PLC AND SCADA BASED ELCTRICITY SUPPLY SWITCHING WITH INTEGRATION OF SOLAR AND WIND ENERGY

DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

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MASTER OF TECHNOLOGY

IN

CONTROL AND INSTRUMENTATION

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I, Harshit Singh, Roll No(s). 2K20/C&I/03 student of M.Tech (Control & Instrumentation), hereby declare that the MAJOR PROJECT PART-II titled "**PLC AND SCADA BASED ELCTRICITY SUPPLY SWITCHING WITH INTEGRATION OF SOLAR AND WIND ENERGY.**" which is submitted by me to the Department of Electrical Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the MAJOR PROJECT PART-II titled "**PLC AND SCADA BASED ELCTRICITY SUPPLY SWITCHING WITH INTEGRATION OF SOLAR AND WIND ENERGY.**" which is submitted by Harshit Singh, 2K20/C&I/03 [Electrical Engineering Department], Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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ABSTRACT

Among all renewable energy sources, solar photovoltaic (PV) represents a very important and reliable energy source. However, the output of the PV module is limited. The system performance in renewable energy sources is improved using DC - DC converters. Moreover, using Wind energy can also be used with solar energy to create a hybrid energy system utilizing Sun's energy even more hence reducing the dependency on conventional sources. This Project is focused on integrating solar and Wind energy with diesel generators to the grid to act as a power backup for an industry. Switching logic is developed to switch between various solar cells and diesel generators. Parameters such as connected load, actual load, circuit breaker ratings, voltage and current ratings of transformer, solar cell, wind turbine, diesel generators are calculated to ensure their synchronization with grid. Bus Couplers are also employed to ensure safety of each and every component connected to the grid. The Ladder logic is designed in Delta WPL soft. The simulation model for power conversion of Solar cell from DC to AC and Model of Wind Turbine with the use of MPPT is implemented in MATLAB Simulink with the use of boost converter and inverter, Meanwhile Wonderware InTouch is used to Simulate various operating conditions in case of failure of mains supply.

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LIST OF ABBREVIATIONS

RES	Renewable Energy Sources
MPPT	Maximum Power Point Tracking
MPP	Maximum Power Point
PV	Photovoltaic
IGBT	Insulated Gate Bipolar Transistor
WECS	Wind Energy Conversion System
TR1	Transformer
DG	Diesel Generator
SC	Solar Cell
BC	Bus Coupler

CHAPTER 1

INTRODUCTION

1.1 General

Energy demands have increased in a remarkable manner in recent centuries and in the last few decades researchers have sought for various types of energy sources. According to the data based on a study between 1990 to 2008 by The International Energy Agency (IEA), the average energy consumption/person increased by 10%.

A sustainable energy source is explained as one that is almost inexhaustible, has much lower emission of greenhouse gasses and does not entail environmental pollutants. Renewable energy sources are carbon-free and appear to be very close to this ideal, as they are restored after they are used or reappears naturally as they get replenished over a period of time.

1.2 Energy

Energy utilization can be classified on the basis of end products as Electrical, Thermal, and Transportation energy. These energy forms are required for our homes, office buildings, vehicles, and manufacturing. Thus, majority of economic sectors that require energy are: residential, commercial, transportation, and industrial and agricultural. The amount of Energy consumption works as a differentiator between developed and developing nations. The energy used by a nation indicates its measure of progress and development compared to others. A citizen in a developing country depends mostly on human and animal power while a developed country consumes large quantities of energy for transportation, industrial and agricultural purposes.

1.3 Renewable Energy Sources

Renewable energy based electrical power systems in the form of biomass energy systems, hydroelectric systems, photovoltaic systems, wind power systems etc. are successively acquiring a significant part of the electric power network worldwide. In recent decades the use of renewable energy sources has substantially increased. This has allowed both developed and developing countries to reduce their dependence on energy from fossil, nuclear fuels and natural gas. In addition, it has also contributed in the elimination of the adverse environmental effects of conventional energy systems. According to a study done by the European Commission, by the year 2050 renewable energy sources will establish their sovereignty over the world's energy supply system having Percentage share of different forms.

Renewable energy can be divided into two groups:

1. Solar renewables
2. Non-Solar renewables

1.3.1 Solar renewables

Solar renewables directly or indirectly depend on solar radiation. Solar radiation is directly converted into useful energy with the use of solar thermal energy conversion technology, Solar Photovoltaic (PV) technology. Solar radiation can be indirectly converted into useful energy forms such as hydro, wind, wave and bioenergy.

1.3.2 Non-solar renewables

These type do not depend on solar irradiation and are termed as non-solar renewables. For example tidal and geothermal energy. Several studies and research are going on and numerous expert studies suggest a bright future for renewable energy systems.

1.4 Solar Energy

Solar renewable energy is the majorly contributing source of renewable energy supplies. With 21st century being called the Solar Age. The sun acts as a gigantic natural fusion reactor which converts hydrogen into helium at the rate of 40 lacs tonnes/seconds. World's annual energy consumption is very trivial compared to the Solar radiation (ten thousand times voluminous). On average, seventeen hundred kWh / (m^2) / year is solarized.

The insolation by the sun at a random point in space, outside the earth's atmosphere, is nearly constant. However, when it reaches the earth , it is affected as a result of three aspects:

1. Relative position of earth with respect to sun.
2. Earth's rotation and its axis of rotation.
3. Earth's atmosphere.

1.5 Solar Energy System

Solar energy systems are designed in a way to accumulate maximum solar energy when it is available and deliver it when needed by the load.

1.5.1 Active solar energy system

Active mechanical, electrical devices like photovoltaic panels, solar heat collectors, charge controllers, pumps etc are used in this system to process the heat energy of the sun. An active solar energy system may also have batteries to collect the energy for later use. There are variety of applications such as pumped solar water heater, solar cooking, solar thermal engines for electricity generation, solar photovoltaic (PV) energy system etc.

1.5.2 Passive solar energy system

Passive systems use sunlight for air, water, and thermal material for heating, cooling, and ventilation purpose and to store heat energy without active mechanical or electrical devices. They take advantage of natural convection of heat. Thus, materials having thermal properties are selected to store heat energy.

1.5.3 Components of a solar energy system

A general PV system is depicted in Figure 1.1. Solar PV array captures the sun's energy from sunlight falling on it. The solar tracking system consists if light sensors such as photodiodes or phototransistors that commands the servo-motor for position control. The output of the PV panel is coupled to a DC / DC converter designed to deliver required current or voltage at load ends to harness maximum power from the PV module. The switching action of the DC/DC converter is controlled by MPPT controllers which is followed by an inverter which supplies electrical energy both to AC load and the grid connected to it. A battery backup may or may not be connected to provide any shortfall in power which might be unavailable from the PV module during night and cloudy weather.

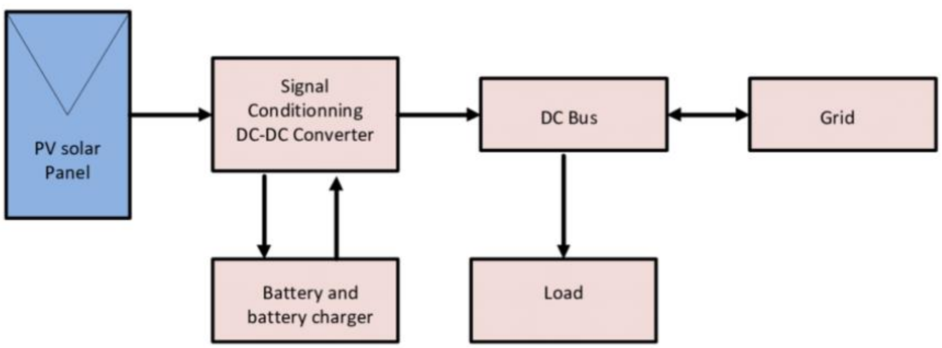

Figure 1.1 – Block diagram of a PV System.

1.6 Motivation

Power failure is one of the major reasons for inefficiency of an Industry and hence backup supply systems are always present to ensure uninterrupted work. But due to high demand of fossil fuels and them decreasing in concentration, standby generators which have always been a reliable option must be replaced with some renewable energy source. Hence in this Project, a power backup system is designed which is made by combination of diesel generators, solar cells, batteries, transformers and bus couplers etc. The interlocking conditions are formulated in such a way that safe uninterrupted supply should be maintained. Further with the help of PLC (Programmable Logic Controller), based on different conditions of working and different load requirements, any one or combination of the Solar Cells or Diesel generators is chosen to supply power in case of power failure.

1.7 Objectives

1. To develop a power backup system by combination of diesel generators, solar cells & batteries, transformers and bus couplers etc.
2. To develop ladder logic for PLC to simulate different operating conditions for supply switching in case of mains failure.
3. Simulate all possible conditions for different plant loads in an industry at different instances of time.
4. Integration of Wind Energy system as all time running backup along with Solar energy.

CHAPTER 2

LITERATURE REVIEW

2.1 General Overview

Solar energy is evolving as the most promising renewable energy source for a sustainable future and solar photovoltaics to be the most ideal energy conversion system. The dc-dc boost converter has become an indispensable component in any given solar photovoltaic system due to its low-voltage output limitations. The output power that can be derived from a solar photovoltaic module is limited. Thus, a control algorithm called maximum power point tracking (MPPT) is indispensable to take full advantage of the available solar energy. This chapter deals with the literature review of the research work and developments in the field of solar photovoltaic (PV) energy systems. The following chapter presents the literature review of the references that are studied in order to make this project.

2.2 Literature Review

The photovoltaic system consists of PV panels connected through DC-DC converter and DC-AC inverter to the grid[1].The automatic transfer switch concept represents the procedure of fast connection of the electrical consumers to a back-up electric power source. The connection to the back-up power source is necessary in the event of failure of the main power source[2].In every process industry, there is a repetition of the tasks. So, in order to get the better productivity in limited time with lesser error probability, we are incorporating Automation into the process industries[3].Electricity switching control systems are basically used for supplying energy efficiently to a given load in building automation applications. The integration of mains power supply with solar power supply and diesel generator power supply is a key element in designing the electricity supply switching control system[4].The main focus is on providing energy at reasonable price but soon the day will come when the utilities will be focusing on encompassing sustainable use and environmental improvement into their agendas. Unlike conventional generation, the sunrays are available at no cost and generate electricity pollution-free[6].The solar power generation system can charge the battery, so the storage power will be converted into AC for the load by independent inverter when the PV power is insufficient; the PV system also can intelligently convey energy to the grid, the grid has the two-way transmission function, in other words, the grid also supply the energy to the load if the PV system fail to drive the load[7].Protection against electrical emergency faults and fuel level operation faults of the diesel generators are taken into consideration in the software. This facility enhances the method of learning of PLC based monitoring of various systems of diesel generator unit operation and control[8].

The system utilizes a solar panel to supply power to batteries and an AC inverter. Batteries' energy is used to satisfy the power needs of a standard household. The proposed constructed system is a scaled down physical model. The system consists of a programmable controller, photovoltaic panel, a buck converter used to charge the batteries, and a single phase inverter to supply power for the residential loads[9].Wind vitality is the second biggest wellspring of sustainable power source after hydropower. It is incredibly reasonable, yet it is discontinuous.[12]As its level of grid penetration has begun to increase dramatically, wind power is starting to have a significant impact on the operation of the modern grid system. Advanced power electronics technologies are being introduced to improve the characteristics of the wind turbines, and make them more suitable for integration into the power grid[13].As a result of extensive research, wind energy is now being widely used for electrical power generation[14].Maximum power point tracking (MPPT) is a very important necessity in a system of energy conversion from a renewable energy source.[16]Wind turbine technology combined with solar photovoltaic (PV), as a hybrid system, can play an effective role to overcome our future energy consumptions with a cost effective energy conversion system.[18]The current trend of research and development are focused in hybrid renewable energy systems (HRES) that allowing hybridization and optimization of the electrical generation[19].The hybrid combination of both distributed energy resources eliminates mutual intermittences due to their adverse nature; therefore, the reliability of the system will be improved[20].The Perturbation and Observation (P&O) algorithm is one of the best tracking technologies for maximum power practically possible for its flexibility and ease of execution in low-fee devices[21].The major challenges of the traditional P&O algorithm are energy waste in steady-state conditions and the dynamic performances are poor when the solar irradiance or temperature is changing suddenly[22].As the maximum power operating point of wind turbine varies with changing meteorological conditions (e.g. wind speed and temperature), an important issue in the design of efficient wind turbine power station is an ability to track the optimal operation point correctly.[24]

CHAPTER 3

SOLAR ENERGY SYSTEM

3,1 General

Solar energy is the most vital renewable energy source (RES) for a sustainable future and probably solar photovoltaics to be the most ideal energy conversion system.

3.2 Solar Photovoltaic (PV) Energy

Solar energy can be produced by two methods either by using solar thermal engines, they generate very high temperature and convert it into mechanical energy to drive the electrical generator. The other approach of generating electricity is photovoltaic. Solar photovoltaic (PV) has been proven to be a very reliable energy source out of all other RES.

3.3 Solar Photovoltaic (PV) Energy System

Solar photovoltaic method directly converts sunlight into electricity there is no requirement of any other additional energy conversion stage. The PV systems in general can be classified in three categories, as:

1. Standalone system,
2. Grid-connected system
3. Hybrid system

3.4 Grid-Connected Solar PV Energy Systems

Electricity generated by the solar power plant is fed into the power grid. The PV cells can exceed 1-MW capacity. Generally, there is not a requirement of a battery backup in a grid connected solar PV plant. However, residential solar PV systems use batteries for storing energy.

Based on whether battery bank is required or not required grid-connected solar PV system, can be categorized as:

1. Grid-Connected PV System without battery.
2. Grid-Connected PV System with battery.

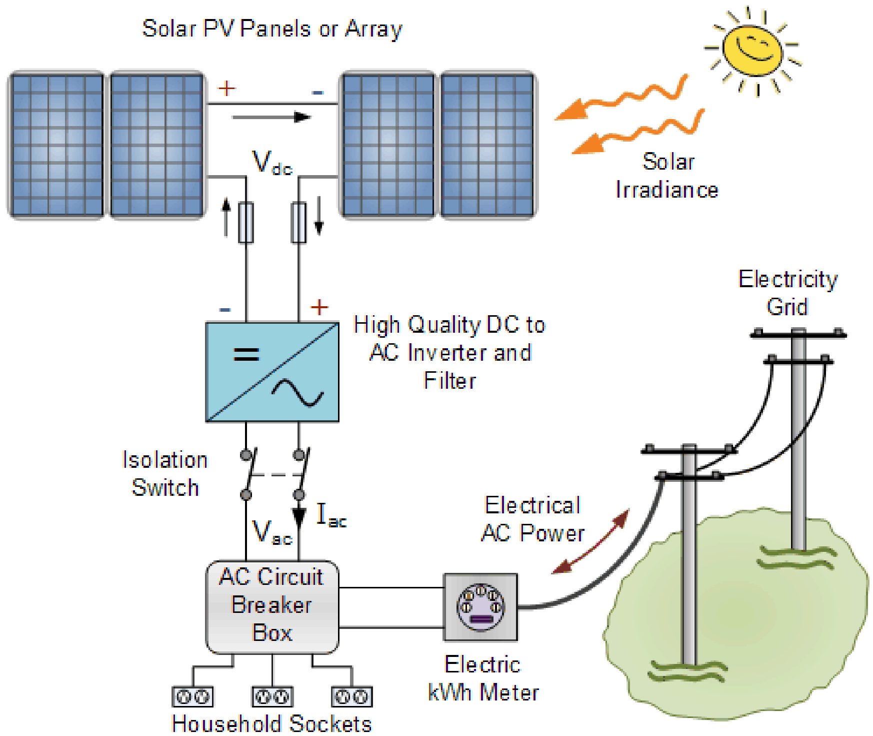

Figure 3.1 - Grid-Connected PV System without battery.

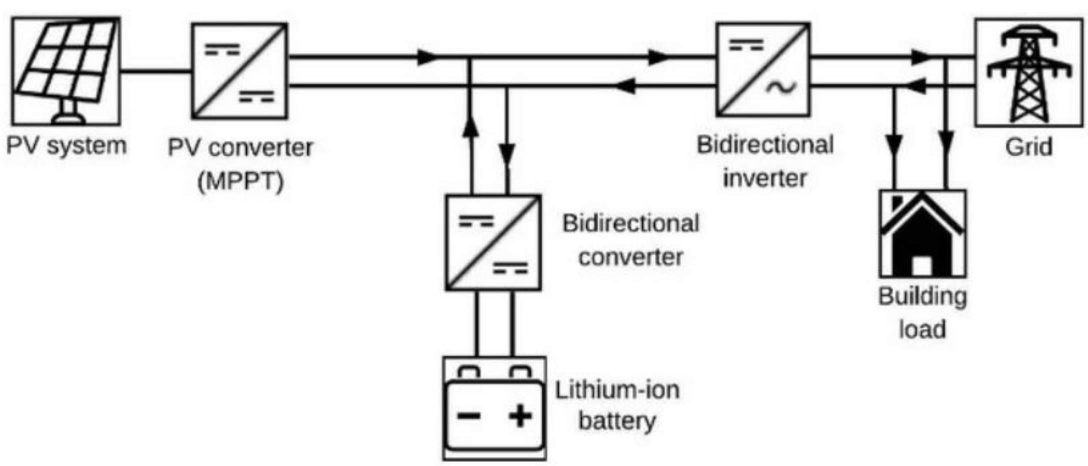

Figure 3.2 - Grid-Connected PV System with battery.

3.5 Solar PV Model (MATLAB Circuit)

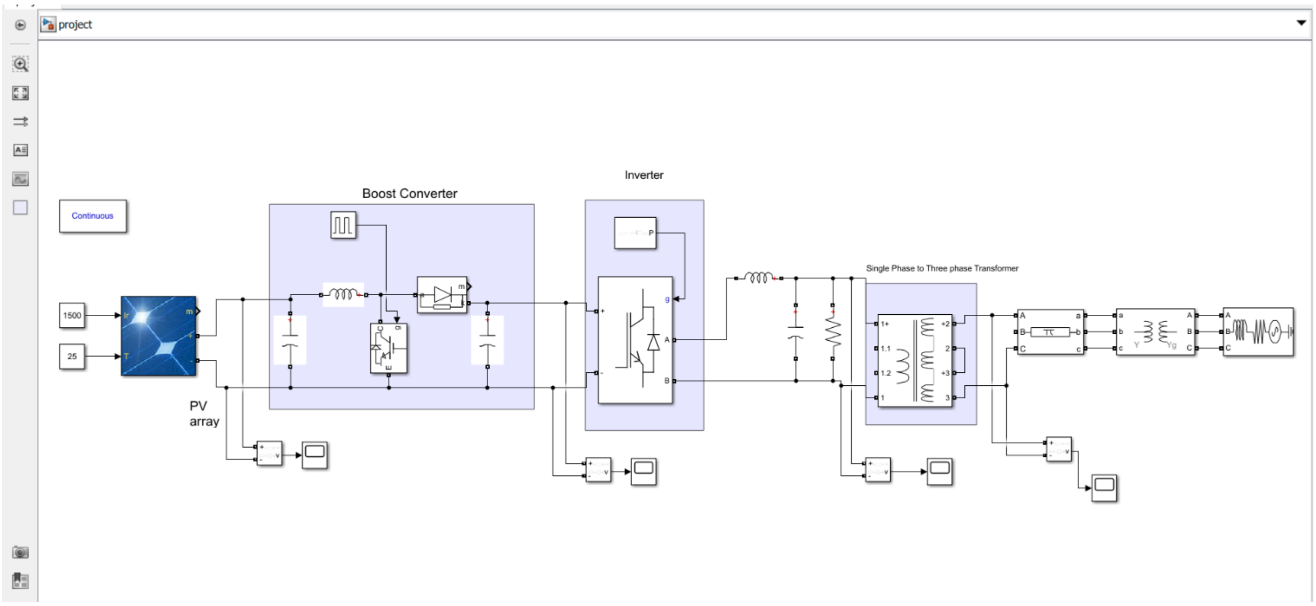

Figure 3.3 – Simulink model of Solar Energy system.

Here, input to PV Array are Irradiation and Temperature, the output of PV array is then fed to Boost converter made with the use of Capacitor, Inductor, Diode and IGBT. The boosted output is then converted into AC with the use of an inverter made of Diode/IGBT which gives pulsating AC at its output. Further the pulsating wave is converted into sinusoidal with the use of passive filter consisting inductor and capacitors. We have taken two solar cells in our line diagram so that system can be more dependable in case there is any issue in starting of one cell, the other should be there to rely on. The capacity of panels is decided at 100Kw to supply medium level load in industry in case of power failure. Lastly a battery is employed to store the solar power is reserve when working conditions are normal. The values of various parameters selected in this circuit are :

- PV Array.
- DC-DC Boost Converter.
- Diode/IGBT Inverter.
- Single phase to 3 phase Transformer.
- 3 phase load.

3.6 Wind Energy Systems

3.6.1 Concept of wind power

Wind power is another byproduct of sun’s energy. Ocean water is one of the major constituents of Earth’s ecosystem. With increasing depth in an ocean, the temperature cools and the pressure will increase. But the contradicting fact between environment and ocean is that the environment possesses greater thermal conductivity. So, the sun's warmth may be transferred into the environment from altitude down to the earth's floor.

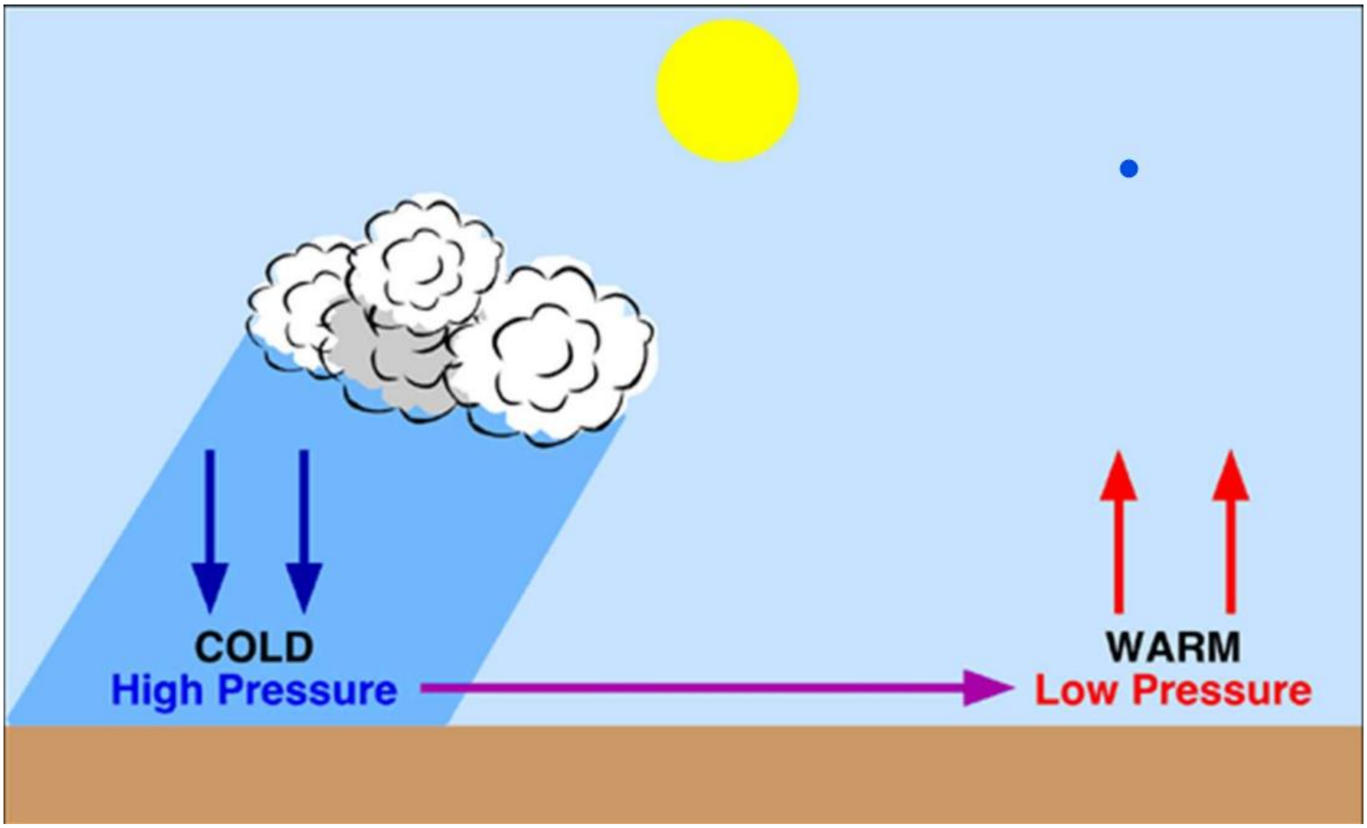

Figure 3.4 - Wind formation due to local temperature Gradient.

Figure 3.4 shows wind formation due to local temperature gradient. When the sun shines on the surface, the atmosphere absorbs heat thus rising its temperature then the warm air will rise due to becoming lighter. Because of its tendency, air flows from in the direction of decreasing pressure gradient to create the balance, referred to as wind.

3.6.2 Constituents of wind energy

Nowadays, widely developed wind turbines are Horizontal axis type. Figure 3.5 is a labelled diagram of A horizontal axis turbine having left sided blades.

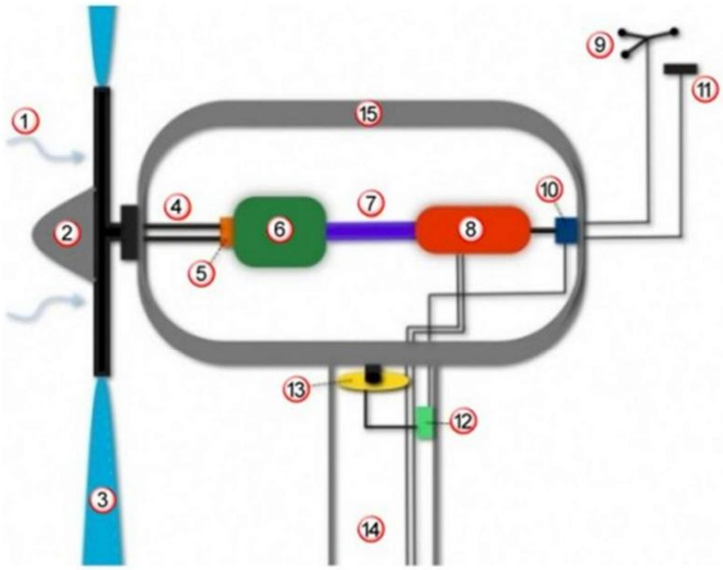

Figure 3.5 - Wind turbine labelled diagram.

1. Wind Direction.
2. **Nose** - Designed with aero-dynamicity for least obstruction to the wind.
3. **Blades** - Joins nose to the rotor. When the wind speeds are sufficient, the blades will start rotating.
4. **Main turbine shaft** - Works as connector between blades and internal components.
5. **Brake -** It stops the wind turbine when speed is exceeding safe speed or the turbine is not in use.
6. **Gearbox** - Rotation speed changes when the gears ascend or descend. It balances the speed and torque.
7. **Turbine shaft** - It connecting gearbox and the generator.
8. **Turbine generator** – Conversion from the wind's mechanical power to electricity.
9. **Anemometer** - Device measuring wind speed.
10. **Controller** - Controls the blades to start or stop using Anemometer.
11. **Wind vane** - Measures the wind direction.
12. **Yaw drive, yaw motor** - Rotates the turbine's face towards wind using wind vane.
13. **Turbine tower**.
14. **Turbine nacelle**.

3.6.3 Principle of wind turbine

Wind power's principle resembles very much to the firepower. However, the wind acts as an alternative to the fuel and water (steam) for propelling action. When a threshold wind speed blows through these propellers, it'll trigger the entire fan rotation. As the speed of the turbine is slow, a gearbox is employed to increase it. It is passed to the generator which converts it into electrical energy. The output electricity has low voltage. Hence It is required to go through rectifier and inverter to become useful in grid.

3.6.4 Wind turbine model (MATLAB Simulink)

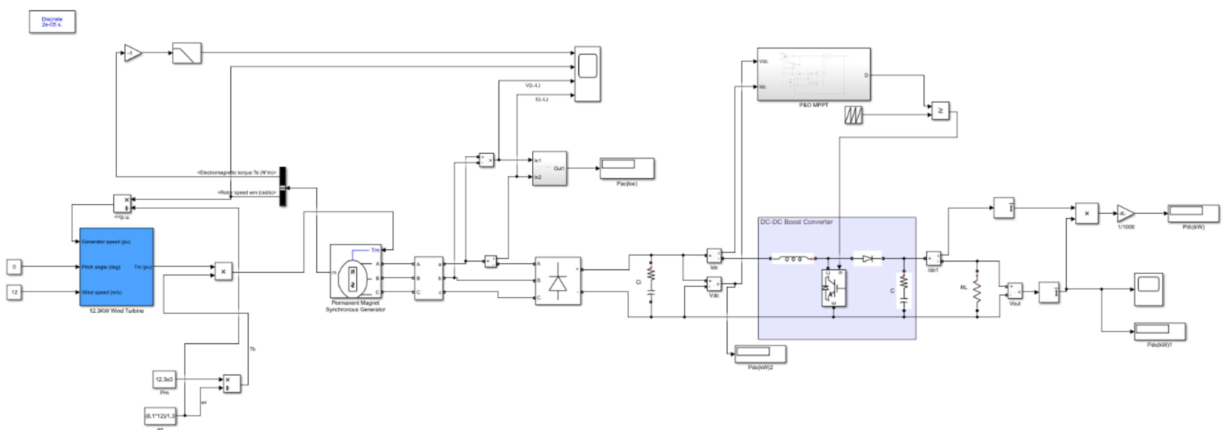

Figure 3.6 – Simulink Model of Wind Energy Conversion System using MPPT.

In the above model, Wind turbine is connected to Permanent Magnet Synchronous Generator (PMSG) which is further acting as an input to the Universal bridge for AC to DC conversion. The DC output is then fed to the boost converter and finally supplied to the load.

Moreover, AC Voltage and current values are also observed to check the AC output power from the PMSG. For Duty cycle of the converter, MPPT system is used with inputs being DC voltage and current. Finally Scopes are used for monitoring AC Voltage and Current (L-L) , DC voltage and DC power output.

3.7 Diesel Generators

A diesel generator (DG) is a combination of a combustion engine with an electrical generator to produce electric power. this can be a selected case of engine generator. A diesel generator runs on fuel, but some are exceptions to run on various liquid fuels or fossil fuel.

Diesel generators are employed in places lacking connection to an energy grid, the other scenario is being used as a power backup during grid failure, other applications include peak load handling, grid support and export.

Generators may range from 8 to 30 kW for small requirements such as homes or shops, whereas industrial generators from 8 k to 2,000 kW for big requirements such as factories and other industrial offices.

Figure 4.1 - An Average 250 Kw diesel generator.

The generators which we have chosen for our backup system are of two capacities which are Generator 1 being 250Kw and generator 2 being 400Kw to provide power in different plant load scenarios and even in worst case scenario i.e., if first generator fails to start, the second one could handle the load. The output voltage being set to 415V of both the generators so that both can be synchronized in case of power failure.

DG_1=250Kw,415V, DG_2=400Kw,415V.

CHAPTER 4

PROGRAMMABLE LOGIC CONTROLLER (PLC)

4.1 Chapter Overview

In the following chapter, an overview of Programmable logic controller is given. Defining PLC, its working function, methods to program a PLC and basics of Ladder logic programming are the topics at glance.

4.2 Introduction To PLC

Today, control systems in industries extensively use PLCs to reinforce the functions of assembly line and machines. In recent times, PLCs are gaining a lot favoritism as they're highly amendable for controlling many inputs and outputs based on the functions they're expected to execute. Like any other automated system, PLCs also use assorted hardware constituents for example CPU, programming devices and also include external hardware like I/O ports, power supply.

The microprocessor-based CPU performs all logical and arithmetical operations, other jobs include handling the pc interfere. 4 types of buses are present in a system: **Information bus** shares information between different elements, **Address bus** allocates addresses, **Control bus** monitors internal actions, **System bus** communicates between the assorted ports and I/o ports. Sensors, switches being inputs control motors, pumps etc.

Thus, with features like memory storage and power supply, PLC acts as a tiny integrated unit that fulfills requirements in variety of applications.

Figure 4.1 - Programmable Logic Controller(PLC).

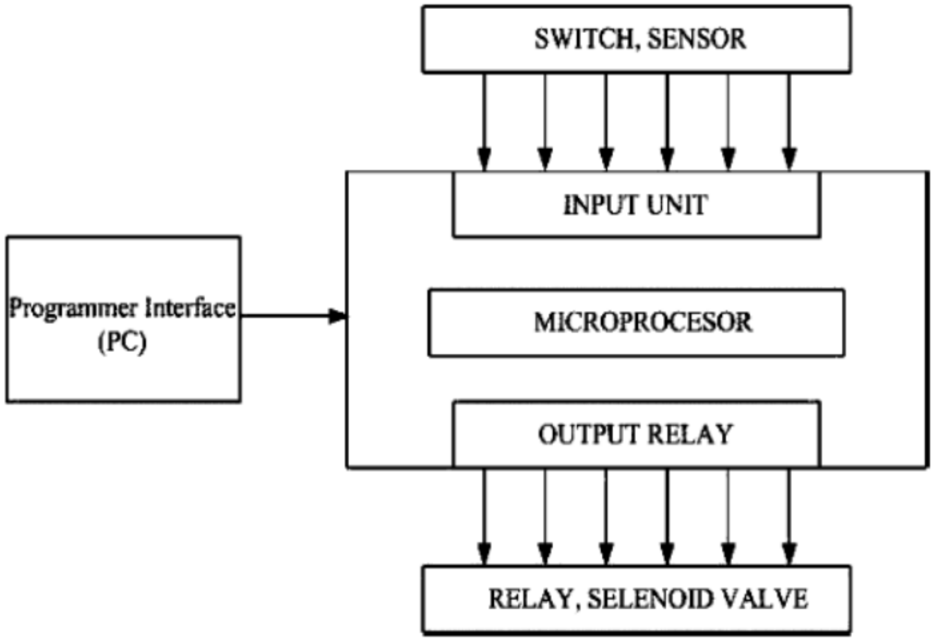

Figure 4.2 – PLC Interfacing block diagram.

4.3 Ladder Logic Programming

Ladder logic is the most prominent method to program a PLC. The ladder represents programming steps using relay coils and contacts to which manage all the actuators and outputs. These outputs can be indicator lights, alarms, solenoids, motors. The ladder diagram of PLCs is a template having 2 bus bars connected to each other using rung lines.

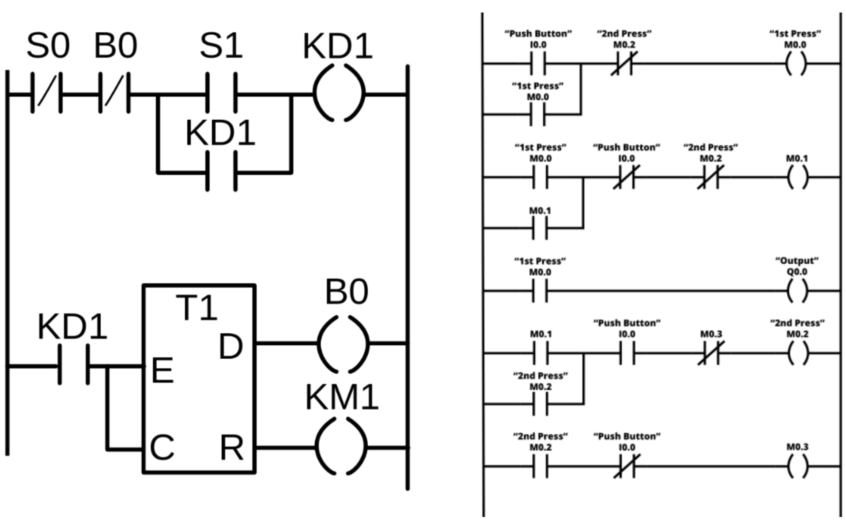

Figure 4.3 - Examples of Ladder Logic

In Every PLC program, Programmers are required to follow few basic steps such as:

1. Clear definition of PLC’s architecture and its I/O ports.

2 Clear understanding of ladder logic and it's symbols of contact coils and output instructions.

3. Sequence of steps for controlling should be defined clearly to identify the instructions which are to be written first and the rungs on which the operation is to be executed.

4. Circuit diagrams of inputs and outputs must be drawn to analyze input responsible for particular output.

CHAPTER 5

MAXIMUM POWER POINT TRACKING (MPPT)

5.1 Chapter Overview

In the following chapter, Introduction of Maximum Power Point Tracking (MPPT) is given. The topics that are covered at a glance in this chapter are MPPT basics, Perturbation and observation (P&O) method. Following that is the MPPT model used for the project which was created in MATLAB Simulink.

5.2 Introduction To MPPT

Wind energy is a source which gets huge attraction as a non-conventional energy source as a result of depletion of fossil fuels. Wind energy is present in abundance and varies continuously with the change in wind speed i.e., it's not constant all times so to form it effective we require to extract variable speed as power conversion. The output power from this conversion system depends upon the accuracy and time of tracking the peak power by the new and ongoing technique i.e., Maximum Power Point Tracking (MPPT) method to control the Wind Energy Conversion System. A proficient tracker iteration is required for the MPPT to amass the utmost power from the turbine. A tracker algorithm tries to trace the optimum point of the turbine as perfect as possible, i.e., as reliable and fast as possible. Throughout the years, many tracker algorithms are established, each together with its own benefits and disadvantages.

There are various MPPT control techniques classified below:

(1) Off-line control techniques

(a) Fractional open-circuit voltage, current.

(ii)On-line control techniques

(a) Perturbation and Observation

(b) Incremental conductance techniques.

(iii) Al based control techniques

(a) fuzzy logic control (FLC) technique

(b) artificial neural network (ANN) technique

(c) genetic algorithm (GA) etc.

5.3 Perturbation And Observation Method

It is one of the generally utilized MPPT calculation. This calculation utilizes basic input game plan and minuscule estimated boundaries. during this methodology, the result voltage is occasionally perturbated and result power at the moment is contrasted and the past cycle. This makes the force of the wind turbine change. On the off chance that the power builds in view of the perturbation, the annoyance is supported inside a similar course. After the peak power is accomplished, the MPP yield understands zero and it diminishes next moment and subsequently the inversion happens as displayed in Figure underneath.

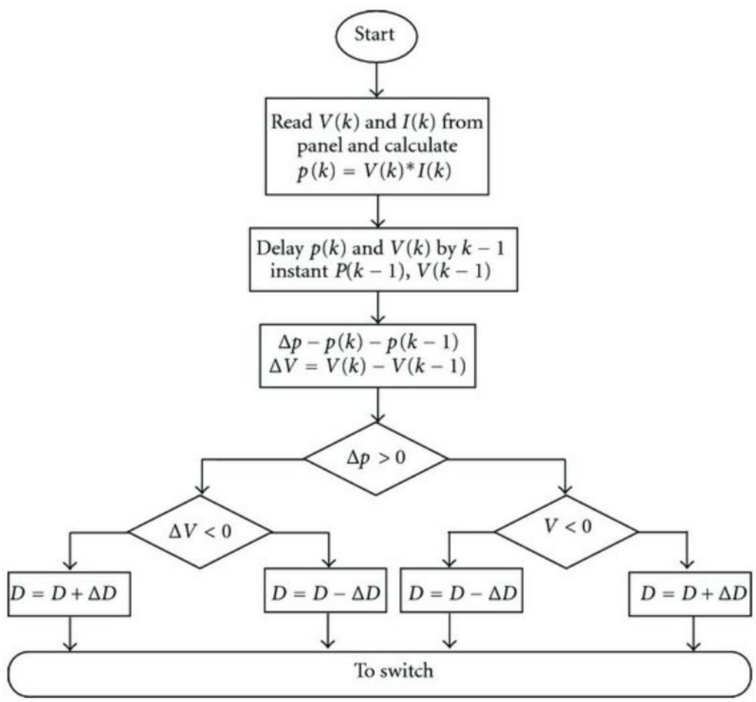

Figure 5.1 - Flowchart of P&O Method.

A PI controller is used to convert the turbine's operating point to the needed voltage. It has been noticed that this perturbation causes some power loss, as well as the failure to track maximum power under rapidly changing air circumstances. Apart from that, this technique is really popular and useful.

5.4 MPPT Model (MATLAB)

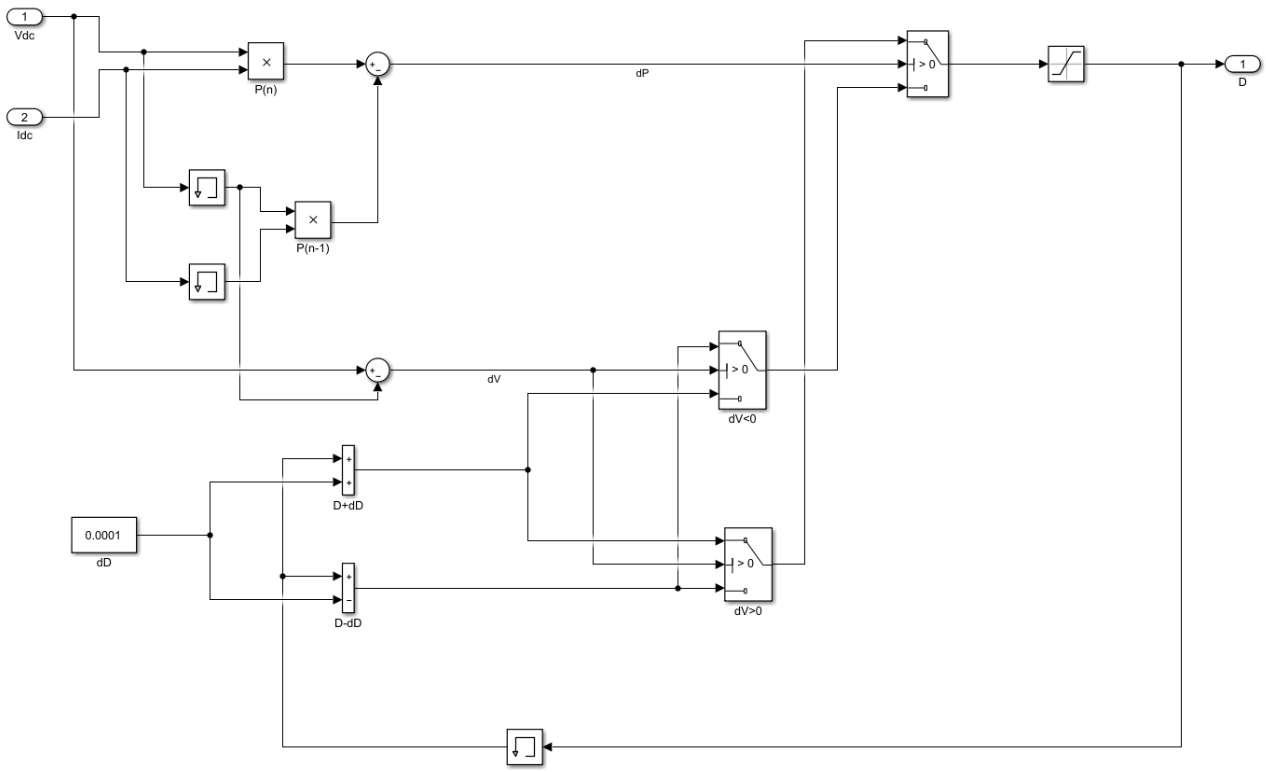

Figure 5.2 – Simulink Model of MPPT Controller for WECS.

Here in the above Model, Product of DC voltage and Current i.e., power are acting as input to the MPP Tracker. Further memory elements are used to produce delay and P(n-1). Then the comparison of P(n) and P(n-1) is done for the MPPT to obtain △P then switch is connected to simulate △P>0 state.

Moreover △V is obtained by difference between V(n) and V(n-1) and switches are used to simulate △V>0 and △V<0 conditions.

CHAPTER 6

CIRCUIT DIAGRAMS AND DC-DC CONVERTERS

6.1 Chapter overview

The following chapter presents single line diagram for the circuit model, parameter calculation, interlocking scheme, operating conditions, DC-DC converter calculations.

6.2 Circuit Diagram

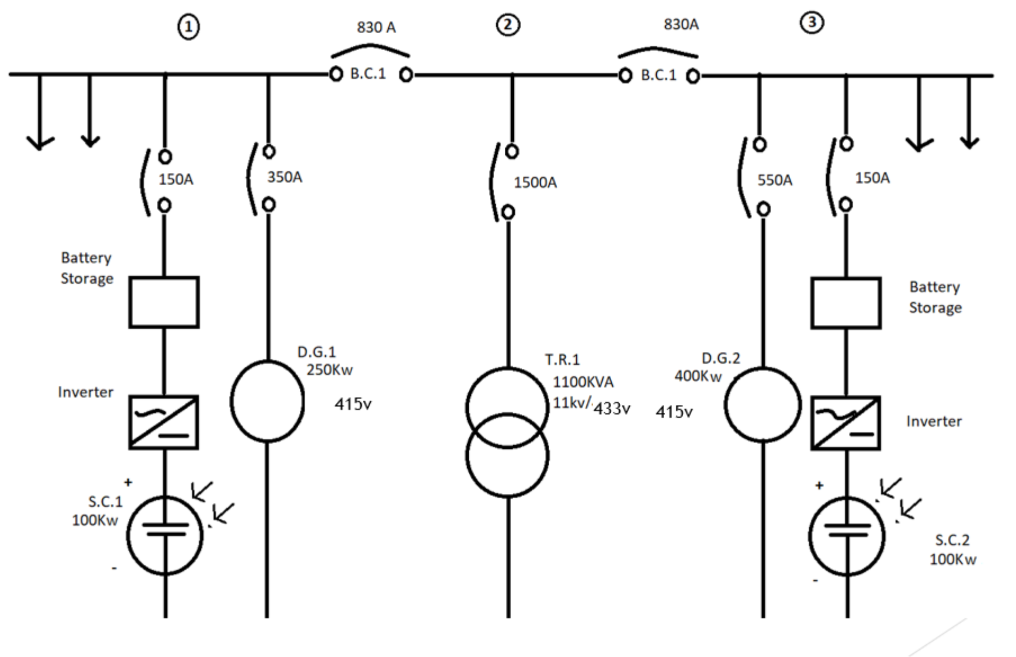

Figure 6.1 - Single line Diagram of the power backup circuit.

This project consists of 1 transformer (grid connected) which supplies load during normal working conditions. Also, we have used 2 DGs and 2 solar cells which are assigned as master and slave according to demand. In case of power failure, when the load is not being transferred from transformers, then Solar Cells or D.G.s will supply the load depending upon requirements. Moreover, the solar cells are also connected with central inverter, a step-up transformer, and a storage battery to store the solar power when working under normal conditions. To ensure protection, Bus Couplers are employed between DGs Transformers.

TR_1= Transformer (grid connected) 1100Kva ,11Kv/433v.

DG_1= Generator 1 (250Kw, 415v),DG_2= Generator 2 (400Kw, 415v).

SC_1= Solar cell 1 (100Kw),SC_2= Solar cell 2 (100Kw).

$BC_{1,}BC_{2,}BC_3$=Bus couplers 1,2,3.

6.3 Parameter Calculation And Circuit Breaker Ratings

i) Transformer

Since we have an industrial plant with high plant load, considering connected load is 2500A.

Formula for calculating Actual load is

Actual load = $\frac{\boldsymbol{Connected\ load \times load\ factor}(\mathbf{0.5-0.7})}{\boldsymbol{Diversity\ factor}(\mathbf{1.2-1.4})}$=*1250A(approx.)*

Using Actual load, we can calculate Transformer rating

$P=\frac{\sqrt{3}\times V\times I}{1000}=900KVA$

After adding 20% of grid margin and 20 % of reserve capacity of plant we get transformer rating equal to 1100KVA.

ii)Generator

As there is presence of reactive power component in DG, hence rating of DG is higher than that of transformer, so we do load shedding by 30 % and operate important machines only.

Formula for D.G. rating calculation is

$P= \frac{\sqrt{3}\times V\times I}{1000\times 0.8}=1050\ KVA\ ;(V=440,\ I=1100A)$

We get 850 KVA (approx.) after shedding 30% of load.

This 850 KVA is divided into four parts of 100KVA,100KVA, 250 KVA and 400 KVA.

For operating D.G.s and solar cells together we need match to Voltage, frequency and magnitude.

iii)Circuit Breaker ratings

Since P = VI$\sqrt{\mathbf{3}}$, it means I = $\frac{\boldsymbol{P}}{\boldsymbol{V}\sqrt{\mathbf{3}}}$

For TR1 – KVA =1100, V = 433, it means I ≈ 1470A, hence CB of 1500 A is used.

Similarly – 150A,150A for SC1 and SC 2

350A for GENERATOR 1 and 550A for GENERATOR 2.

6.4 Interlocking Schemes

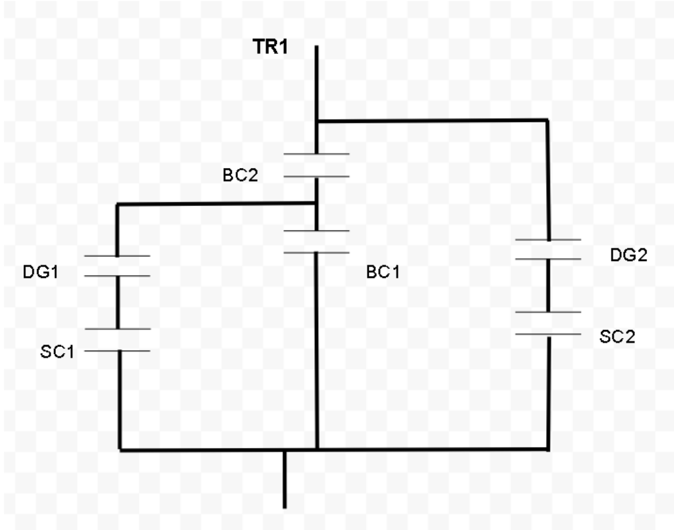

Figure 6.2 - Interlocking Scheme for TR1.

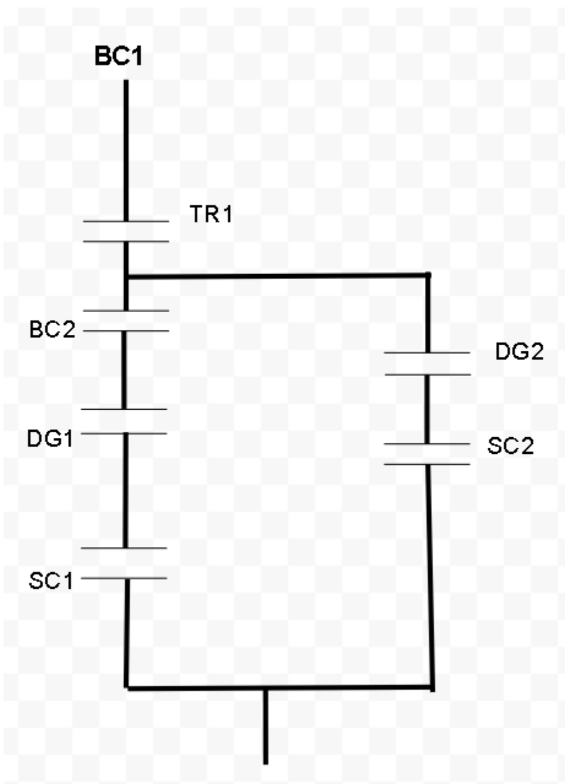

Figure 6.3 - Interlocking Scheme for BC1.

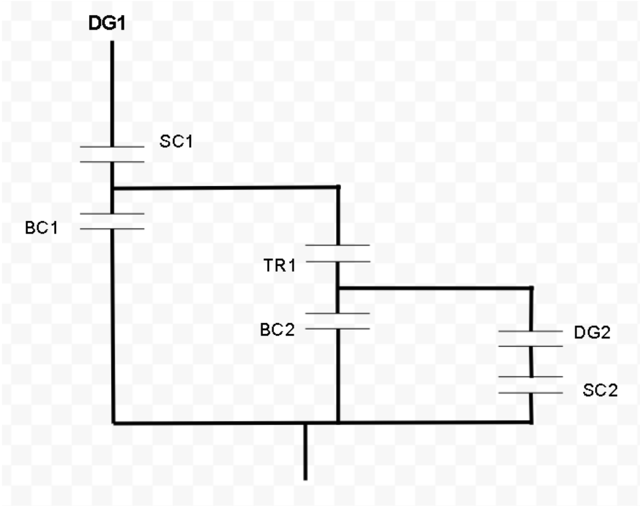

Figure 6.4 - Interlocking Scheme for GENERATOR 1.

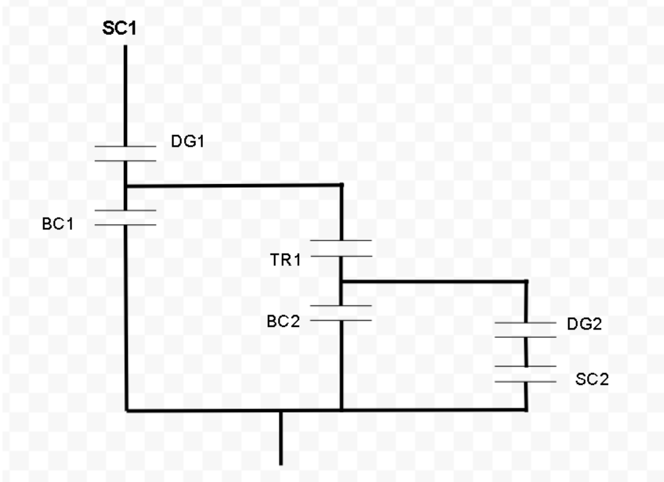

Figure 6.5 Interlocking Scheme for SC1.

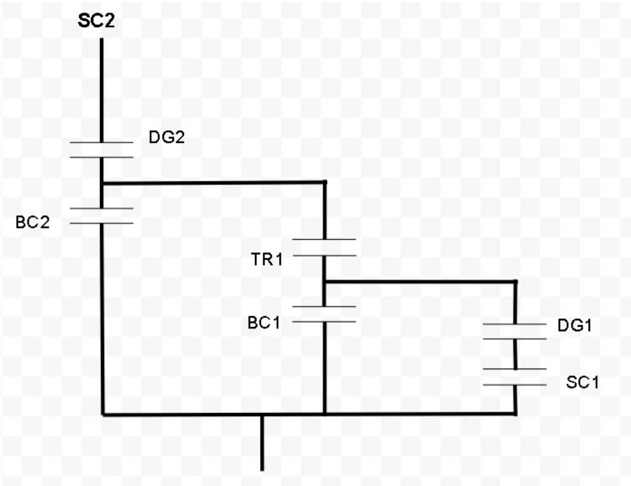

Figure 6.6 - Interlocking Scheme for SC2.

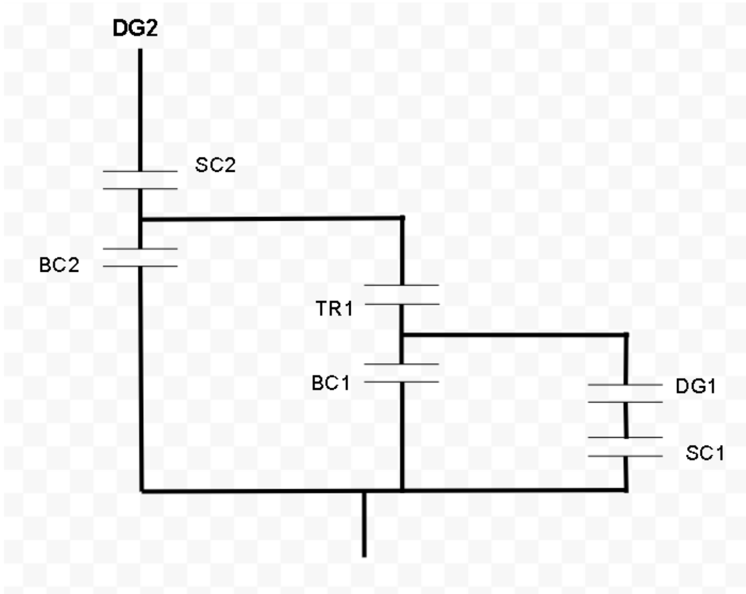

Figure 6.7 Interlocking Scheme for GENERATOR 2.

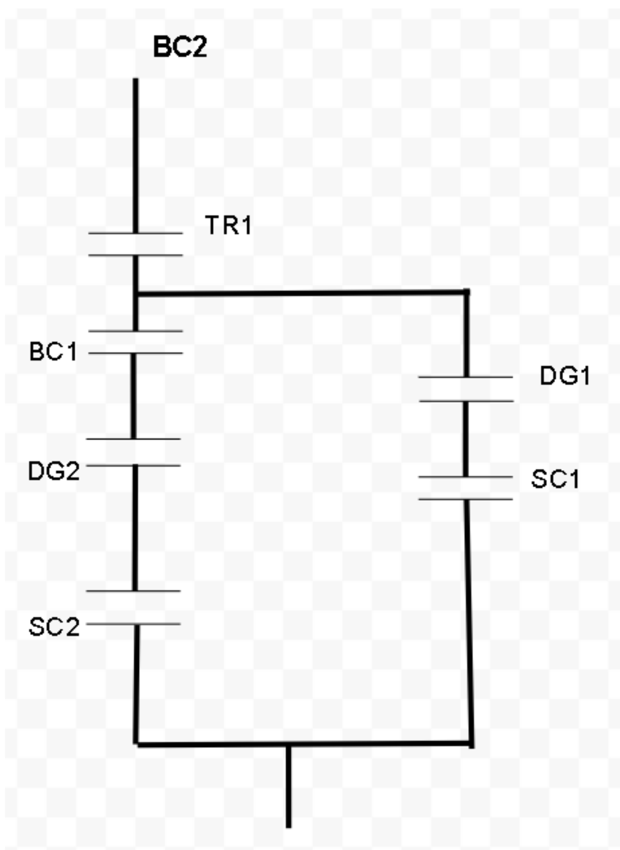

Figure 6.8 - Interlocking Scheme for BC2.

6.5 Operating Conditions

The following diagrams depict operating conditions of our power backup system:

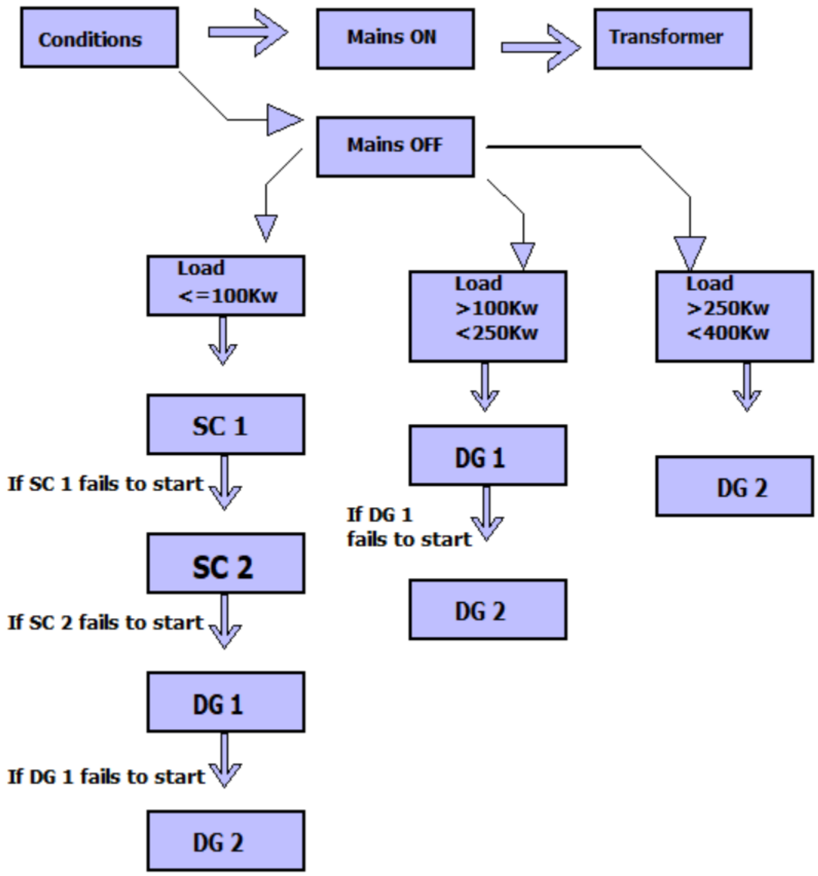

Figure 6.9 - Set of conditions 1

- If Mains is ON, transformer will supply the load.
- If Mains goes OFF, and max. plant load is less than or equal to 100Kw, then SC1 will supply the load.
- If SC1 fails to start, then SC2 will supply the load.
- If SC2 fails to start, then GENERATOR 1 will supply the load.
- If GENERATOR 1 fails to start, then GENERATOR 2 will supply the load.
- If Mains goes OFF and max. plant load is between 100Kw to 250Kw, then GENERATOR 1 will supply the load.
- If GENERATOR 1 fails to start, then GENERATOR 2 will supply the load.

- If Mains goes OFF and max. plant load is between 250Kw to 400Kw, then GENERATOR 1 will supply the load.

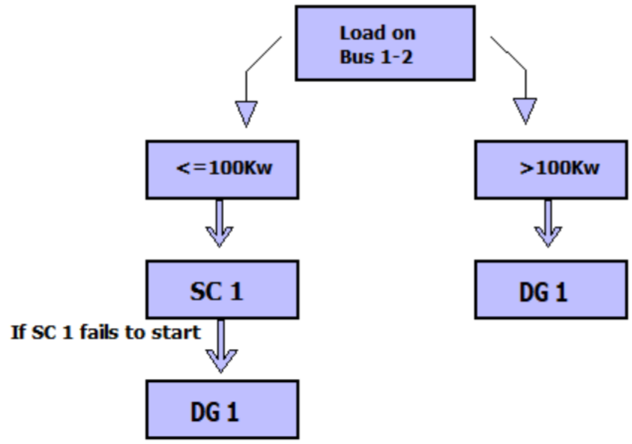

Figure 6.10 - Set of conditions 2

- If Mains is OFF and plant load on Bus 1-2 is less than 100Kw , then SC1 will supply the load.
- If SC1 fails to start, then GENERATOR 1 will supply the load.
- If Mains is OFF and plant load on Bus 1-2 is between 100Kw to 250Kw , then GENERATOR 1 will supply the load.

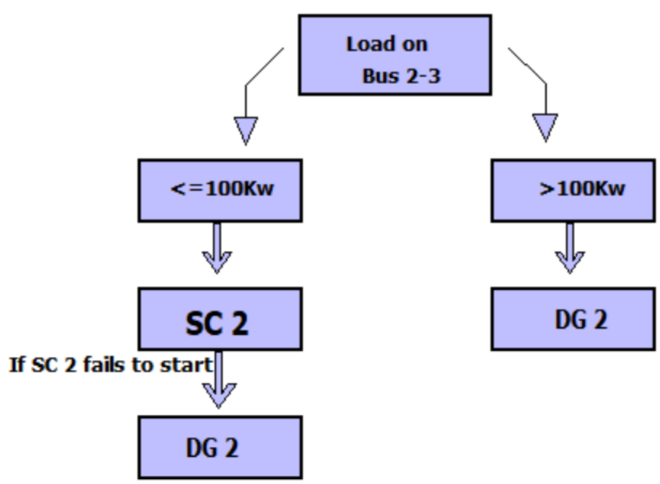

Figure 6.11 - Set of conditions 3

- If Mains is OFF and plant load on Bus 2-3 is less than 100Kw , then SC2 will supply the load.
- If SC2 fails to start, then GENERATOR 2 will supply the load.
- If Mains is OFF and plant load on Bus 1-2 is between 100Kw to 400Kw , then GENERATOR 2 will supply the load.

	Conditions	SC1	SC2	TR1	G1	G2	BC1	BC2
Mains On	Normal Working Conditions	0	0	1	0	0	1	1
Mains Off	Max. Plant load <=100Kw	1	0	0	0	0	1	1
	Max. Plant load <=100Kw, SC1 fails to start.	0	1	0	0	0	1	1
	Max. Plant load <=100Kw, SC2 fails to start.	0	0	0	1	0	1	1
	Max. Plant load <=100Kw, GENERATOR 1 fails to start.	0	0	0	0	1	1	1
	Max. Plant load b/w 100Kw to 250Kw.	0	0	0	1	0	1	1
	Max. Plant load b/w 100Kw to 250Kw, GENERATOR 1 fails to start.	0	0	0	0	1	1	1
	Max. Plant load b/w 250Kw to 400Kw.	0	0	0	0	1	1	1
	Load on bus section 1-2 is <=100Kw.	1	0	0	0	0	1	0
	Load on bus section 1-2 is <=100Kw, SC1 fails to start.	0	0	0	1	0	1	0
	Load on bus section 1-2 is b/w 100Kw to 250 Kw.	0	0	0	1	0	1	0
	Load on bus section 2-3 is <=100Kw.	0	1	0	0	0	0	1
	Load on bus section 2-3 is <=100Kw, SC2 fails to start.	0	0	0	0	1	0	1
	Load on bus section 2-3 is b/w 100Kw to 400 Kw.	0	0	0	0	1	0	1

Table 6.1 - All operating conditions for Switching System.

All these operating conditions and interlocking schemes can be fed to a PLC and efficient switching can be obtained along with integration of solar cells and diesel generators.

6.6 DC-DC Converter Calculations

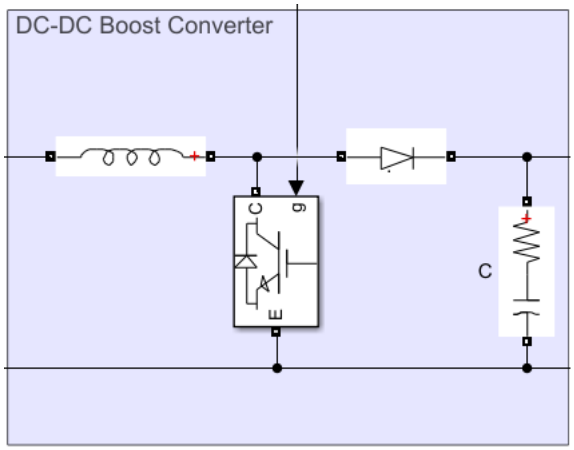

Figure 6.12 - DC-DC Boost Converter

Minimum out voltage available at rectifier output**:** $\boldsymbol{v_{in(min)} = 50}$

DC-DC converters output: $\boldsymbol{v_{out} = 400}$

The power rating of converter: $\boldsymbol{P_o = 12000}$

The switching frequency (fs): $\boldsymbol{f_s = 20000}$

The efficiency(n) of the DC-DC converter: $\boldsymbol{n = 0.95}$

Duty cycle of the converter: $\boldsymbol{D = (1 - \frac{(v_{in(min)} * n)}{v_{out}})}$ **= 0.8813**

Input current ripple (dI): $\boldsymbol{i_o = \frac{P_o}{v_{out}}}$ **= 30,** $\boldsymbol{i_{o(ripple)} = 0.2}$ (20%-40% of the output current)

$\boldsymbol{dI = i_{o(ripple)} * i_o \frac{v_{out}}{v_{in(out)}}}$ **= 48**

Output voltage ripple(dV) I am considering 0.5% voltage variations in output voltage, standard is 0.5%-1%: $\boldsymbol{dV = v_{out} * \frac{0.5}{100}}$ **= 2**

The inductance value (L): $\boldsymbol{L = \frac{v_{in(min)} * (v_{out} - v_{in(min)})}{dI * f_s * v_{out}}}$ = $\boldsymbol{4.5573 \times 10^{-5}}$

The capacitance value(C): $\boldsymbol{C = \frac{I_o * D}{f_s * dV}}$ = $\boldsymbol{6.6094 \times 10^{-4}}$

Minimum load that should be applied: $\boldsymbol{RL = \frac{v_{out}}{i_o}}$ **= 13.33Ω**

CHAPTER 7

RESULTS AND INFERENCES

7.1 MATLAB Simulation Results

7.1.1 Outputs from solar model

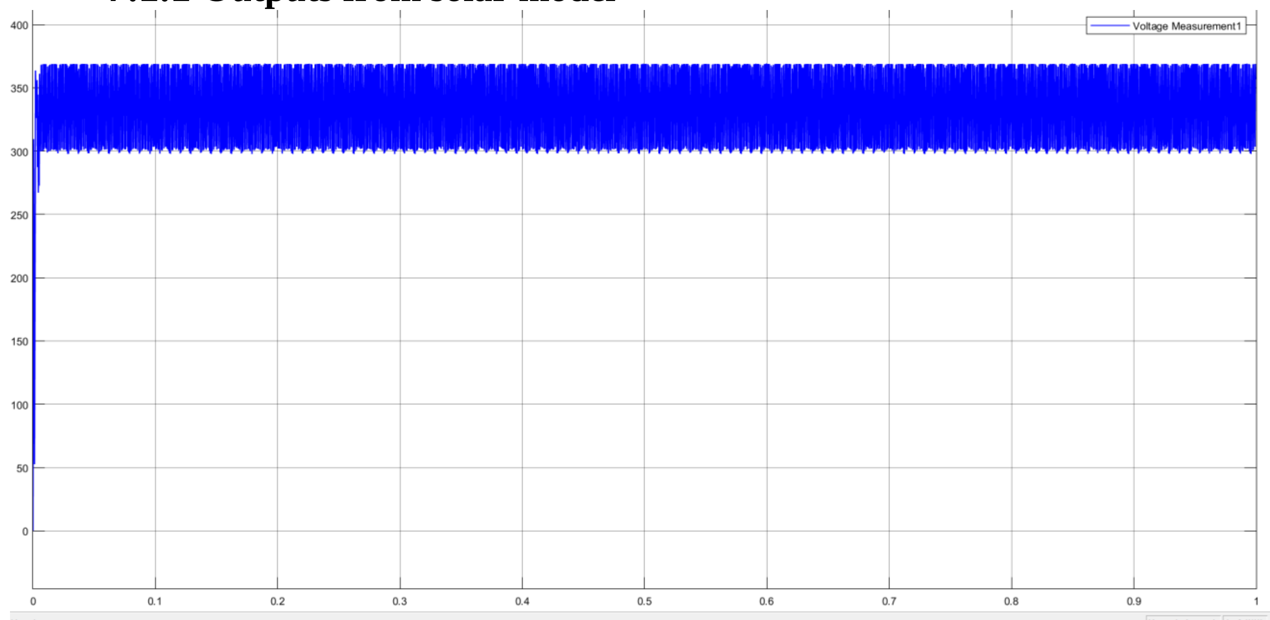

Figure 7.1 - Output Voltage from PV Array.

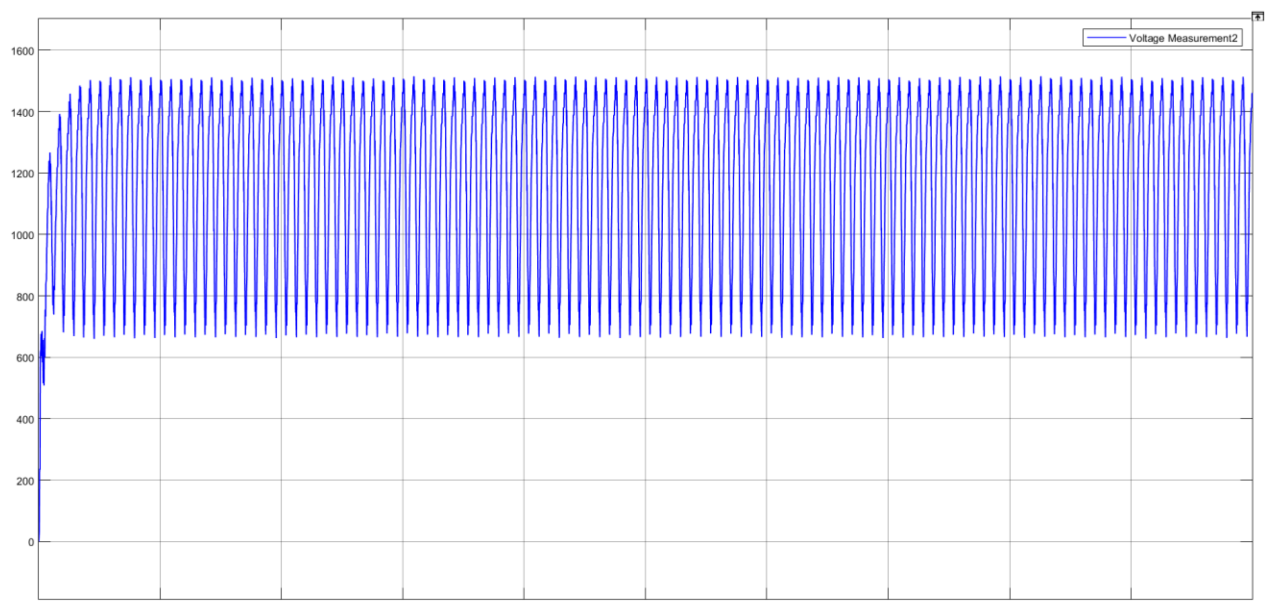

Figure 7.2 - Boosted DC Output voltage.

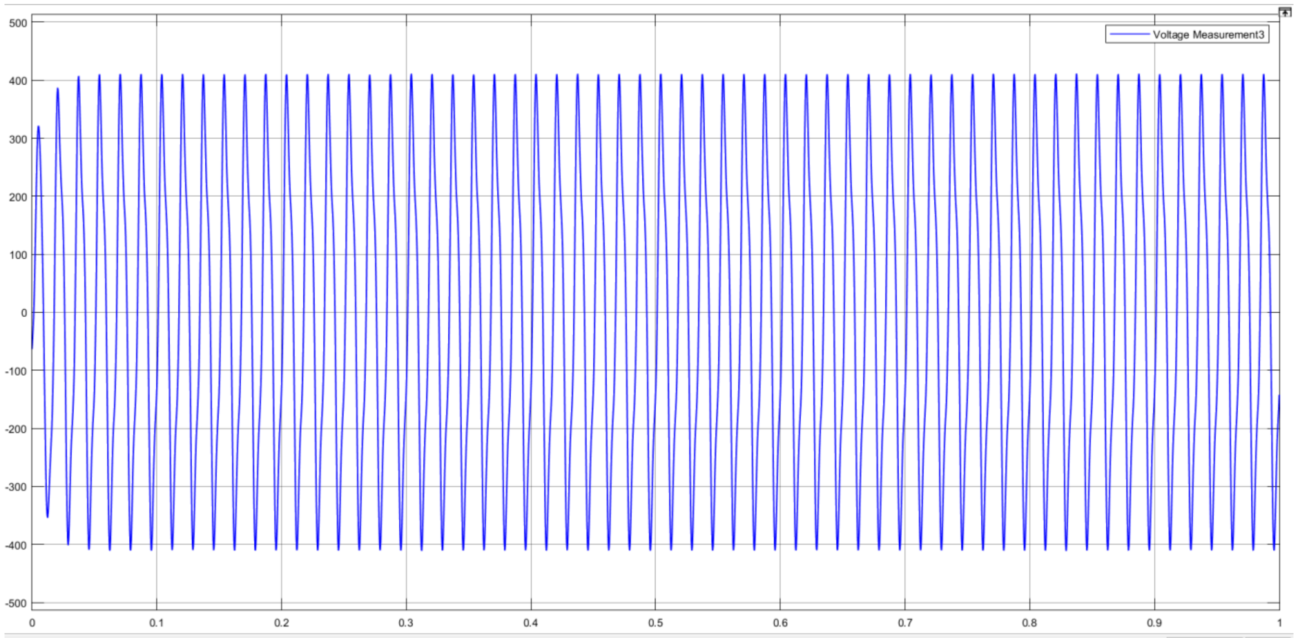

Figure 7.3 - Output AC Voltage Waveform.

In Figure 7.1, Output from PV array is obtained as DC voltage varying between 300-350V. As there is presence of ripples, hence there is need for a converter and inverter to obtain output AC voltage.

In figure 7.2, Output DC voltage after boosting is obtained. The voltage is varying between 700-1500 volts, with frequency of 50Hz. This output is then passed through an inverter to obtain AC power.

In figure 7.3, Output AC voltage approximately 415V is being obtained, This output is then sent to the grid for power supply operation.

7.1.2 Outputs from wind model

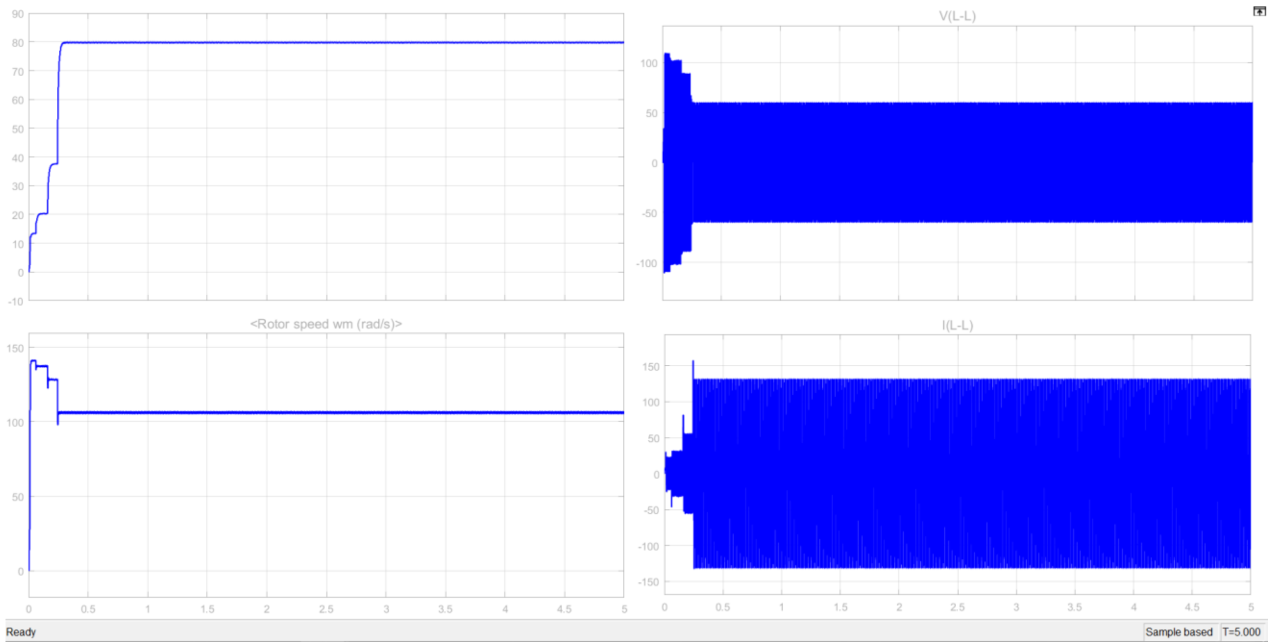

Figure 7.4 - Output Waveforms from PMSG – Rotor speed, I(L-L), V(L-L)

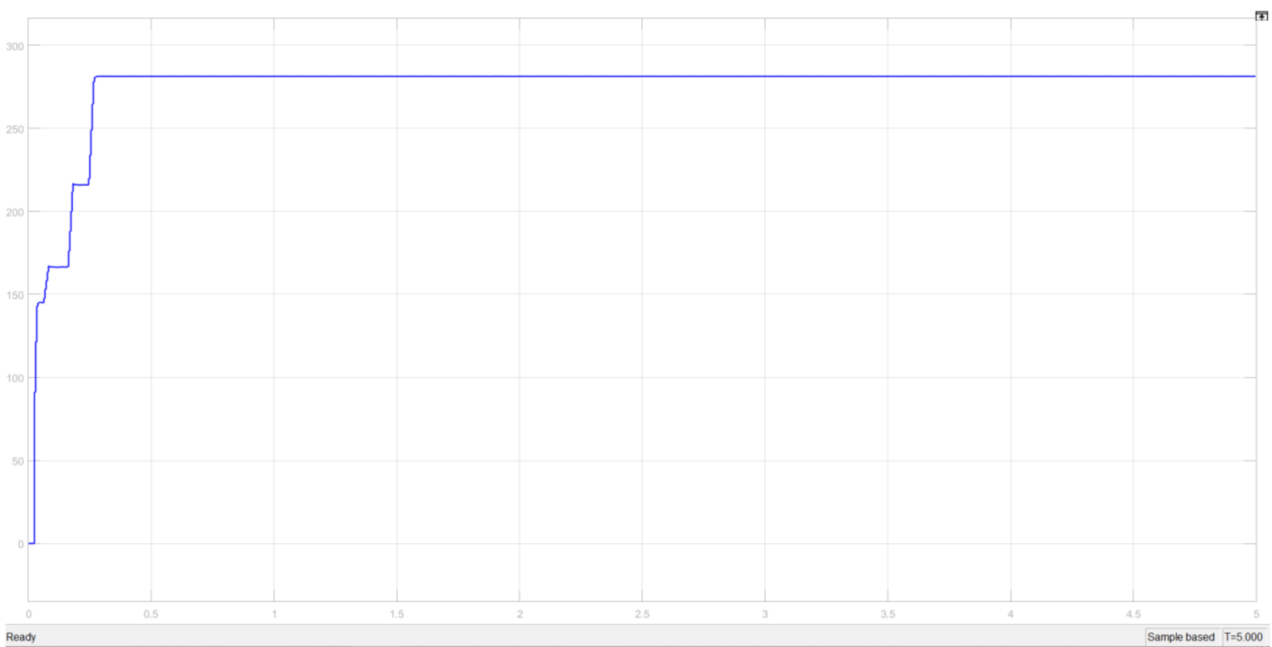

Figure 7.5 - Output DC Voltage Waveform.

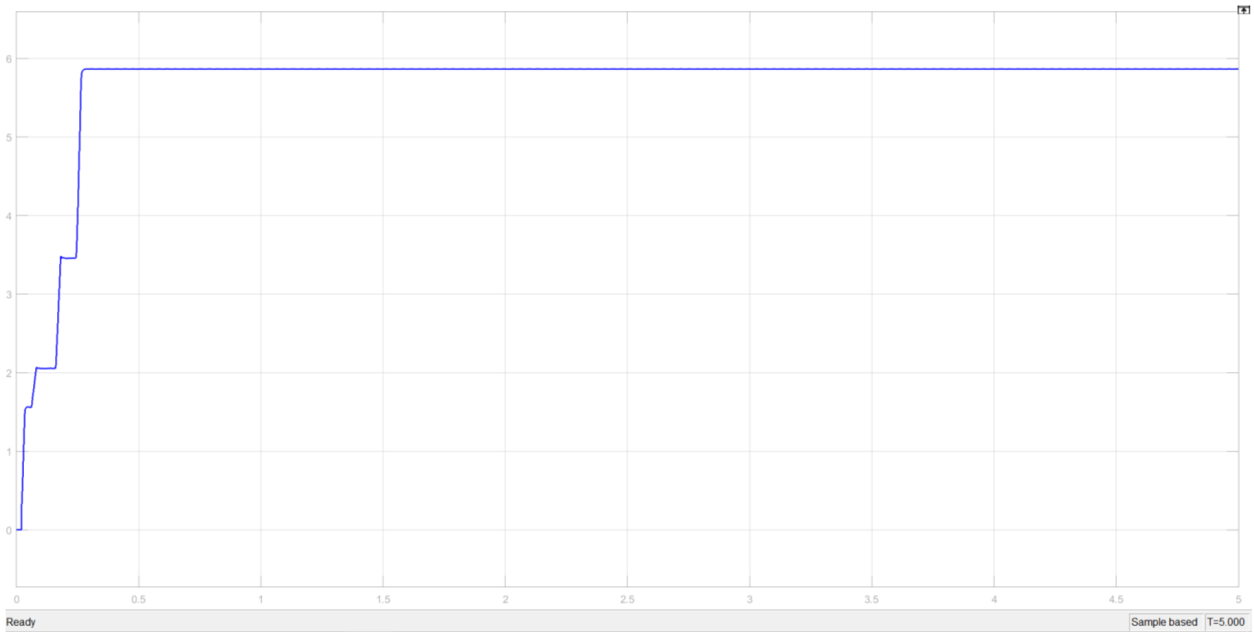

Figure 7.6 - Output DC power from Wind Turbine.

In figure 7.4, as you can see the Torque is nearly 80 Nm with the rotor speed being constant at 100 Rad/s (approx.). Also the Line to line voltage and current can be seen from the output ports of PMSG. With V(L-L) nearly equal to 60V and I(L-L) nearly equal to 125A.

In figure 7.5, output DC voltage is obtained with magnitude being approximately equal to 280V, the output is constant as no ripples are found. This can be used in purpose of battery storage for emergency backup.

In figure 7.5, the output DC power of the WECS is observed to be nearly 5.8Kw, as this turbine is going to be functional the whole time, this power can be stored in a battery which can be used to supply in case of emergency backup requirement.

7.2 Intouch Simulation Results

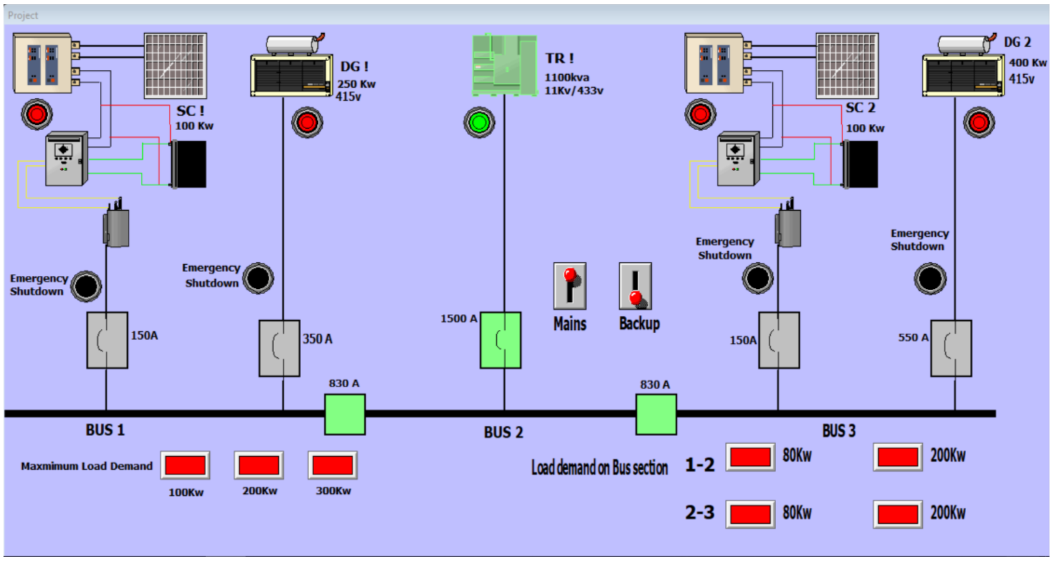

Figure 7 .7 - Normal condition – Mains On, TR1 supplying load.

Figure 7.7 depicts normal working condition, mains is turned on and TR1 is supplying the load to the plant. Backup systems are switched off.

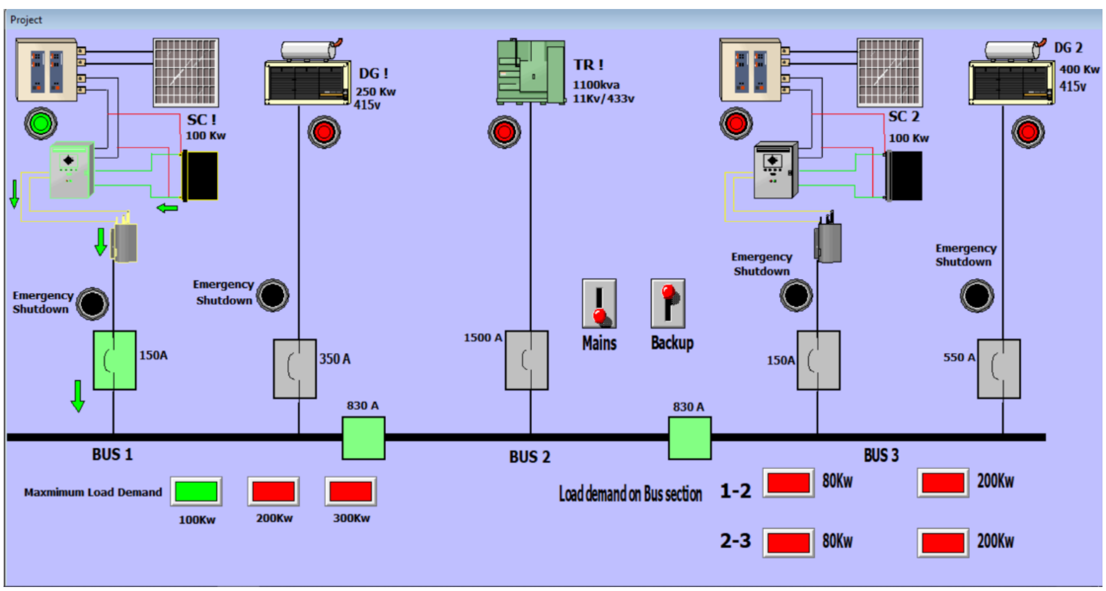

Figure 7.8 - Operating Condition 1 – Mains off, SC1 Supplying load.

In figure 7.8, Mains is off and Backup is turned on automatically. When the load requirement is nearly 100Kw, then SC1 will turn on and supply the load.

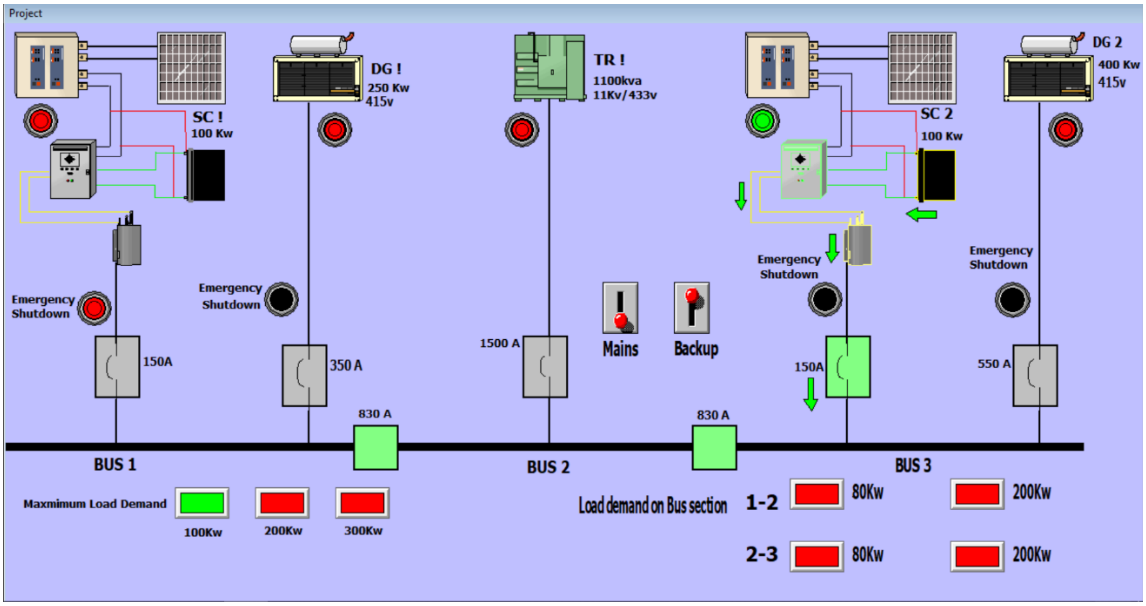

Figure 7.9 - Operating Condition 2 - SC1 fails, SC2 Supplying load.

In figure 7.9, failure of SC1 is shown. When SC1 fails to supply the load, then SC2 will start and supply the demand automatically. With load still being nearly equal to 100Kw.

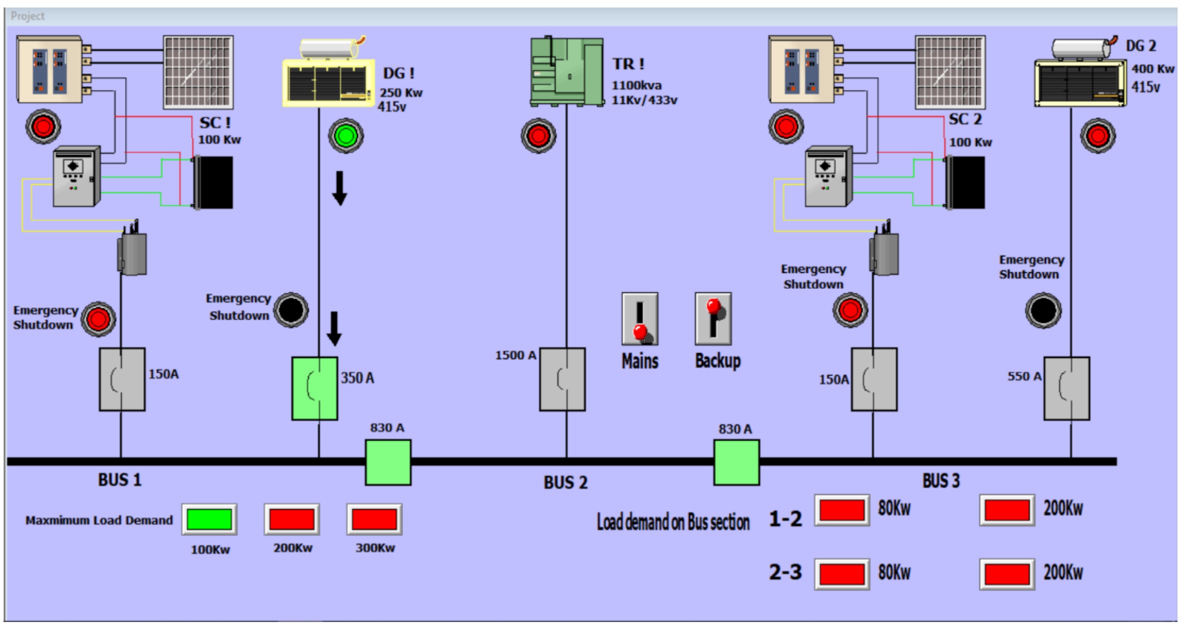

Figure 7.10 - Operating Condition 3 – SC2 fails, GENERATOR 1 Supplying.

In figure 7.10, failure of SC2 is shown. When SC2 fails to supply the load and demand is still nearly equal to 100Kw, then Generator 1 will start and supply the demand automatically.

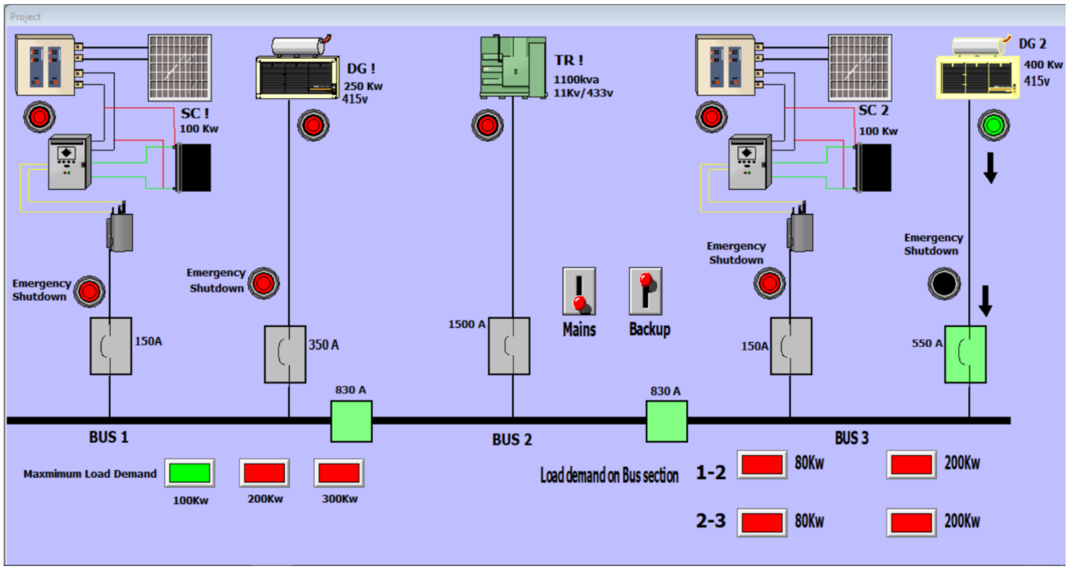

Figure 7.11 - Operating Condition 4 – GENERATOR 1 fails, GENERATOR 2 supplying Load.

In figure 7.11, failure of Generator 1 is shown. When Generator 1 fails to supply the load and demand is still nearly equal to 100Kw, then Generator 2 will start and supply the demand automatically.

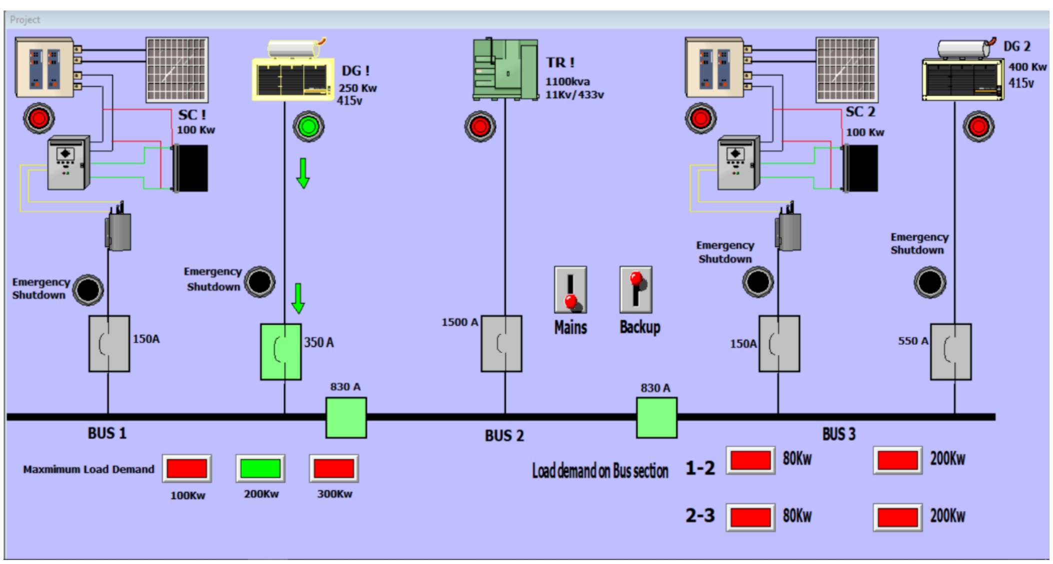

Figure 7.12 - Operating Condition 5 – Mains Off, GENERATOR 1 supplying load.

In figure 7.12, Mains is off and Backup is turned on automatically. When the load requirement is nearly 200Kw, then Generator 1 will turn on and supply the load. As the load is more than 100Kw, solar cells will not supply the load.

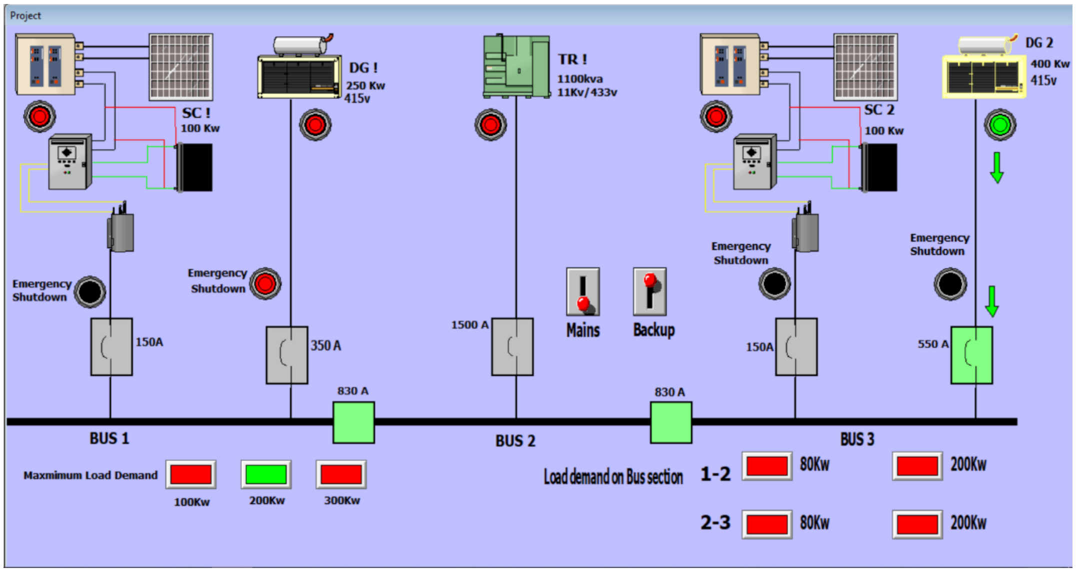

Figure 7.13 - Operating Condition 6 – GENERATOR 1 fails, GENERATOR 2 supplying Load.

In figure 7.13, failure of Generator 1 is shown. When Generator 1 fails to supply the load and demand is still nearly equal to 200Kw, then Generator 2 will start and supply the demand automatically.

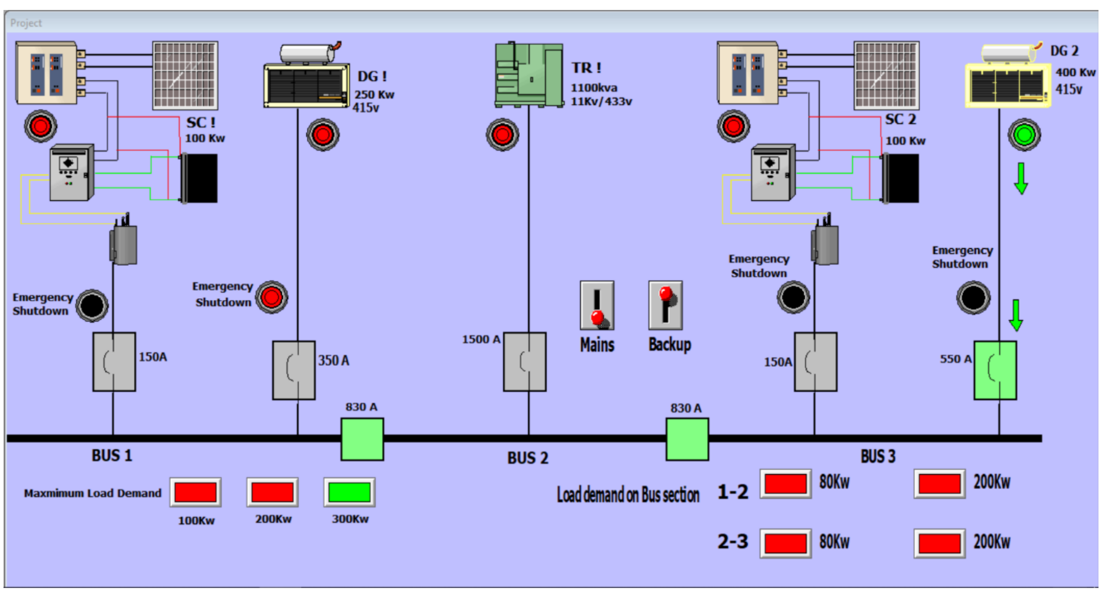

Figure 7.14 - Operating Condition 7 – Mains Off, GENERATOR 2 supplying load.

In figure 7.14, Mains is off and Backup is turned on automatically. When the load requirement is nearly 200Kw, then Generator 1 will turn on and supply the load. As the load is more than 200Kw, solar cells and Generator 1 will not supply the load.

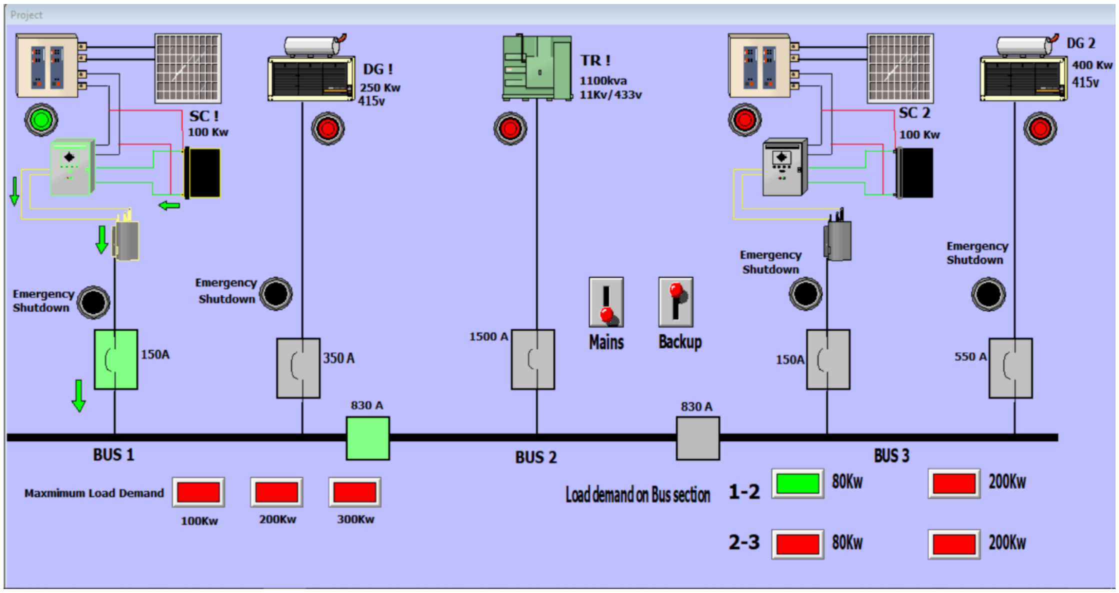

Figure 7.15 - Operating Condition 8 – Load on Bus 1-2, SC1 supplying load.

In figure 7.15, Mains is off and load demand on Bus 1-2 is less than 100Kw, then SC1 will supply the load automatically. Since it is sectional load demand, then SC2 and Generator 2 will not be operating.

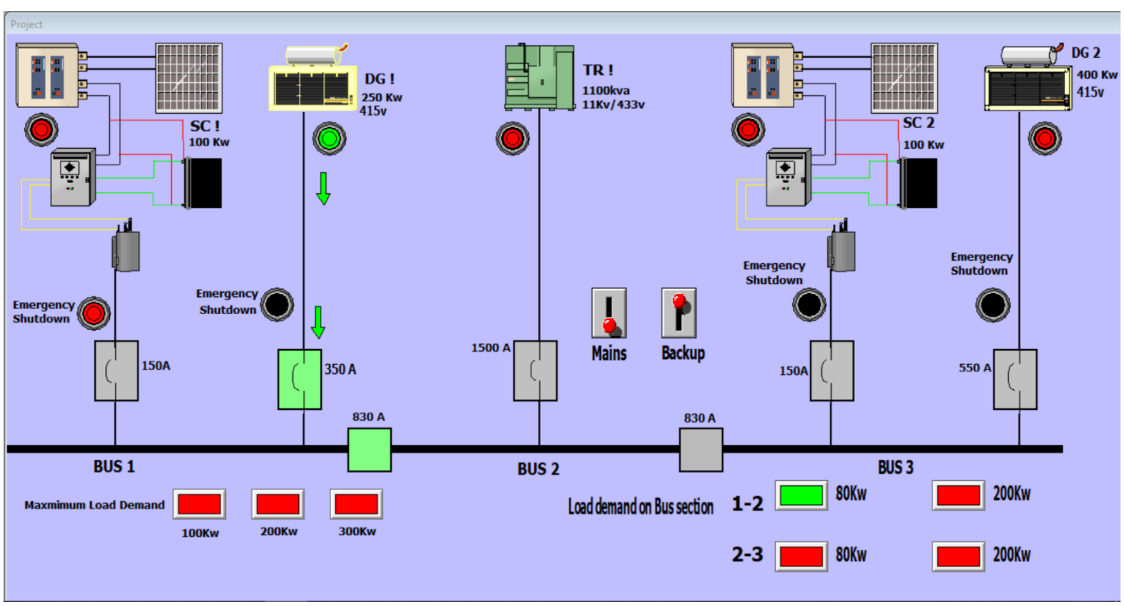

Figure 7.16 - Operating Condition 9 – SC1 fails, GENERATOR 1 supplying load.

In figure 7.16, failure of SC1 in case of sectional load demand on bus 1-2 is depicted. If SC1 fails due to any reason and load being less then 100Kw, then Generator 1 will supply the load.

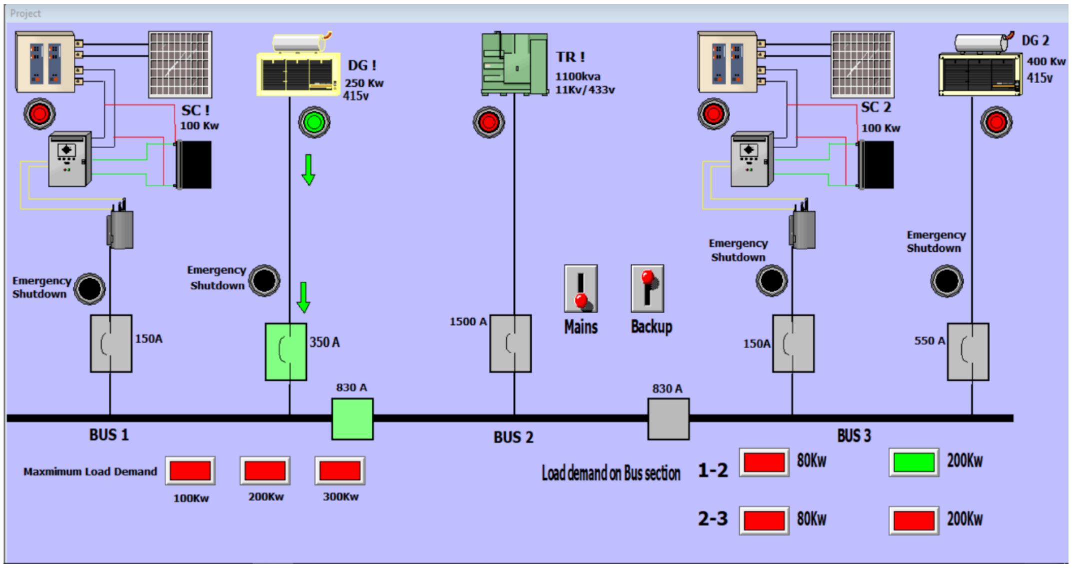

Figure 7.17 - Operating Condition 10 – Load on bus 1-2, GENERATOR 1 supplying load.

In figure 7.17, Mains is off and load demand on Bus 1-2 is less than 200Kw, then Generator 1 will supply the load automatically. Since it is sectional load demand, then SC2 and Generator 2 will not be operating.

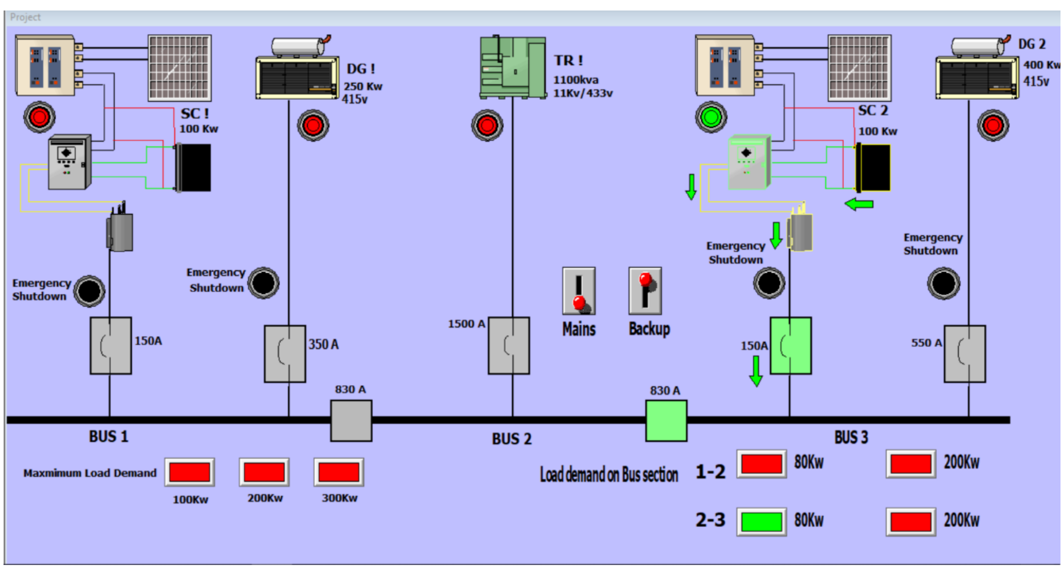

Figure 7.18 - Operating Condition 11 – Load on bus 2-3, SC2 supplying load.

In figure 7.18, Mains is off and load demand on Bus 2-3 is less than 100Kw, then SC2 will supply the load automatically. Since it is sectional load demand, then SC1 and Generator 1 will not be operating.

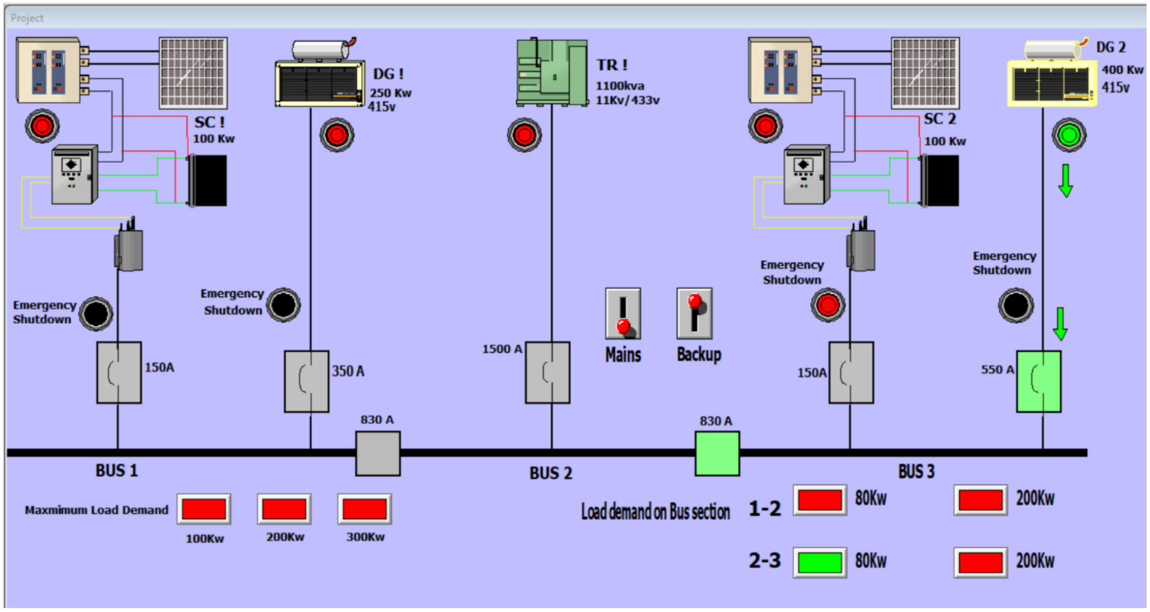

Figure 7.19 - Operating Condition 12 – SC2 fails, DG 2 supplying Load.

In figure 7.19, failure of SC1 in case of sectional load demand on bus 2-3 is depicted. If SC2 fails due to any reason and load being less then 100Kw, then Generator 2 will supply the load.

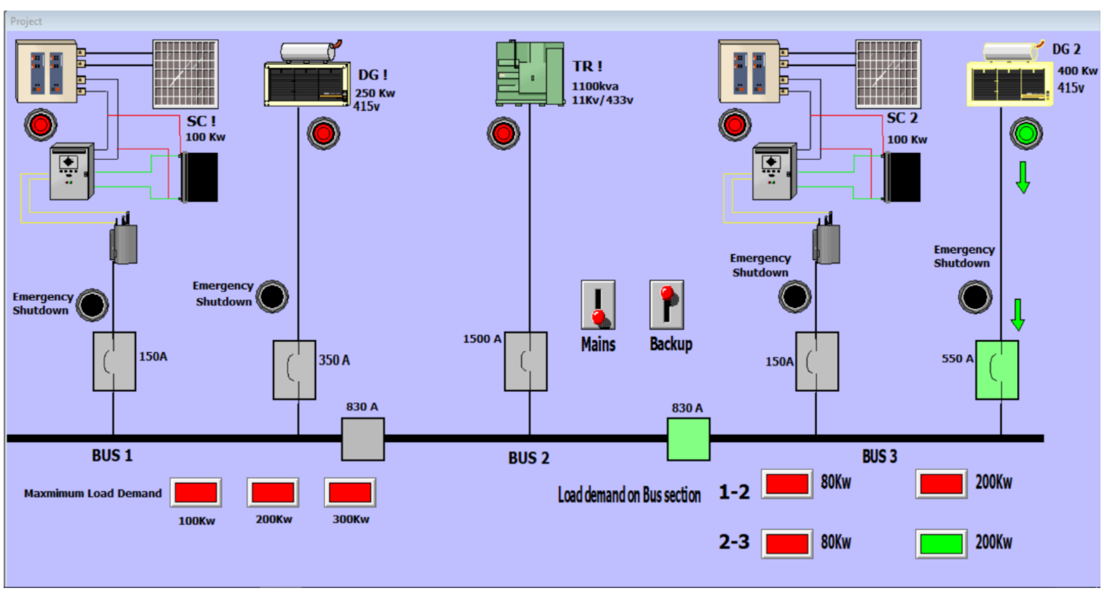

Figure 7.20 - Operating Condition 13 – Load on bus 2-3, GENERATOR 2 supplying load.

In figure 7.15, Mains is off and load demand on Bus 2-3 is less than 200Kw, then Generator 2 will supply the load automatically. Since it is sectional load demand, then SC1 and Generator 1 will not be operating.

7.3 Intouch Simulation Results With Wind Energy Model

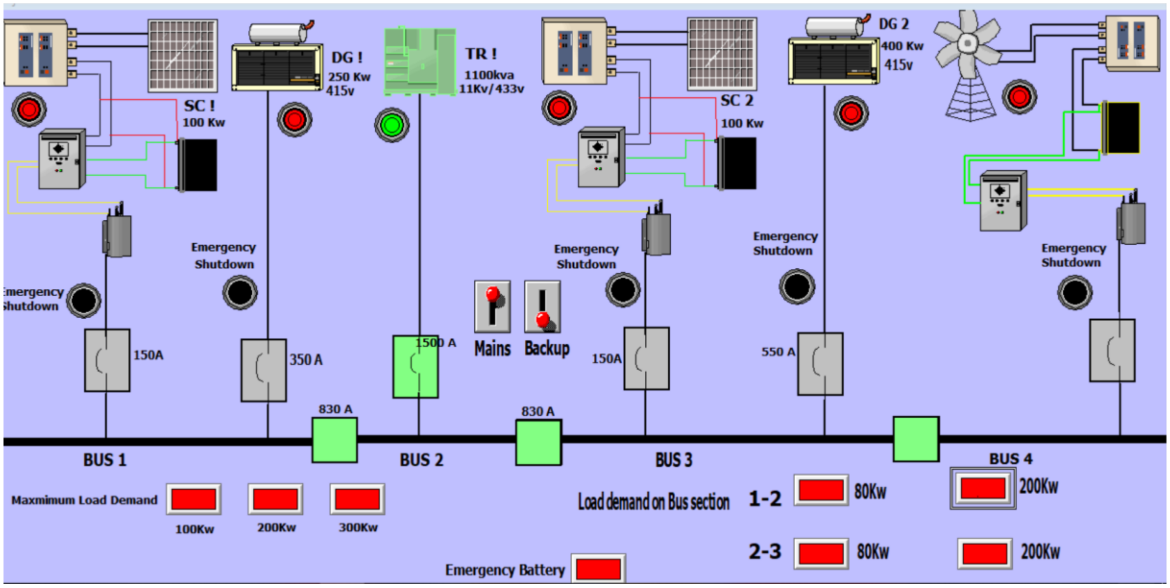

Figure 7.21 - Operating Condition 14 –Integration of constantly running wind turbine storing Electrical Energy in battery.

In figure 7.21, integration of all-time running WECS with storage is integrated. But it is still not being used as emergency backup is not switched on. Mains is on and backup is off.

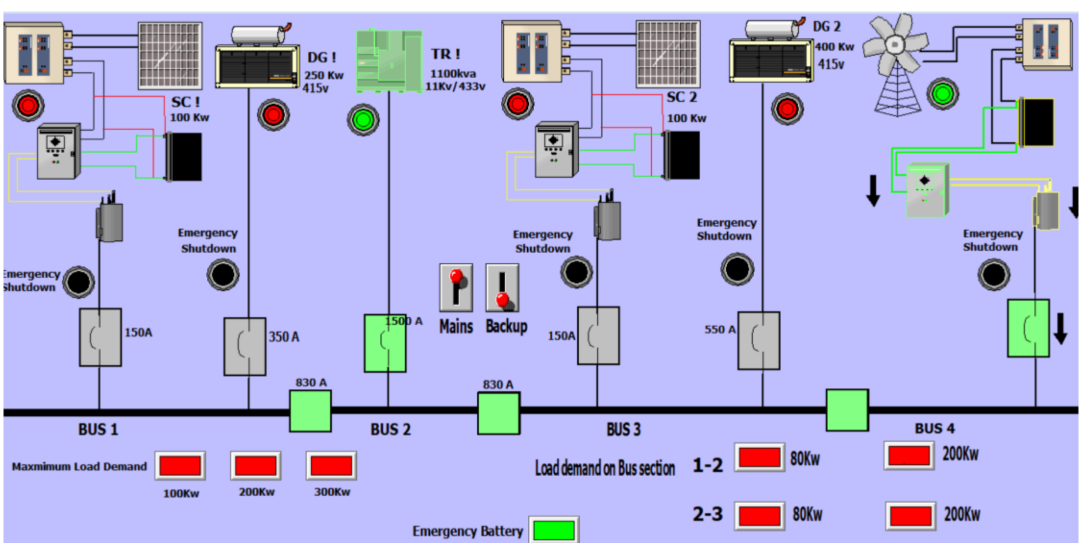

Figure 7.22 - Operating Condition 15 – Mains is ON and wind energy is also Switched on to extra power needed.

In figure 7.22, Emergency battery button is switched on, hence WECS based storage is now suppling the extra demand along with mains being switched on.

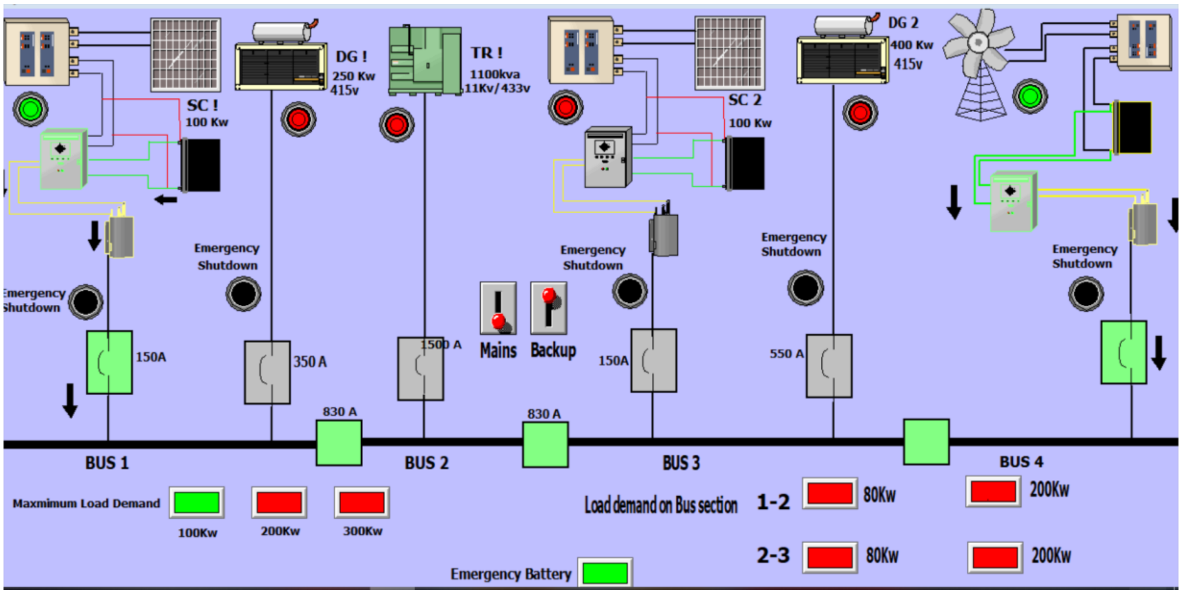

Figure 7.23 - Operating Condition 16 – Wind energy supplying additional power when mains is OFF and backup is being used.

In figure 7.23, Emergency battery button is switched on, hence WECS based storage is now suppling the extra demand along with backup power systems already available. In this condition, mains is off.

CONCLUSION

Integration of solar panel with Diesel generators to act as a hybrid power backup system has been successfully conducted. Output Voltage of 415V has been obtained through solar panels with the help of converter and inverter circuit. The MATLAB simulation shows that output AC voltage has a value of 415V and is sinusoidal in nature, hence synchronization with diesel generators is possible. Moreover, All the operating conditions in case of Power failure has been formulated and implemented in script, and switching scheme related to the same has also been simulated with the help of Wonderware InTouch. Furthermore, wind energy system with using MPPT is also integrated with the previously existing system for extra power requirement condition in both Mains and Backup condition.

FUTURE SCOPE

For future scope, an alarm system can be connected with the emergency shutdown buttons so that the control system can be notified by the alarm in case of failure of any power supply of all the available backup options.

Moreover, Load shedding arrangement can be added so that there will be availability to reduce load selectively in case power failure occurs and backup is in use.

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