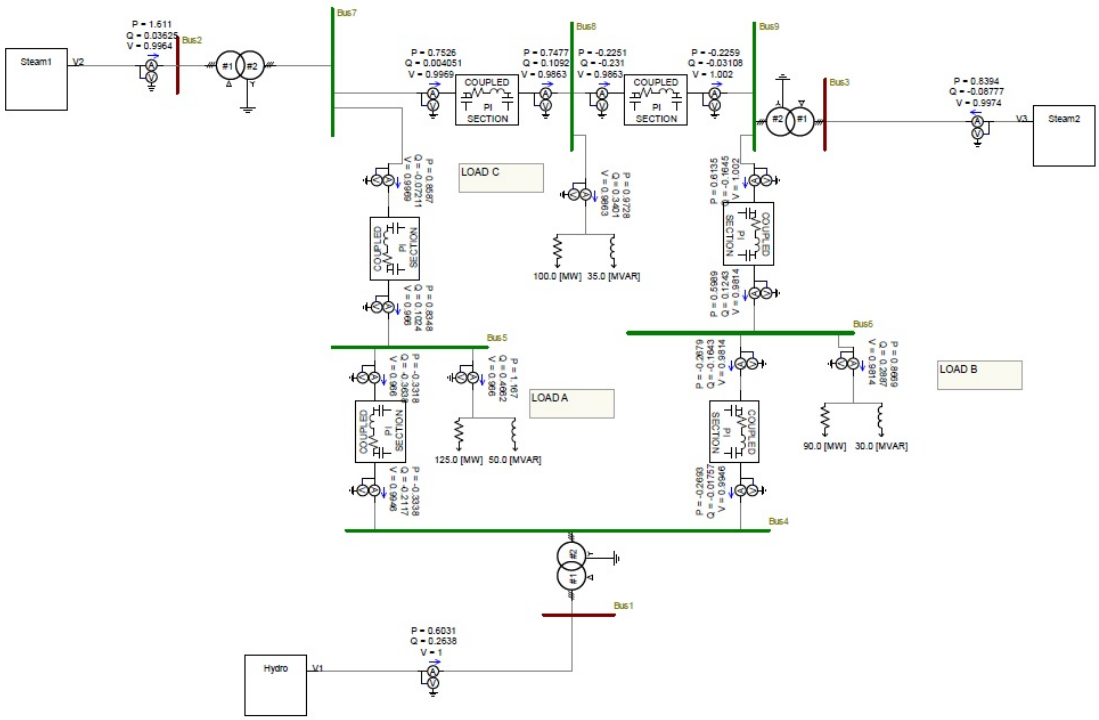

Figure 2.6: Main grid

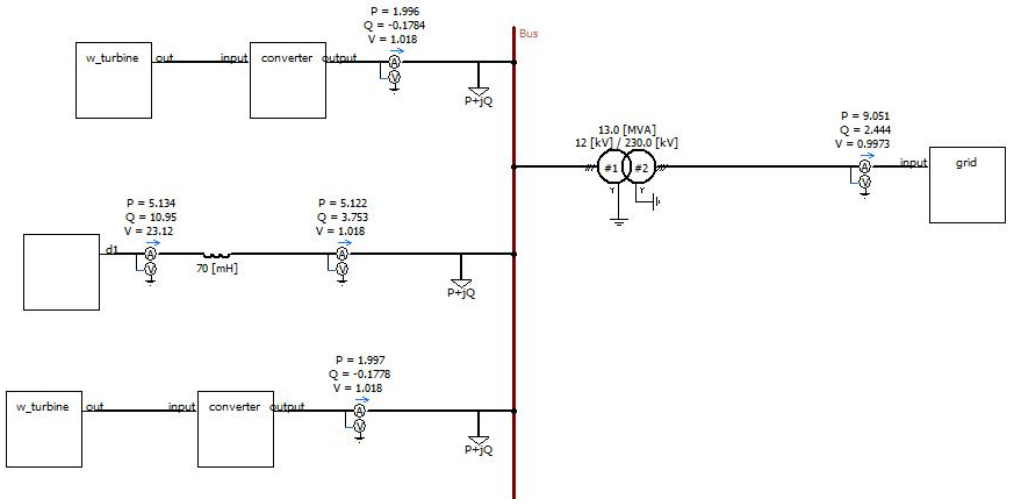

Figure 2.7: Micro grid system

Chapter 3

Protection

In power system main branch is power system protection.That deals with the power system's protection from faults by isolating the faulted part from remain healthy electrical network.The purpose of protection scheme is to keep power system safe by isolating the components which are under fault,therefor remain network can still in operation. Thus Protection schemes must apply with very intercepting and approaching to clear systems fault.Protection system devices has to do with utmost selectivity, sensitivity and speed. In power system fault are not frequently happen so that protective devices interpolate all life watching the power system.

3.1 Types of Protection Schemes

A protection scheme consists of one or more protective relays for same or different type of faults.It is totally based on needs of protection for equipment or section of line. In power system based on this protection scheme classified into four categories:
1) Over current protection scheme
2) Distance protection scheme
3) Differential protection scheme
4) Carrier protection scheme

OVER CURRENT PROTECTION SCHEME: A shunt fault is leads to unexpected build of current.When this current goes beyond the range it harm the equipment and the system. It is natural that the magnitude of current be utilized as a positive clue of existence of fault.When type of protection rely on only magnitude of current is defined as non-directional over current protection. Many times it is required to recognize between faults in front of the breaker and fault behind the breaker.In such matter we take into account the magnitude of current and also phase with respect to voltage at relay location take into. these are called as directional over current protection.

Distance protection scheme: The fault current can be given as a function of the source impedance and the fault type.Both the parameters are floating so relays

whose reach is unconstrained of the current magnitude should be selected principally in case of EHV lines. As no mal-operation can be endured in EHV lines.Due to boundary of over current protection, i.e. variable reach and variable operating time due to changes in source impedance and fault type distance protection came into presence. Distance relays reach is dependent on the ratio of voltage at relay location and fault current. Modern distance relays put forward high speed fault clearance. These are used for protection of high and extra high voltage transmission and sub transmission line (220kV,132kV,66kV,33kV). Prerequisite distance relays include Impedance relay,Reactance relay and Mho relay.

Differential protection scheme: In power system at normal situation current entering and leaving an equipment is same. But fault take place in electrical equipment, it would cause current entering it and leaving it both are different. This logic is used by differential protection. Thus after encountering two current at equipment's terminal and it emerge a trip signal if difference surpass a set value .This is applicable in case of transformer, large motor. Generator and buses etc. In case of transmission lines the large length becomes barrier.
Carrier Protection Scheme: This protection scheme appropriate for EHV & UHV lines. Distance protection scheme has deficiency not to cover whole length so it leads to this protection scheme. The lag point of distance Scheme is not able to provide instantaneous and simultaneous tripping from both ends of lines. It procure high speed accurate protection to only 60% of whole line. Any unit protection scheme like carrier protection does not encounter any such problems. It is able to provide high speed and accurate protection to whole line.

3.2 Over current protection

Project focuses on directional over current protection.As depicted earlier, over current component make a use of the fact that fault directs to unnoticed rise in current level.In over current protection both numerical relays and electro mechanical relays finds applicable.The OC relay operates on plug setting which states current required for relay to pick up and time setting which decides the time taken to operate. In pursuance of the different time-current characteristics relay can be classified.

a. Definite time over current Relay: When the current surmount the set pick up value, a definite time over current relay operates after predestined time. The operating time is constant,irrespective of magnitude of current beyond the pick up value.The desired operating time can be set with cooperation of an intentional time delay mechanism.

b. Instantaneous overcurrent relay: An instantaneous signify that there is

no time delay in relay.Although some time is still extracted by relay to operate. The time of operation is in terms of few milliseconds. Such relay has only pick up setting no time setting.

c. Inverse time over current relay: This relay operates when the current overshoot its pick up value. The time of operation rely on the operating current magnitude.As the fault current expands the operating time is lesser. This is beneficial, due to higher the fault current more speedily relay operates.

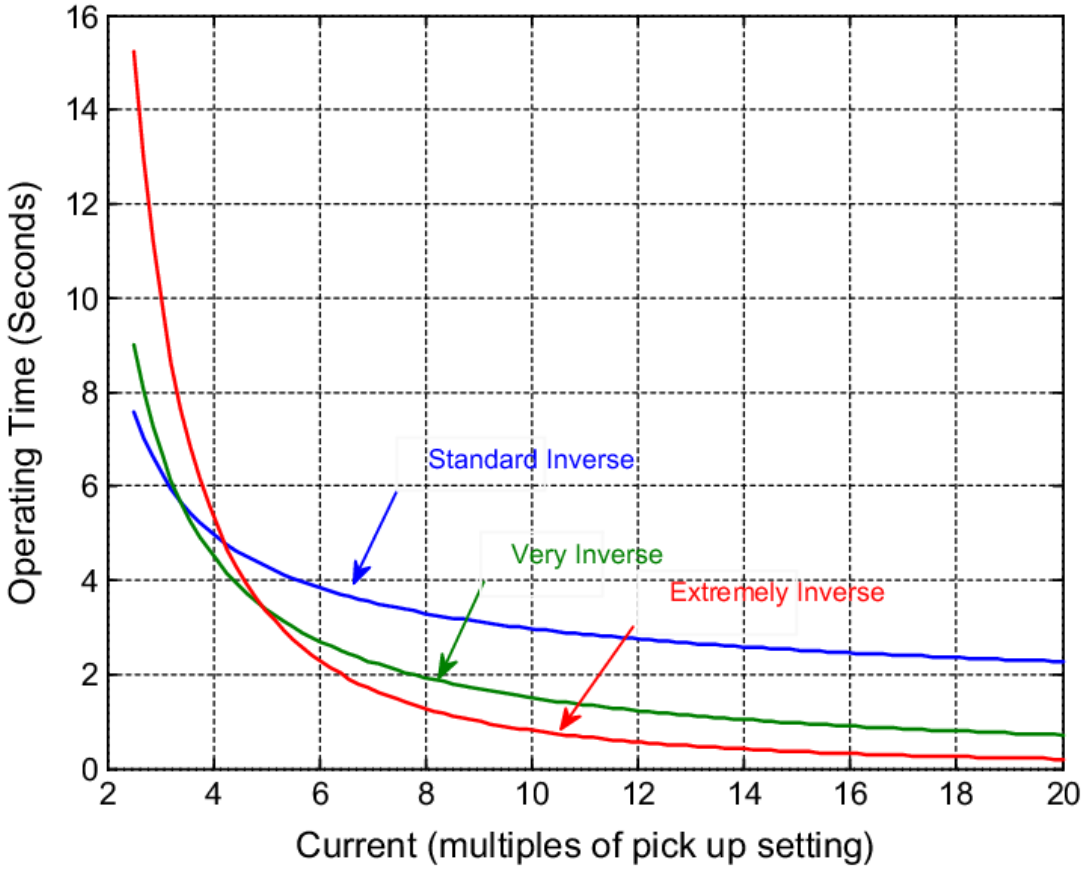

Figure 3.1: Time-Current Characteristic

d. Inverse Definite Minimum Time Over current Relay: IDMT relay comprises features of both inverse time relay and definite time relay.When the plug setting is less than 10, the relay acts like inverse time over current relay. when plug setting more than 10 it tends to act as definite minimum time over current relay.IDMT relay widely used for distribution lines protection.

e. Very inverse Time over current Relay: This relay gives more inverse time-current characteristics than other inverse relay or IDMT relay. Its time-current characteristic stays between an IDMT characteristic and extremely inverse characteristic.This relay has better selectivity than IDMT. The operating time of this relay can given by:

$$T_{op} = \frac{13.5(TMS)}{PSM - 1} \tag{3.1}$$

f. Extremely inverse time over current Relay: The time-current characteristic are even more inverse than IDMT relay and very inverse relay. When the selectivity of IDMT relay and very inverse relay bust up than these relays are employed. The operating time is given by:

$$T_{op} = \frac{80(TMS)}{PSM^2 - 1} \tag{3.2}$$

All above discussion about relay time-current characteristics can be represented by fig.

3.3 Directional Over current Relay

In state of parallel feeder or in radial feeder fed from both the ends, to maintain uninterrupted supply to all the loads,feature of over current is not advisable.In such scenario, along with over current a directional feature is also to be employed. Directional character assures operation only for the direction they are designed to operate. Directional character is compiled by comparing the direction of flow of current and the bus voltage. Mainly it measures the phase angle between voltage and current vectors.In the project voltage and current phasers are generated in PS CAD using FFT block and then these are compared to get the phase difference.

3.4 Coordination

The protective appliances that together build the protection scheme need to work in coordination.By adjusting the time of operation of each devices the coordination has been done after the fault seen.by separating power system into zones also helps in coordination scheme. In the model prepared directional over current relays are used. All these relays are coordinated in terms of their operating time.

3.5 Protection Scheme in PSCAD

The micro grid designed and simulated that required to operate without any obstacles. For smooth,uninterrupted supply of power a reliable protection scheme should be engaged.In this project protection scheme designed using directional over current relays. As defined earlier,Directional over current relays trip when the current goes above the pickup value and also the direction of fault current is as per the relay setting.To add over current feature an over current relay block accessible in PS-CAD is used. This block promote in setting a pick up value, above which it gives a logic one,otherwise zero. A logic circuit is prepared to incorporate both directional and over current features combined. This circuit makes use of AND and OR logic gates. Bidirectional relays use only two parameters,time setting and pick up value. So as the current value increases beyond pick up value at given time, the relay sends a trip signal to respective circuit breaker. The logic circuit is shown in figure.

To add directional character to this logic, one more AND gate required. It is also

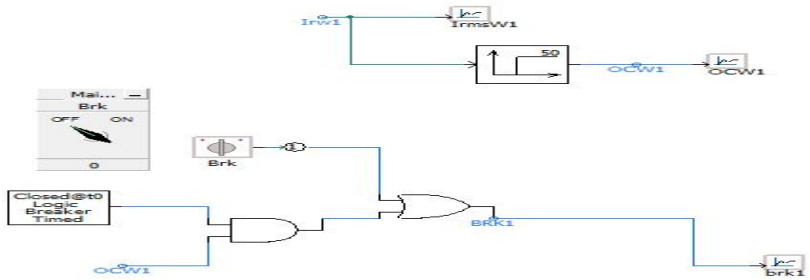

Figure 3.2: Logic circuit for Bi directional Relay

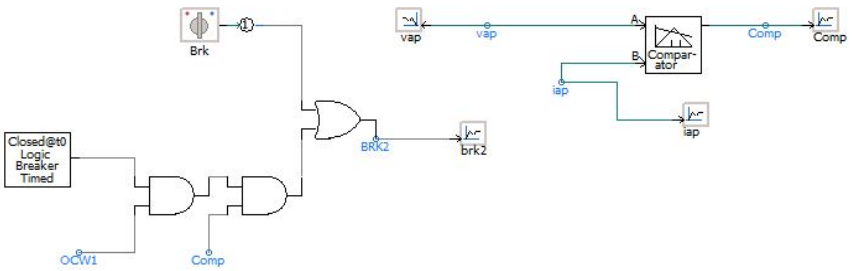

Figure 3.3: Logic for directional Relay

taken care that circuit breaker is initially closed. That logic also shows in figure.
It is extreme importance that relays trip only when they are supposed to, relay should not trigger falsely in case of overloading. So the pick up value has to set like it takes care of overloading current. The current flowing in normal condition and

overloading condition(10%) was measured and noted down.The pick up value set was kept higher than this overloading current. Whole protection scheme installed in the micro grid which is shown in figure 3.4. By the figure it is clear that the relays are both directional and bidirectional.The motive behind is that,relays near source does not require to be directional. Whereas, the ones close to the bus need to intercept the reverse flow of current in case of fault.So, directional component is to be added to them. If a fault happen at line1 i.e line of wind source 1, BRKw1 opens first, followed by opening of BRKw1d. The bidirectional relay is connected to relay logic which act on time setting and current setting,so as soon as the current goes beyond pickup value at the desired time the relay sends logic one to breaker BRKw1 operate. BRKw1d prevents the current feeding from other sources to fault current.Similar this two other lines connecting Diesel and Wind source 2. For the line connecting micro grid to main grid one breaker near bus is bidirectional and other near grid uses directional logic.the logic used in that is same as before.

As the project discussed protection scheme using only directional over current relays, this scheme was proposed. Although there are also some more protective schemes that can be included to the existing scheme for better reliability of the system. The Results obtained are explained in next chapter.

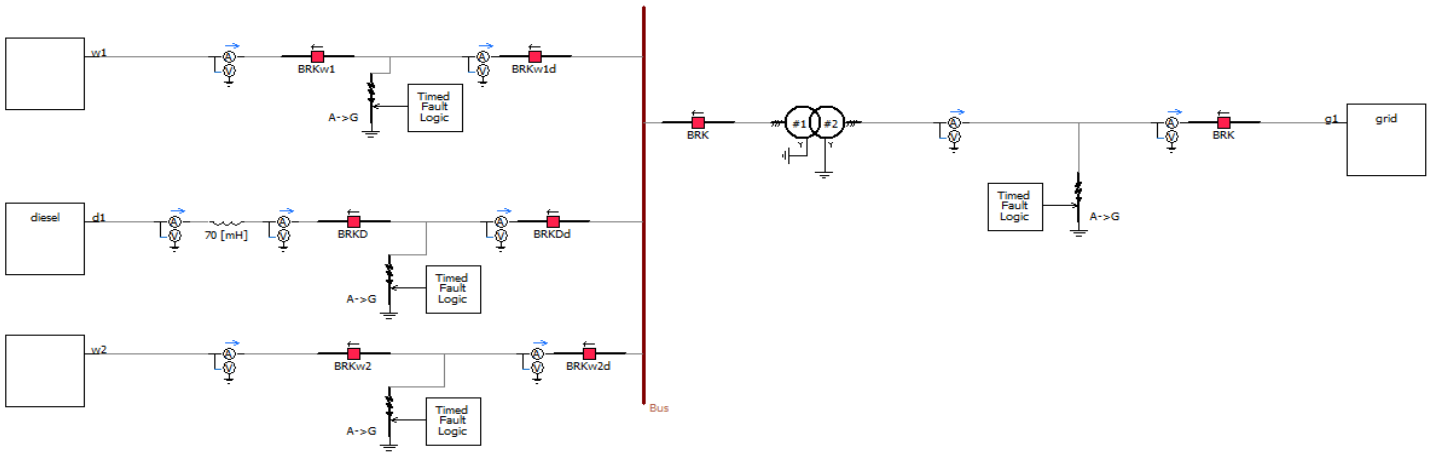

Figure 3.4: Protection Scheme for grid connected Microgrid

Chapter 4

Result and Discussion

The simulation model prepared in PS CAD, All were run individually in grid connected mode and corresponding wave forms were extracted.Here are explained those wave forms.

4.1 Photo voltaic system

Photo voltaic module is generating the DC, which is modified into the AC with the help of the inverter circuit. The voltage waveform obtained is shown in fig.3.1 It is having the amplitude of 1.5kV which is then stepped up by transformer before connecting to the grid. Another figure 3.2 shows the current wave forms at inverter end.The current waveform is not smooth it has some harmonics which one introduced by converter circuit. Power waveform is also indicate that it has some harmonics which is shown in the figure 3.3 .

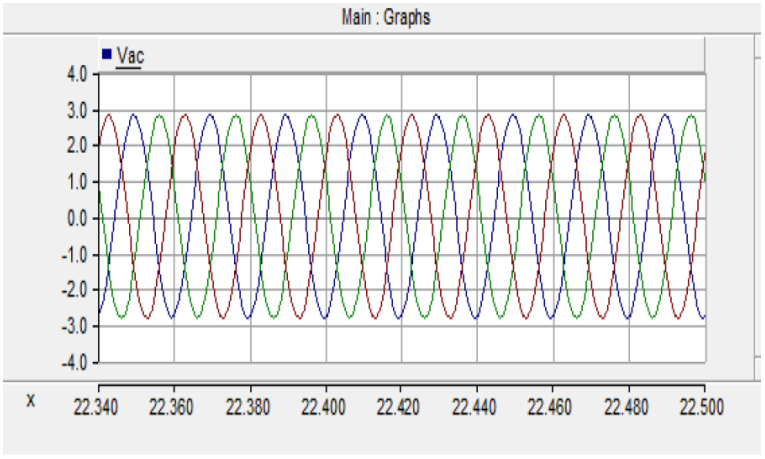

Figure 4.1: Voltage output at inverter end of PV system

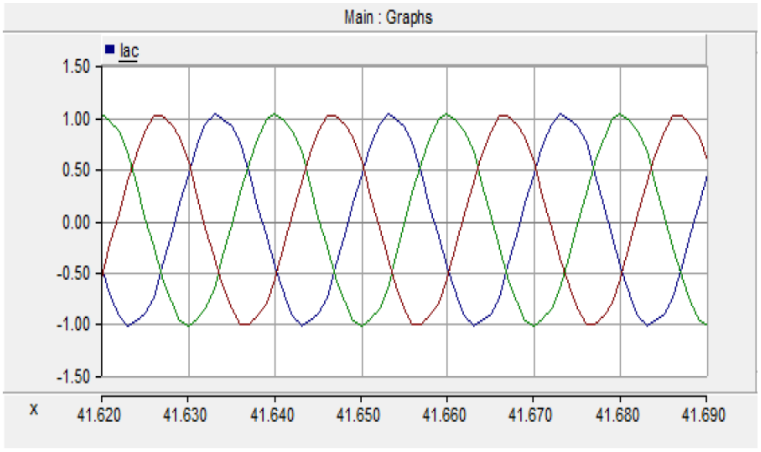

Figure 4.2: Current output at inverter end of PV system

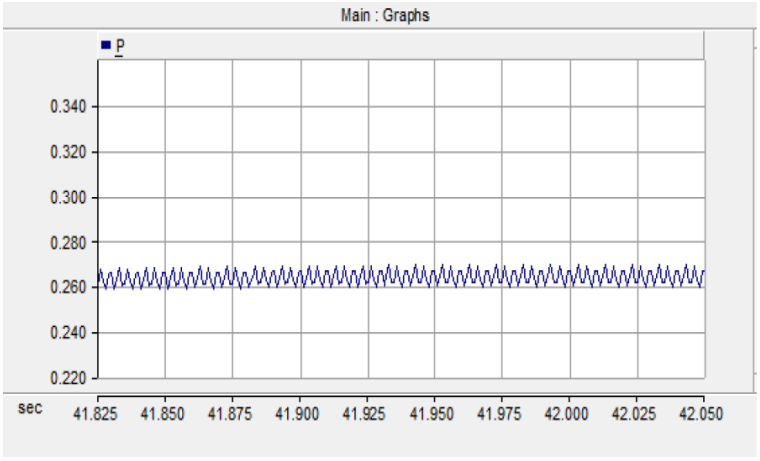

Figure 4.3: power output at inverter end of PV system

4.2 Wind farm

Same as Photo voltaic system wind is connected to the main grid via converter circuit.This converter circuit is responsible for frequency conversion from AC to DC and then again back to DC to AC conversion. In mid way voltage regulation also done to avoid voltage violations.The figure 3.4 shows the wave forms before conversion.This includes wave forms of voltage,Torque,both electrical and mechanical,mechanical speed and output power. (figure: 3.4 to 3.7)

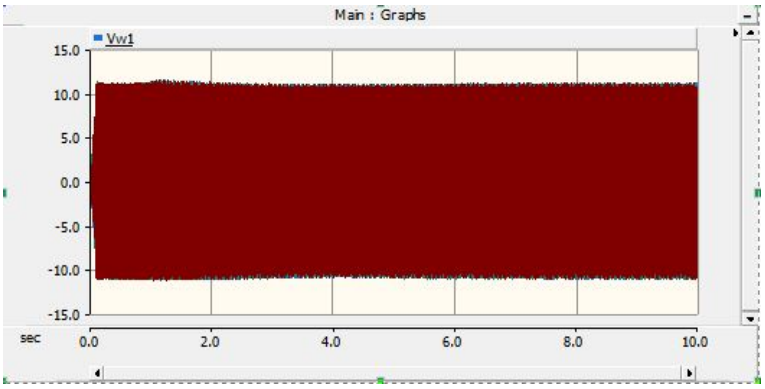

Figure 4.4: Voltage before conversion

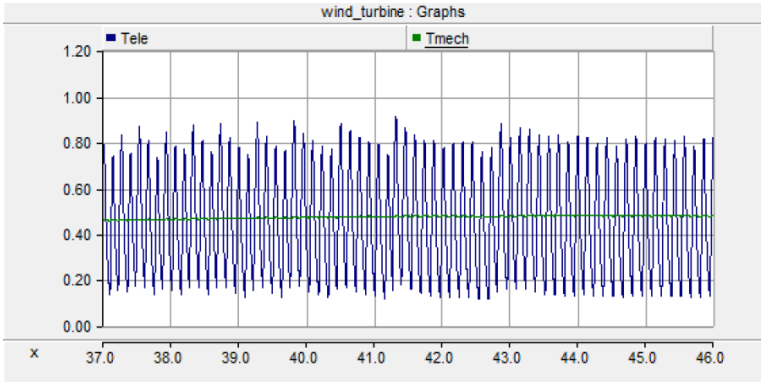

Figure 4.5: Electrical and Mechanical torque

4.3 Diesel system

The Diesel generator output is in AC form.The output voltage and current procured shown in figure 3.8 and 3.9.The output real power and reactive power measured at the end of the generator which is shown in figure 3.10 and 3.11.

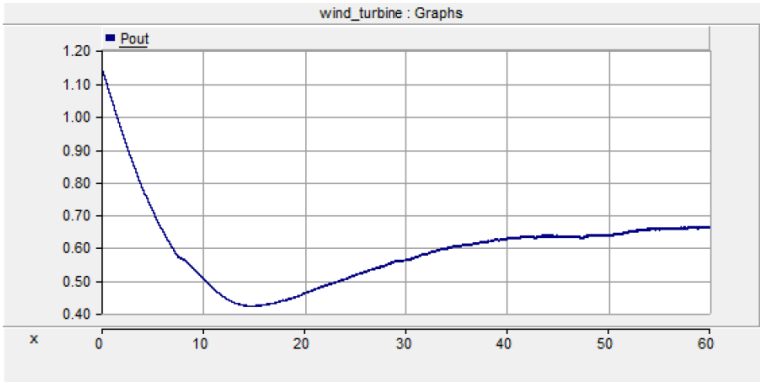

Figure 4.6: Mechanical speed

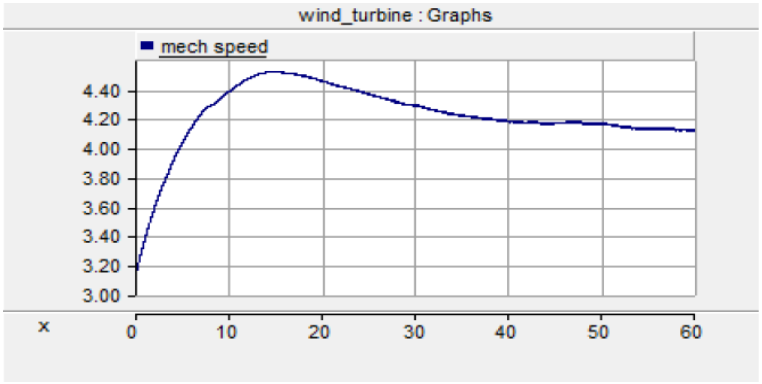

Figure 4.7: Electrical power output

4.4 Battery system

The battery output is in DC form that is modified into AC by inverter.The output power,voltage and current wave forms are shown in the figures.The inverter get triggers at alpha angle which is calculated by comparing grid voltage and system voltage. (figure 3.12 to 3.14)

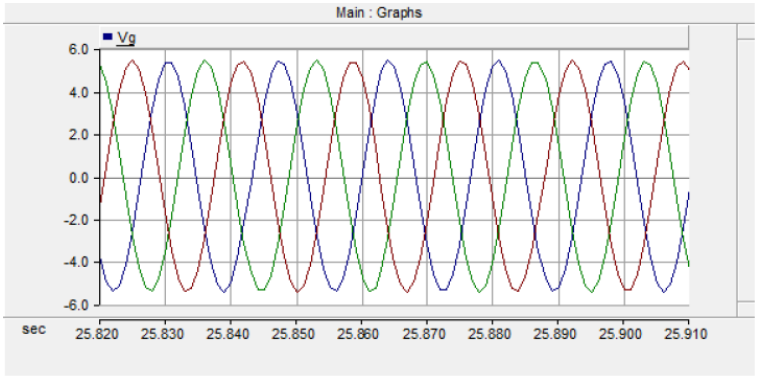

Figure 4.8: voltage at end of generator

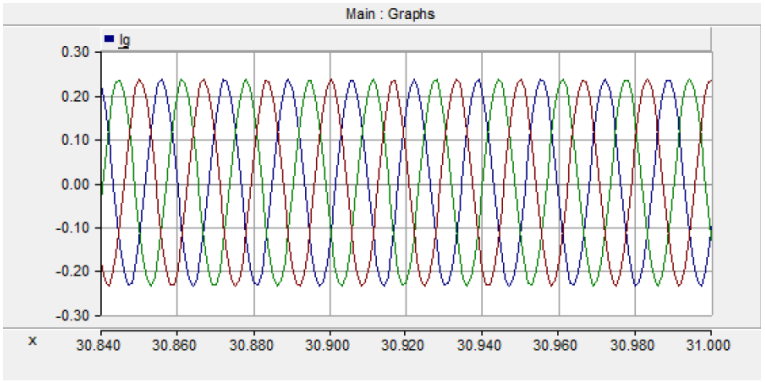

Figure 4.9: Current at the end of generator

4.5 Nine bus system

WSCC nine bus system shown in previous chapter that was simulated for getting output.There are output power waveform,current waveform and voltage waveform.There are different waveform of three machines.There are two steam generators and one hydro generators. Each waveform shows in figure. (figure 3.15 to 3.19)

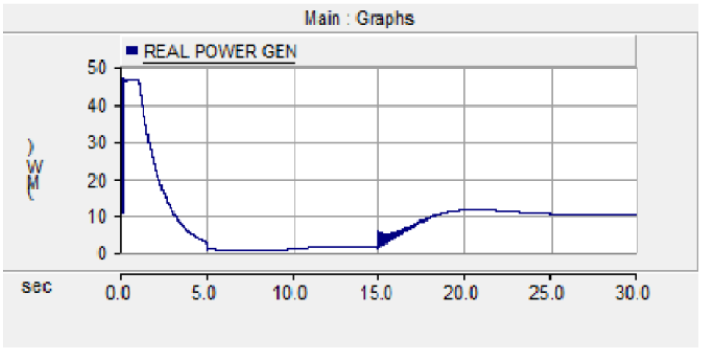

Figure 4.10: Real power output at generator

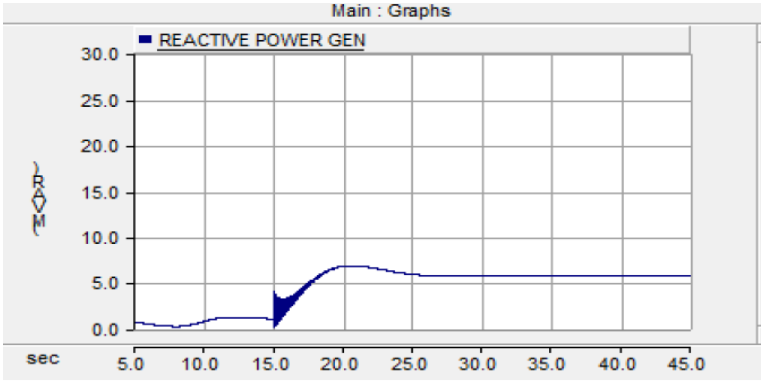

Figure 4.11: Reactive power output at generator

4.6 Microgrid system to Main grid

Micro grid system shown in previous chapter that was simulated for getting output.There are output voltage waveform,current waveform, power waveform and synchronized waveform.The waveforms thus obtained are placed in this chapter.

4.7 Protection scheme for grid connected Microgrid

The microgrid synchronized and required protection scheme. A protection scheme using directional over current logic was designed and implemented.The results obtained consist the fault condition and current wave form after fault clearance.It also include the comparator output which turns one in presence of fault in the desired direction. Fig 4. shows the existence of fault in system, which leads to sudden rise in RMS current in the system.Once the fault is detected,the relay operates.If

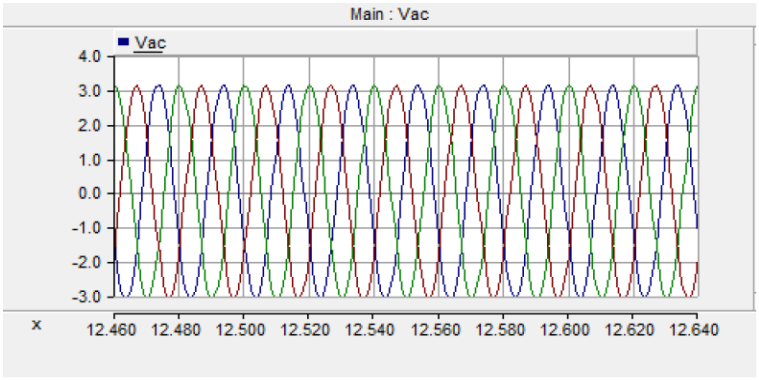

Figure 4.12: voltage output after conversion

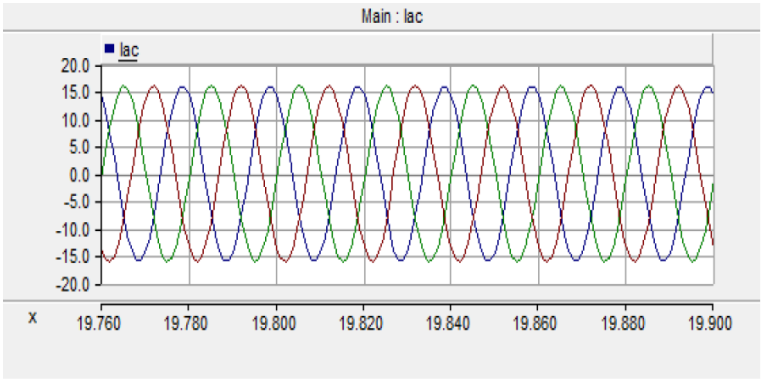

Figure 4.13: Current output of battery system

it is overcurrent bidirectional relay it sends a trip signal suddenly, and the current can seen in fig. In case of directional overcurrent relays, one additional feature is implemented, where both voltage and current phasers are compared to detect the direction of fault current.When direction is against the desired the comparator gives a logic one as output, which is sent to the logic of relay.And relay gives trip signal for breaker operate.

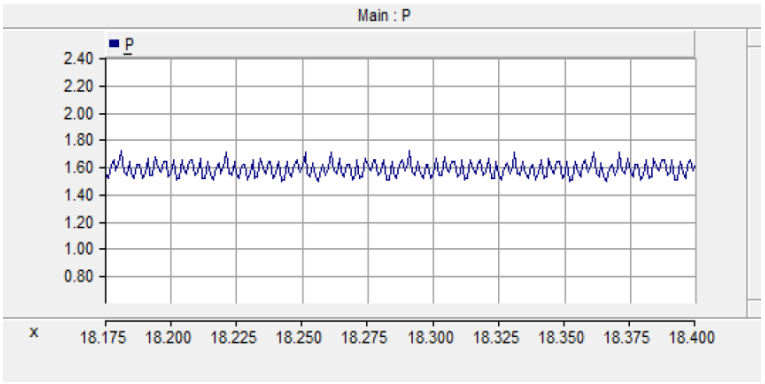

Figure 4.14: electrical power end of system

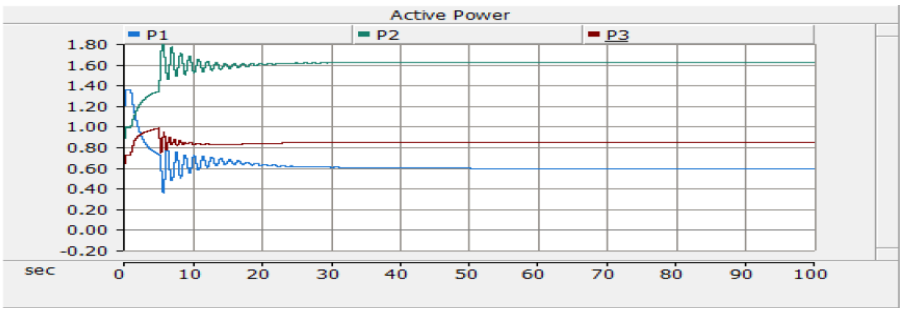

Figure 4.15: Active power of generators

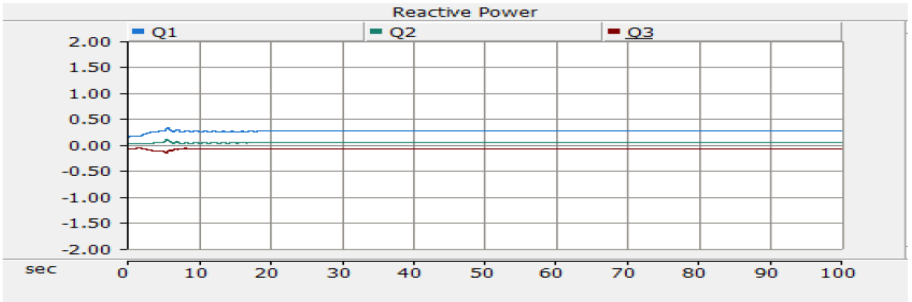

Figure 4.16: Reactive power of generators

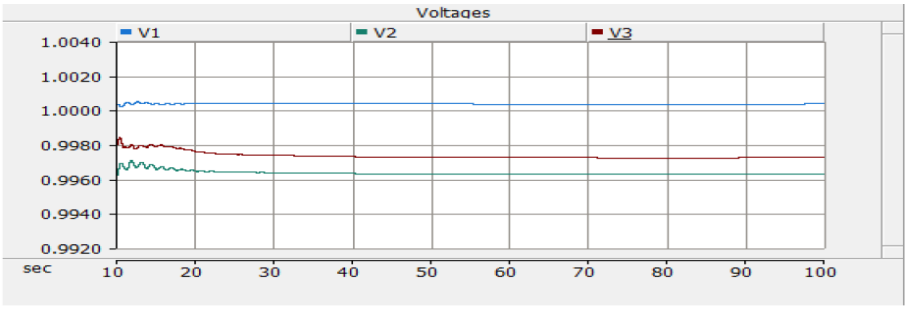

Figure 4.17: voltage output of generators

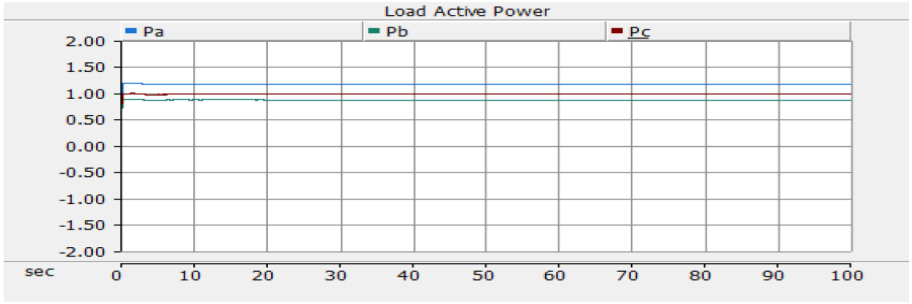

Figure 4.18: Active power at load

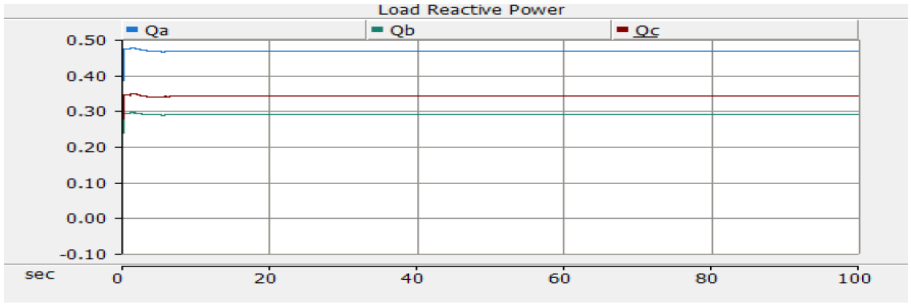

Figure 4.19: Reactive power at load

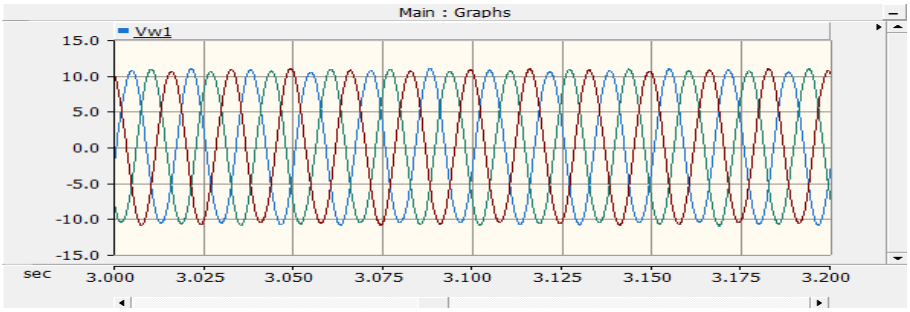

Figure 4.20: voltage output of wind generator(1)

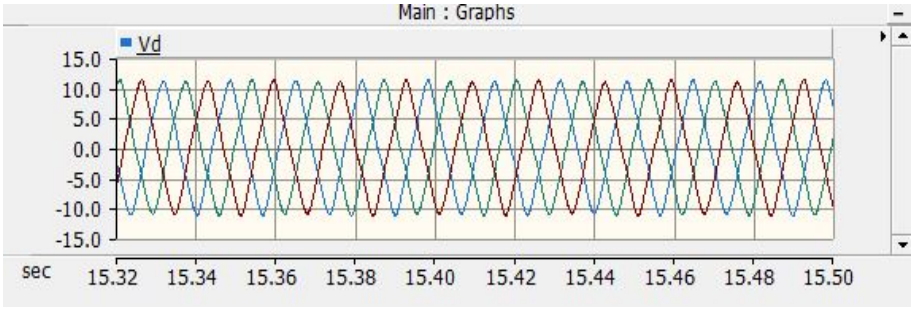

Figure 4.21: Voltage output of diesel generator

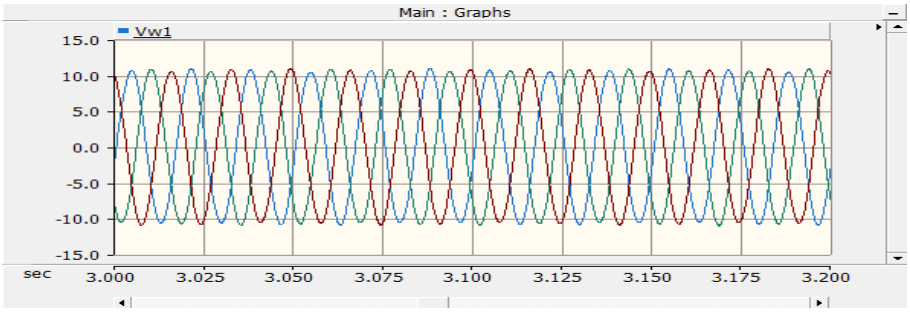

Figure 4.22: voltage output of wind generator(2)

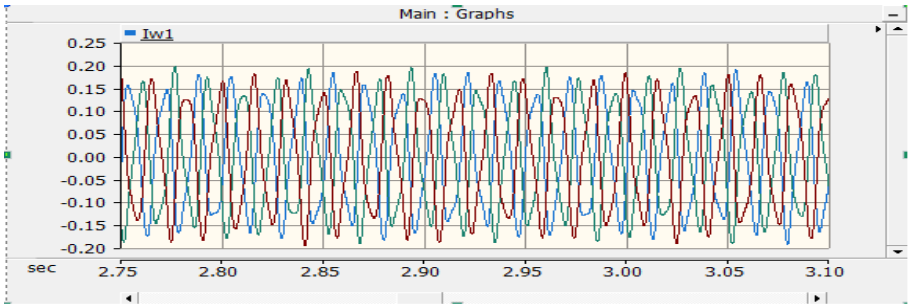

Figure 4.23: Current output of wind generator(1)

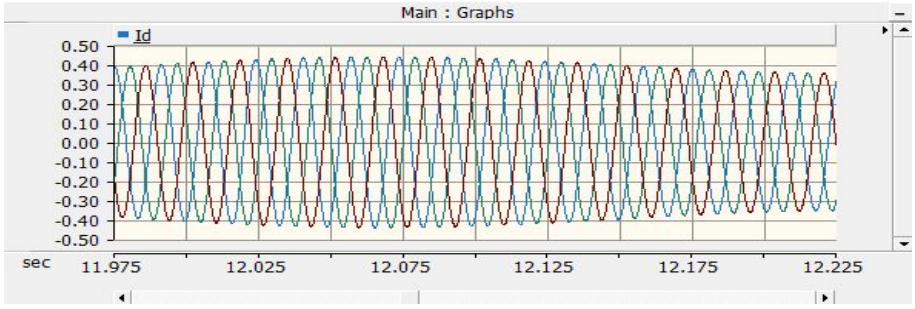

Figure 4.24: Current output of diesel generator

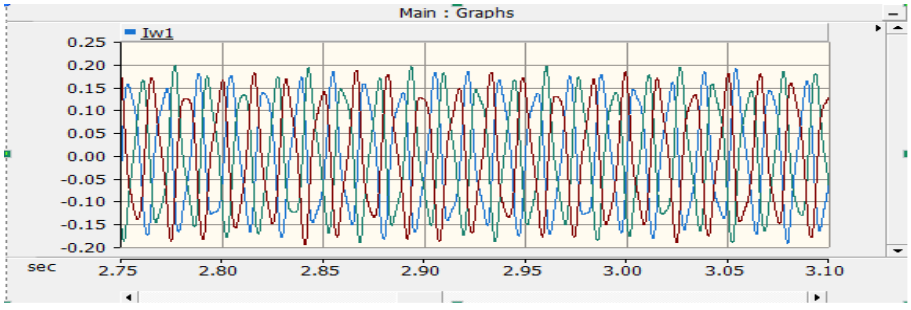

Figure 4.25: Current output of wind generator(2)

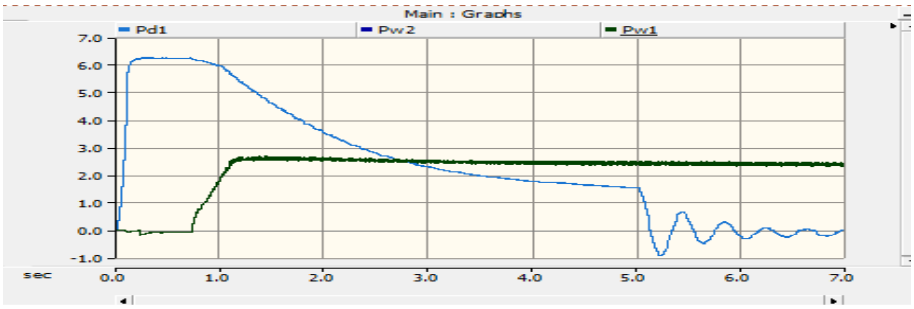

Figure 4.26: Active power of distributed generators

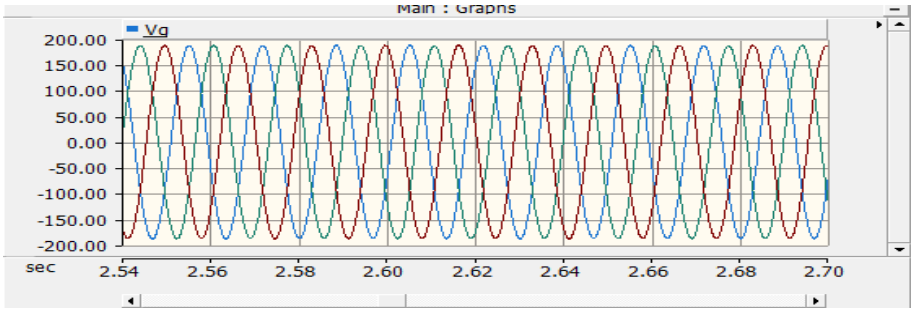

Figure 4.27: voltage output of microgrid

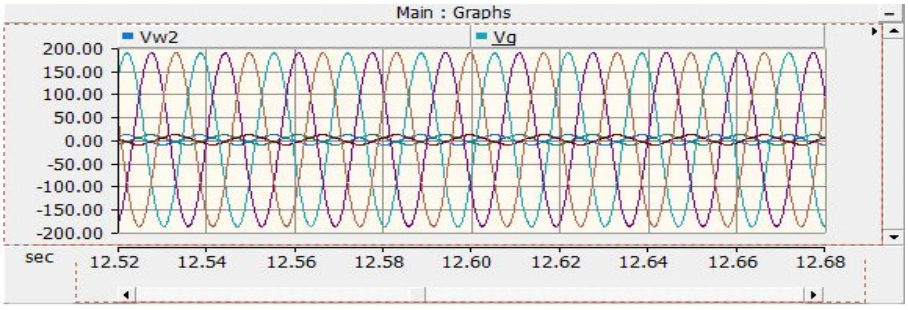

Figure 4.28: synchronized voltage

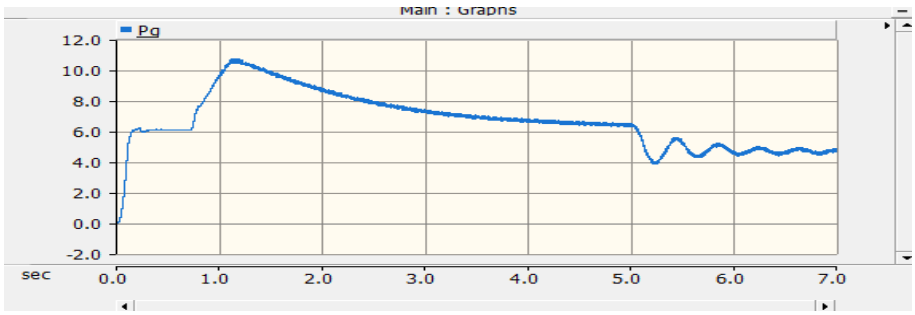

Figure 4.29: power output of microgrid

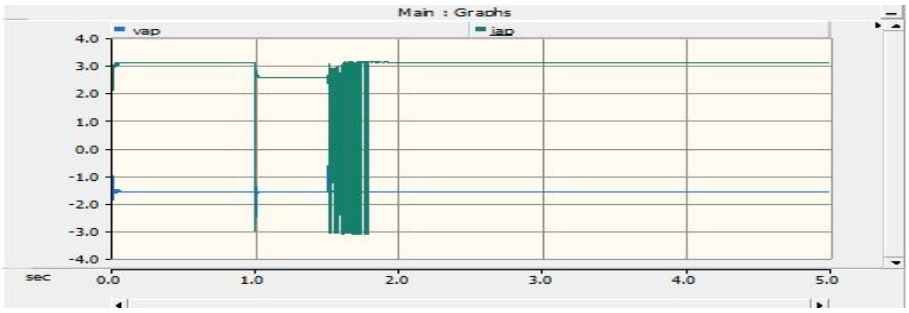

Figure 4.30: voltage and current comparision

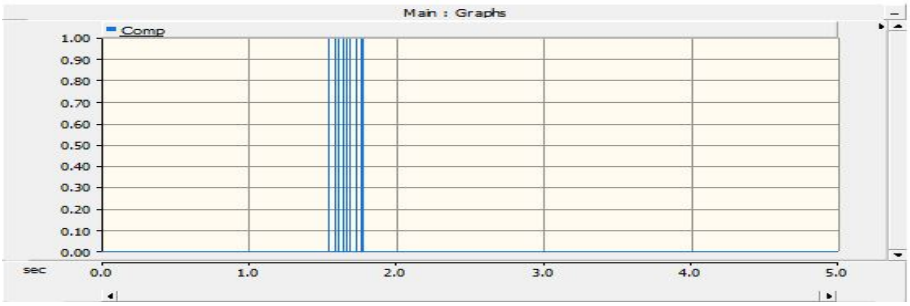

Figure 4.31: comparator output

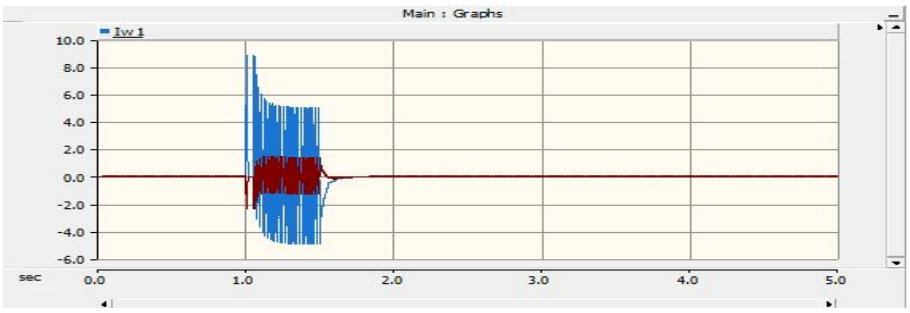

Figure 4.32: current after breaker operation

Chapter 5

Conclusion and Future work

5.1 Conclusion

In this project,so far the micro-grid has been prepared using PSCAD/EMTDC which consist of wind system and diesel generator system.The simulated models discussed in above chapters with their waveforms.That microgrid system model synchronised of sources to main grid and obtained required power and voltage magnitude.

5.2 Future work

The micro-grid modelled synchronised; now the protection schemes for faulty situations in micro-grid has been designed.The available protection schemes have been categorized according to their effectiveness for particular operational modes of Microgrid and network topology.After selecting appropriate protection scheme it will applied such a way that it should capable of protecting the system from faults.

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