SHARDA UNIVERSITY SCHOOL OF ENGINEERING AND TECHNOLOGY

CANDIDATE'S DECLARATION

I hereby declare that the work that is presented in this dissertation entitled "**Design of SCADA System for Micro-grid with Distributed Renewable Energy Resources with Reference to Sharda University**" towards partial fulfillment of the requirement for the award of the degree of **Master of Technology in Electrical and Electronics Engineering** with specialization in **"Power Systems Engineering"**, submitted to Department of Electrical and Electronics Engineering, School of Engineering and Technology, Greater Noida, is an authentic record of my own work carried out from January 2016 to June 2016, under the guidance of **Prof. H.K.Verma** , Distinguished Professor, Department of Electrical and Electronics Engineering, School of Engineering and Technology, Sharda University.

The matter embodied in this dissertation has not been submitted for the award of any other degree.

Date:

Place: Greater Noida (India) **(BIMENYIMANA Theogene)**

Roll No: 140134024

CERTIFICATE

This is to certify that the above statement made by the candidate is true to the best of my knowledge and belief.

Prof.H.K.Verma
Distinguished professor
Department of Electrical and Electronics Engineering
School of Engineering and Technology
Sharda University, Greater Noida

ACKNOWLEDGMENT

On the submission of my Dissertation on "**Design of SCADA System for Micro-grid with Distributed Renewable Energy Resources with Reference to Sharda University",** I wish to express my profound gratitude and indebtedness to **Prof. H.K.Verma ,** Distinguished Professor, Department of Electrical and Electronics Engineering, Sharda University, for his inspiring guidance, constructive criticism and valuable suggestions throughout this work.

I am grateful to **Prof. Gajendra Singh**, Professor, Head of Department of Electrical and Electronics Engineering, Sharda University. He has been a great source of inspiration to me.

I would also express my gratitude to all the professors of the department of Electrical and Electronics Engineering, Sharda University, for their guidance and the support they have provided to me. Last but not least, my sincere thanks to all my friends & seniors who have patiently extended all sorts of help for accomplishing this undertaking.

Date:

Place: Greater Noida (India)

BIMENYIMANA Theogene

Roll No: 140134024

ABSTRACT

Energy will continue to play an important role in the future. Availability of energy at reasonable price is one of the key issues for the development of any country. The deterioration of local and global environmental conditions has become the driving force towards the development of energy alternatives and improvements in the efficiency of energy use. A shift towards Renewable Energy Sources (RES) is an option worth considering.

There is a good opportunity of reducing the wastage of energy and carbon footprint in Sharda University as in any other teaching institution. In this dissertation work, **a Supervisory Control and Data Acquisition (SCADA) System for Micro-grid with Distributed Renewable Energy Resources,** has been designed **with reference to Sharda University** to reduce the wastage of energy through centralized energy management and to identify any problem in the micro-grid and address it for its efficient and reliable operation. The system design has considered all possible energy resources available at University, power demand, economics, energy conversion efficiency, and environmental concerns. Power from Noida Power Company Limited (NPCL) and distributed Diesel Generator sets along with proposed distributed roof-top PV solar plant units will be utilized to generate electricity. The university micro-grid with connected loads, and distributed energy resources has been designed to support the micro-grid operation with improved reliability, resiliency and power quality.

Micro-grid enabling technologies, including control and monitoring functions of SCADA and smart meters are used here to carry out real time information and take control decisions to meet the ever-changing demand optionally.

In the proposed SCADA system, 14 Remote Terminal Units/Programmable Logic Controllers (RTU/PLC) will be in bus data network for communicating with Master Terminal Unit (MTU) located in control room by using existing Ethernet LAN of Sharda University. Here, 4 RTUs are for 4 Electrical Substations and 10 RTUs are for selected 10 buildings in which 10 Units of distributed roof -top solar plant will be placed. The unit controllers (RTU/PLC) will acquire digital inputs (status) from Field Devices (FDs) through 24 V DC cable and deliver digital outputs (control commands)

to Fields Devices (FDs) through 240V AC cable .RS 485 LAN will be used as communication network between Smart Multi-Function Meters (SMFM) and RTU.

Due to the intermittent behavior of sunlight, the integration of PV energy generation into micro-grid results in challenges such as the changes in voltage profile and frequency response of the system. Possible solutions to PV connection issues have been considered for the better operation of the system. Use of energy storage units and other renewable resources are among many means to offset these challenges.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS

SCADA: Supervisory Control and Data Acquisition

MTU: Master Terminal Unit

RTU: Remote Terminal Unit

PLC: Programmable Logic Controller

SMFM: Smart Multi-Function Meter

FD: Field Device

RES: Renewable Energy Source

DER: Distributed Energy Resource

NPCL: Noida Power Company Limited

PV: Photovoltaic

DC: Direct Current

AC: Alternative Current

LAN: Local Area Network

SLD: Single Line Diagram

PV SP: Photovoltaic Solar Plant

ESS: Electrical Substation

DG: Distributed Generation

TW: Terawatt

PCU: Power Conditioning Unit.

CHP: Combined Heat and Power

US: United States

DOE: Department of Energy

DA: Distribution Automation

MVA: Mega Volt Amp

SS: Substation

DS: Distribution Substation

DBB: Distribution Board of Block

SET: School of Engineering and Technology

kWp: kilowatt peak

SF6: Sulfur hexafluoride

EM: Energy Meter

CB: Circuit Breaker

MCB: Miniature Circuit Breaker

MCCB: Module Case Circuit Breaker

MCCB-RTC: MCCB with Remote Trip and Close arrangements

MCCB-RT: MCCB with Remote Trip arrangements

CHAPTER 1: INTRODUCTION

1.1: GENERAL

Energy is the lifeblood of modern civilization. With the increasing needs for domestic and industrial power, energy management has become a challenge. It is required to adopt evolutionary strategies across the globe to provide consistent, cost effective, affordable, green and quality power for socio-economic, environmental and technical benefits [1]. Distribution generation located close to the demand delivers electricity with minimum losses. This power may therefore have a high value than power coming from large, central conventional generators through the traditional utility transmission and distribution infrastructure. With the use of renewable distributed generation, the dependency on fossil fuels and their prices can be minimized.

A new type of Distribution Generation (DG) network structure, a micro-grid is organized using DG, and the local loads and it can operate in two modes: grid connected and islanding modes [2]. The grid is continually run in the Islanded Mode due to failure in the main grid or high disturbances created in the micro-grid. Micro grid provides reliable and flexible power to consumer and provides benefits which can be classified into two major groups: Economical/Environmental and Power quality [3]. In this dissertation work, the layout of micro-grid of Sharda University organized with proposed 10 distributed roof-top PV plant units of 100kW for each, existing 6 Diesel generator sets, loads and power from the Noida Power Company Limited (NPCL) has been designed as the single controllable unit. The space availability and demand has been considered for the locations of roof-top PV Solar plant units and all PV Solar plant units are connected to the electrical main panel of selected building at University.

A Supervisory Control and Data Acquisition (SCADA) system can be used to monitor and control the devices or equipment in the micro-grid, based on computer technology, communication technology and automation technology. Through gathering and analyzing real time data, SCADA system affects micro-grid safe operation and reasonable dispatch [3]. In this master 'thesis dissertation work, the SCADA system for micro-grid with distributed renewable energy resources with reference to Sharda university has been designed in order to reduce to waste of energy through energy management, and for reliable of operation of micro-grid. In this work, the governing of the system will be a Master Terminal Unit (MTU) in control room, which is the brain of micro-grid, it will tell us what happened, why it happened and what we need to do.

In this SCADA system, using the existing Ethernet LAN of Sharda university, 14 Remote Terminal Units/Programmable Logic Controllers will be in bus data network for communicating with Master Terminal Unit (MTU). In this data network, 4 Remote Terminal Units are assigned for 4 electrical substations present at University while 10 Remote Terminal Units are assigned for 10 buildings with proposed 10 units of distributed roof-top PV solar plant. In addition to these, Smart Multi-Function Meters (SMFM) will be placed on all feeders for showing different reading parameters in buildings, but the main work will be for the master controller. The unit controllers will communicate with field devices through individual wired circuit.

Connections of distributed roof top PV Solar plant units in micro-grid play an increasingly significant role as electric supply source and as an integral part of the electrical. However, PV poses some notable challenges to grid engineers and operators. They include rapid output variation, effects on power quality, especially voltage and current harmonics [4]. In this dissertation work, issues related to the connections of PV generation in micro-grid has been clarified as well as the possible solutions to manage those challenges.

1.2: PROBLEM STATEMENT

A reliable and flexible power infrastructure is required due to the intensive need of electricity and vulnerability of traditional electrical power systems. As an important supplementary for traditional power system, the micro-grid with distributed generation (DG) provides economical/Environmental and Power quality benefits [2]. Like large power grids, micro-grids generate, distribute and regulate electricity, but on local level.

Alongside the many advantages, the micro-grid organized with Distributed generation bring, they raise several problems which are due to the complexity of the system configuration in which they are used. This aspect is mainly caused by the diverse topologies of renewable energy sources and the varying over time availability. Therefore the development of electronics and software technology can represent a solution. A convenient solution to this problem can be the management of information system in general and SCADA in particular [5]. The design of Supervisory Control and Data Acquisition (SCADA) system in which local controllers are used based on local power needs can save energy and money through reliable and economical operation of micro-grid.

1.3: OBJECTIVES

This dissertation work on "Design of SCADA system for Micro-grid with Distributed Renewable Energy Resources with Reference to Sharda University has the following objectives:

1. Economical operation of micro-grid by reducing the waste of energy through energy management
2. To identify any problems in the micro-grid and report them instantly for its reliable operation

1.4: METHODOLOGY

To achieve to above objectives, the following steps has been followed:

1. Single Line Diagram of distribution network scenarios in Sharda University.
2. Locations and Connections of 10 Units of proposed distributed PV Solar Plant in Sharda University distribution network.
3. Control logic for Micro-grid
4. Creating the proposed micro-grid of Sharda University
5. Layout of SCADA System for Micro-grid.
6. Panel Layout in each block
7. Layout of Master Terminal Unit in Control Room.
8. Data Network for Communication between MTU and RTUs

9. Design of RTUs for Digital Inputs and Outputs at different locations in micro-grid.

10. Communication between RTU and Field Devices.

11. Issues related to the connection of PV Solar Plant to micro-grid and possible solutions to these challenges.

1.5: OUTLINE OF REPORT

The remainder of the work is organized in 4 chapters as follows

Chapter 2 outlines the background information which started with introduction (section2.1), gives background information on PV energy generation(section 2.2); distribution generation along with its merits compared to centralized generation(section 2.3), introduce micro-grid with its enabling technologies(section 2.4), and introduce SCADA with its purposes, suitability and advantages (section 2.5).

Chapter 3 shows the layout of micro-grid of Sharda university, where it started with introduction (section 3.1), show SLD of distribution system in Sharda University (section 3.2), the locations of proposed distributed roof-top PV solar plant units (section 3.3) and show the layout of micro-grid of the Sharda university (section 3.4)

Chapter 4 shows the design of SCADA system for micro-grid, where it started by introduction (section 4.1), show layout of panel with interconnections in a building (section 4.2), give layout of SCADA system (section 4.3), the design of MTU in control room along with the date network for communication between MTU and RTU's (section 4.4), the design of RTU for inputs and outputs for different locations in micro-grid along with communication between RTU and FD's (section 4.5).

Chapter 5 outlines the issues related to the connections of PV solar plant units in the micro-grid where it started with introduction (section5.1), challenges with solar PV integration (section 5.2), various solution of PV integration where solutions has been clarified in standalone PV systems, grid-tied PV systems and specifically for Sharda university micro-grid (section 5.3); current electric energy storage technologies has been described in section (5.4)

Chapter 6 summarizes the results and discusses the conclusion and recommendation and gives the suggestions for future scope.

CHAPTER 2: BACKGROUND INFORMATION

2.1: INTRODUCTION

2.2: PV ENERGY GENERATION

The huge amount of solar energy is available on the earth. Humans consume almost 15 TW of solar energy. Customers are interested in solar power due to low cost, environment friendly, flexible installation [6]. A PV array produces power when exposed to sun light, number of other components is required to properly conduct, control, convert, distribute, and store the energy produced by the Array. Grid-connected PV systems are designed to operate in parallel with and interconnected with the utility [7].

Photovoltaic power systems are generally classified according to their functional and operational requirements, their component configurations, and how the equipment is connected to other power sources and electric loads. The two principal classifications are grid-connected or utility-interactive systems and stand –alone systems [7].

2.2.1: Stand- alone Photo voltaic Systems

Stand –alone PV systems are designed to operate independent of the utility grid, and are generally designed and sized to supply certain DC and /or AC electric loads. These types of systems may be powered by a PV array only, or may use wind, an engine –generator or utility power source in what is called PV-hybrid systems [7]. Stand –alone PV systems is most relevant and successful in remote and rural areas having no access to grid supply.

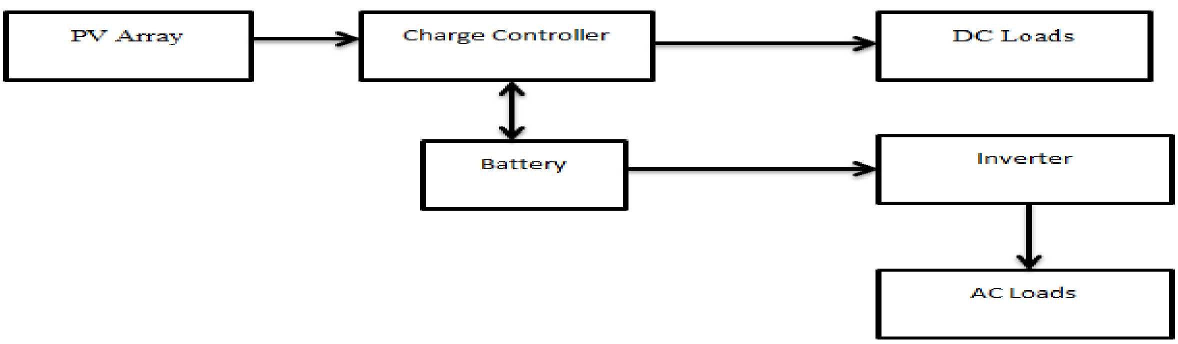


Figure 1: Diagram of stand –alone PV system with Battery storage Powering DC and AC loads [7].

2.2.2: Grid-connected Photovoltaic systems.

Grid-connected systems are designed to operate in parallel with and interconnected with the utility grid. The primary component in grid connected PV systems is the inverter, or Power conditioning Unity (PCU) [6]. The DC power is first converted into AC by inverter, harmonic are filtered and then only the filtered power is fed to the grid after adjusting the voltage level [7]. A bidirectional interface is made between the PV system AC output circuits and the electric utility network, typically at an on-site distribution panel or service entrance. This allows the AC power produced by the PV system to either supply on-site electric loads or back-feed the grid when the PV system output is greater than on-site load demand [7].

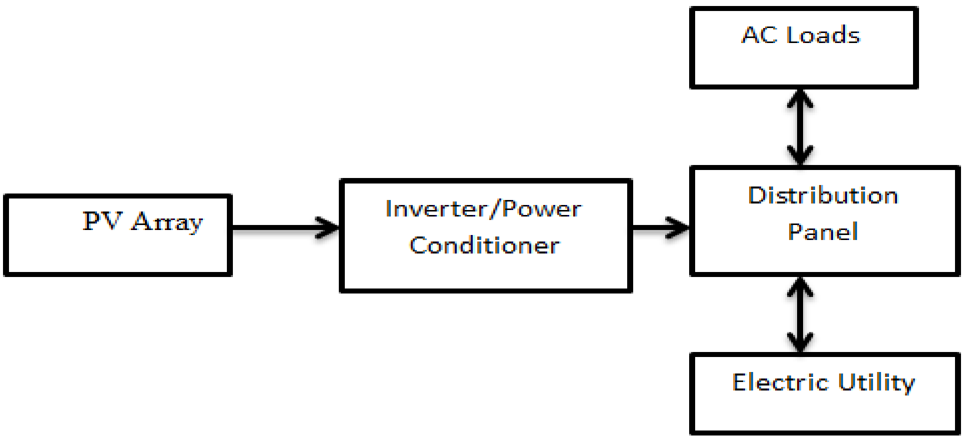


Figure 2: Diagram of Grid –connected photovoltaic system [7].

2.3: DISTRIBUTED GENERATION

2.3.1: Definition

Distributed generation can be defined as the integrated or stand-alone use of small, modular electricity generation resources by utilities, utility customers and private individuals or other third parties in applications that benefit the electric system, specific end-use customers, or both [8].

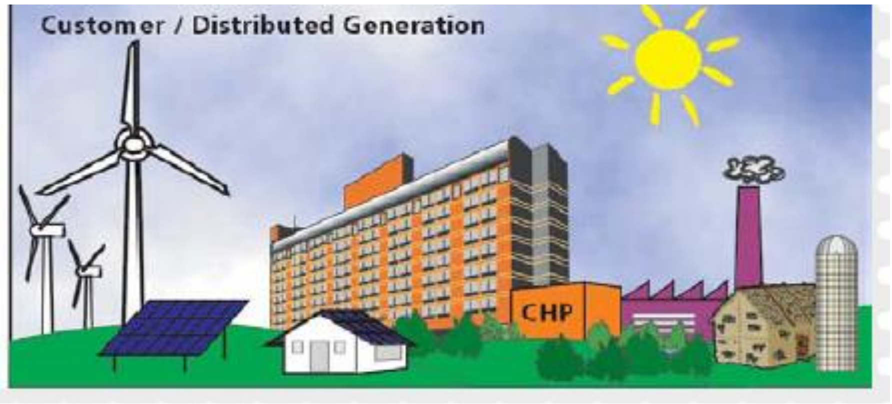


Figure 3: Distributed Generation System [8].

2.3.2: Relative Merits of Distributed over Centralized PV generation

a) Sitting Issues and land Requirements

Distributed PV is typically customer sited on building rooftops and therefore, no land costs are associated with the installations. Distributed PV is in fact, one of the few renewable energy resources that can be easily customer sited on pitched or flat roof buildings. Some distributed PV installations are an actual part of the building construction, and can replace the material cost associated with a new or replacement roof, ceilings. Central PV requires large land areas without shading, ideally in a location that is close to transmission lines. Tree or other obstruction shading is usually not a concern for central station applications as they are typically sited in remote scrub or desert areas. These very remote areas can sometimes provide lower priced land costs, but lack of access to nearby transmission lines can be an issue. Extending transmission lines to a site can be very costly [9].

b) Cell Performance Issue

Distributed PV is located on building rooftops and is often not directly mounted on to the roof. There is often a small gap between the PV installation and the rooftop that allows for air circulation to reduce heat build-up. This is important, as higher temperatures of PV crystalline silicon solar cells reduces performance. The output of the cell will reduce about -0.5% for every °C above Nominal Operating Cell Temperatures (NOCT) under PV-USA Test Conditions (PTC) (20 degrees C ambient). Central PV are not on rooftops, but may be in more remote, desert like conditions with higher outdoor temperatures. Crystalline silicon solar cells captured over 90% of the total worldwide installation in 2003. If crystalline solar cells are used for centralized applications in warmer locations, cells will be operating at higher temperatures and therefore may have reduced performance [9].

2.4: MICRO-GRID

2.4.1: Definition of Micro-grid

The U.S. Department of Energy (DOE) has offered the following description of Micro-grid: "A Micro-grid, a local energy network, offers integration of distributed energy resources (DER) with local elastic loads, which can operate in parallel with the grid or in an intentional island mode to provide a customized level of high reliability and resilience to grid disturbances. This advanced, integrated distribution system addresses the need for application in locations with electric supply and/or delivery constraints, in remote sites, and for protection of critical loads and economically sensitive development. In another slightly different definition of a Micro-grid: Micro-grid can be used to serve the electricity needs of data centers, colleges, hospitals, factories, military bases, or entire communities (i.e., village power)"[10].

2.4.2: Key features of Micro-grid

Operation in both island mode or grid-connected:

- Presentation to the Micro-grid as a single controlled entity
- Combination of interconnected loads and co-located power generation sources
- ·Provision of varied levels of power quality and reliability for end-uses, and
- Designed to accommodate total system energy requirements

2.4.3: Micro-grid enabling technologies

The key capability and feature of a Micro-grid is its ability to island itself (i.e., separate and isolate itself) from a utility's distribution system during brownouts and blackouts. However, in order to have an operational Micro-grid that can perform in the manner expected – both online and islanded – requires use of the following technologies [10].

- Distributed Generation (DG)
- Inverters
- Smart Meters
- Distribution Automation (DA)

- Substation Automation
- Micro-grid Control Systems
- Smart Transfer Switches

2.4.4: Benefits of Micro-grid

a) Economic benefits

- **Local Consumer Benefit**: Micro-grid can accelerate economic opening avenues of job opportunity at the local level. The cost per units is reduced. This encourages a new electricity generation business model that is more efficiency with renewable resources.
- **Generates Revenue**: Transmission cost as far as the end use is concerned is reduced significantly.

b) Technical Benefits

- **Reliability**: Local power generation and storage allow portions of to operate independently of the National grid when necessary, thus avoiding black outs. Redundant sources enable continuous power flow even during environmental interruptions in the system [1].
- **Stability:** Independent local control of generators, batteries and loads are based on frequency droops and voltage levels at the terminal of each device and hence it is highly stable.
- **Compatibility**: Micro-grids are completely compatible with existing utility grid. They may be considered as functional units that support the growth of the existing system in an economically and environment friendly way.

c) **Environmental Benefits**:

- **Reduce carbon print**: micro-grid can reuse the waste energy produced during generation of electricity to heat up building, sterilization and cooling. This reduces the reliance on fossil fuel and greenhouse gases emission. Thus enabling carbon credits.

2.4.5: Application of micro-grid.

a) Military bases
b) Industrial and educational campuses
c) Remote villages
d) Community micro-grid.

2.5: SCADA

2.5.1: Definition of SCADA

"Supervisory Control and Data Acquisition, or SCADA, is the control technique that enables the operator of a controlled industrial process or plant to obtain data from one or more of its distant facilities and send limited control instructions to those facilities"[11].

2.5.2: Purpose of SCADA

1. To extend the ability of the operator of a controlled industrial process or plant to see what is happening in the process or plant
2. To extend the operator's ability to make changes in the controlled process or plant.

2.5.3: SCADA Suitability

The foregoing discussion suggests that the SCADA technology is best suited to the process:

a) That are spread over large areas,
b) That are relatively simple to control and monitor, and
c) That requires frequent, regular or immediate intervention of the operator [11].

2.5.4: Advantages of using SCADA

1. Real-time monitoring
2. System modification
3. Troubleshooting
4. Increase equipment life
5. Automatic report generation

2.5.5: SCADA for Micro-grid

SCADA system can be viewed as a set of software and equipment destined to data acquisition and transmission of commands from and toward the process. The SCADA system also informs the operator or the management level on the current functioning state of the surveyed equipment and process.

With an application based on renewable energy sources ,the SCADA system gathers information such technical fail in electrical equipment, transfer the information to the central system, generate an alert signaling the failure, conducts the analysis and the control of the operations to determine if the failure is critical, displays the information in a logical and organized manner according to the time report between the way in which the process inside the monitored system are performed and making of operational decisions[12].

CHAPTER 3: LAYOUT OF MICRO-GRID OF SHARDA UNIVERSITY

3.1: INTRODUCTION

3.2: SLD OF DISTRIBUTION SYSTEM AT SHARDA UNIVERSITY.

During our survey about power distribution network at Sharda university , we have found that the power after receiving at 33 kV from Noida Power Company Limited (NPCL) is stepped down to 11 kV with the help of two 5 MVA and 3 MVA transformers, this power is fed to three 11/0.415 kV substations situated near block-3(SS-1), near 33/11 kV substation (SS-2) and near hospital (SS-3).From these substations, the power is distributed to various buildings at low voltage though underground cables.

To meet the demand during non-availability of grid power from NPCL, 6 diesel generating sets of 6250 kVA (4x1000, 3x750kVA) capacities have been installed. To meet the additional demand during summer, few DG sets are hired from April to October every year. The single line diagram of distribution system of Sharda University is shown below.

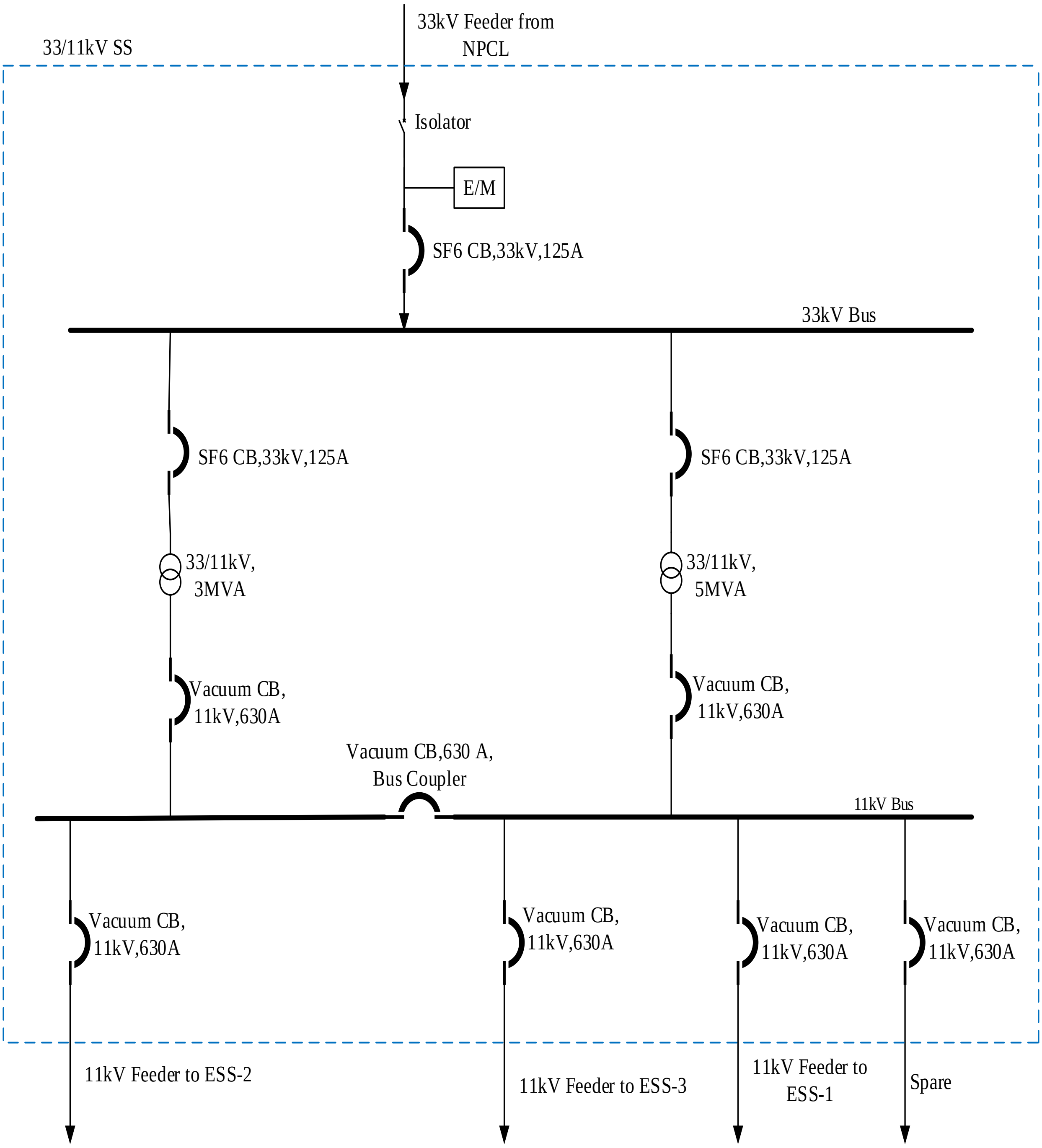
3.2.1: SLD of Distribution Substations

Power after being received at 33 kV from Noida Power Company Limited (NPCL) is metered before stepped down to 11 kV with the help of two 5 MVA and 3 MVA transformers, this power is fed to three 11/0.415 kV substations situated near block-3(SS-1,), near 33/11 kV substation (SS-2) and near hospital (SS-3).

To meet the demand during non-availability of grid power from NPCL, 6 diesel generating sets have been installed; where 2DG sets (1000KVA and750MVA) are at SS-1; 2DG sets(1000KVA and750KVA) are at SS-2; 2DG sets(100KVA and 750KVA) are at SS-3.

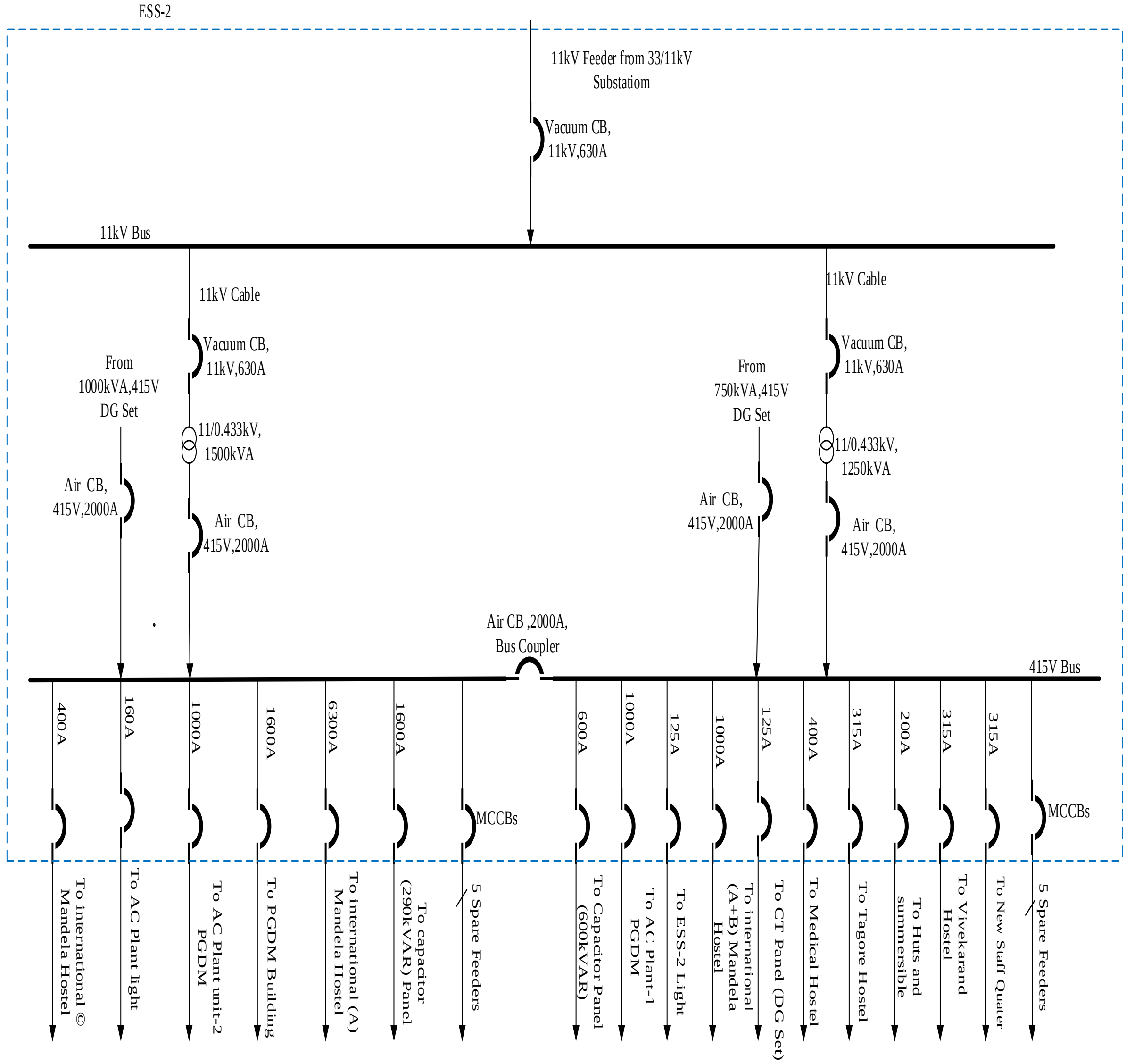
For high tension feeders, the SF6 and Vacuum Circuit Breakers are used while Air Circuit Breakers are used for low tension feeders. The power is distributed to various buildings at low voltage though underground cables

Single Line Diagram of 33/11kV Substation



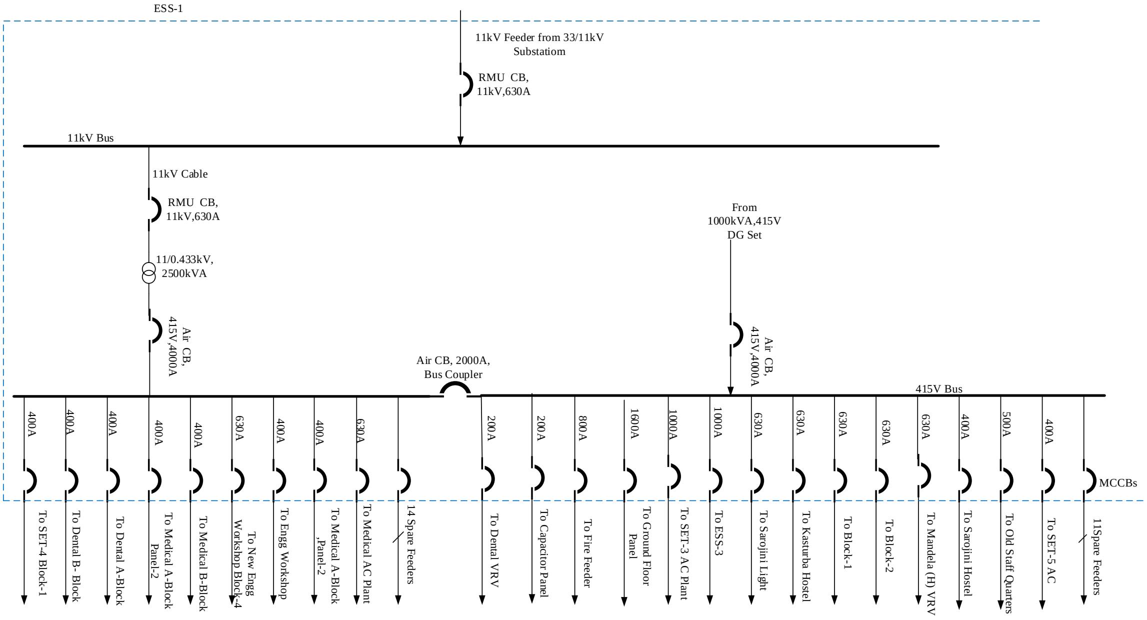
Sheet No. DS-1/4

Single Line Diagram of 11/0.433kV ESS-2

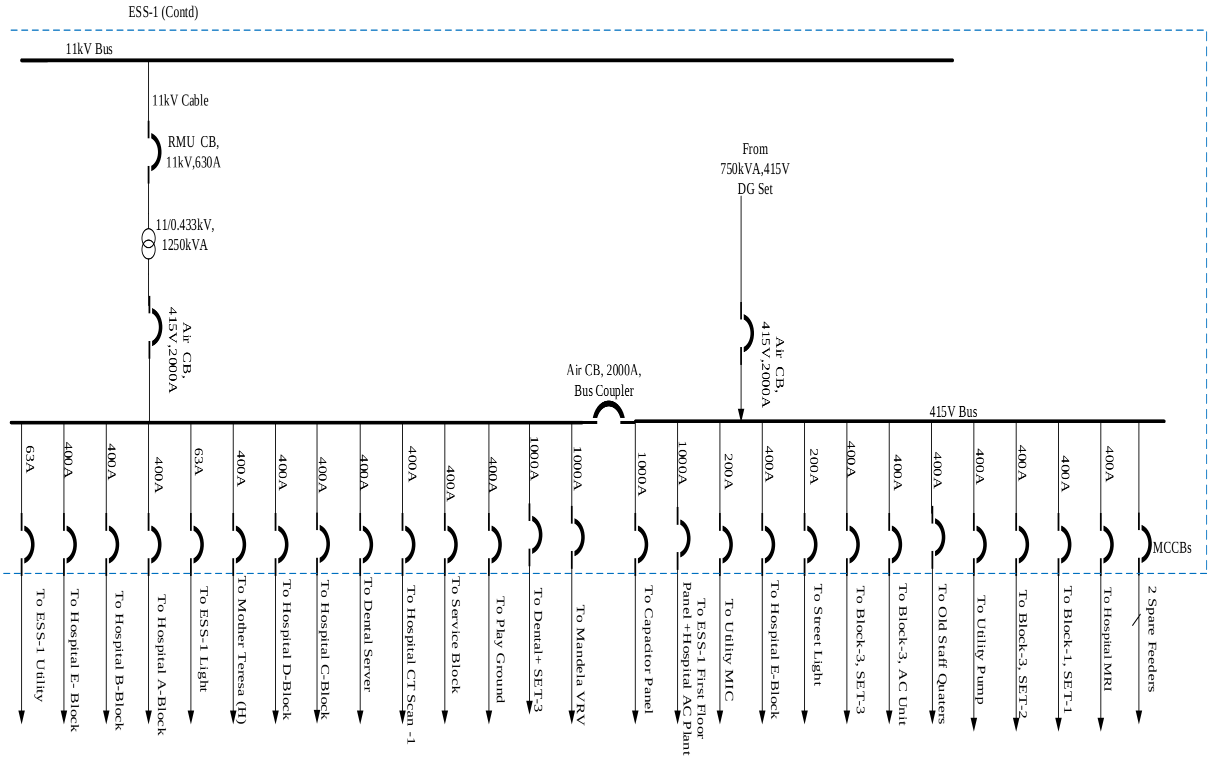


Sheet No. DS-2/4

Single Line Diagram of 11/0.433kV ESS-1

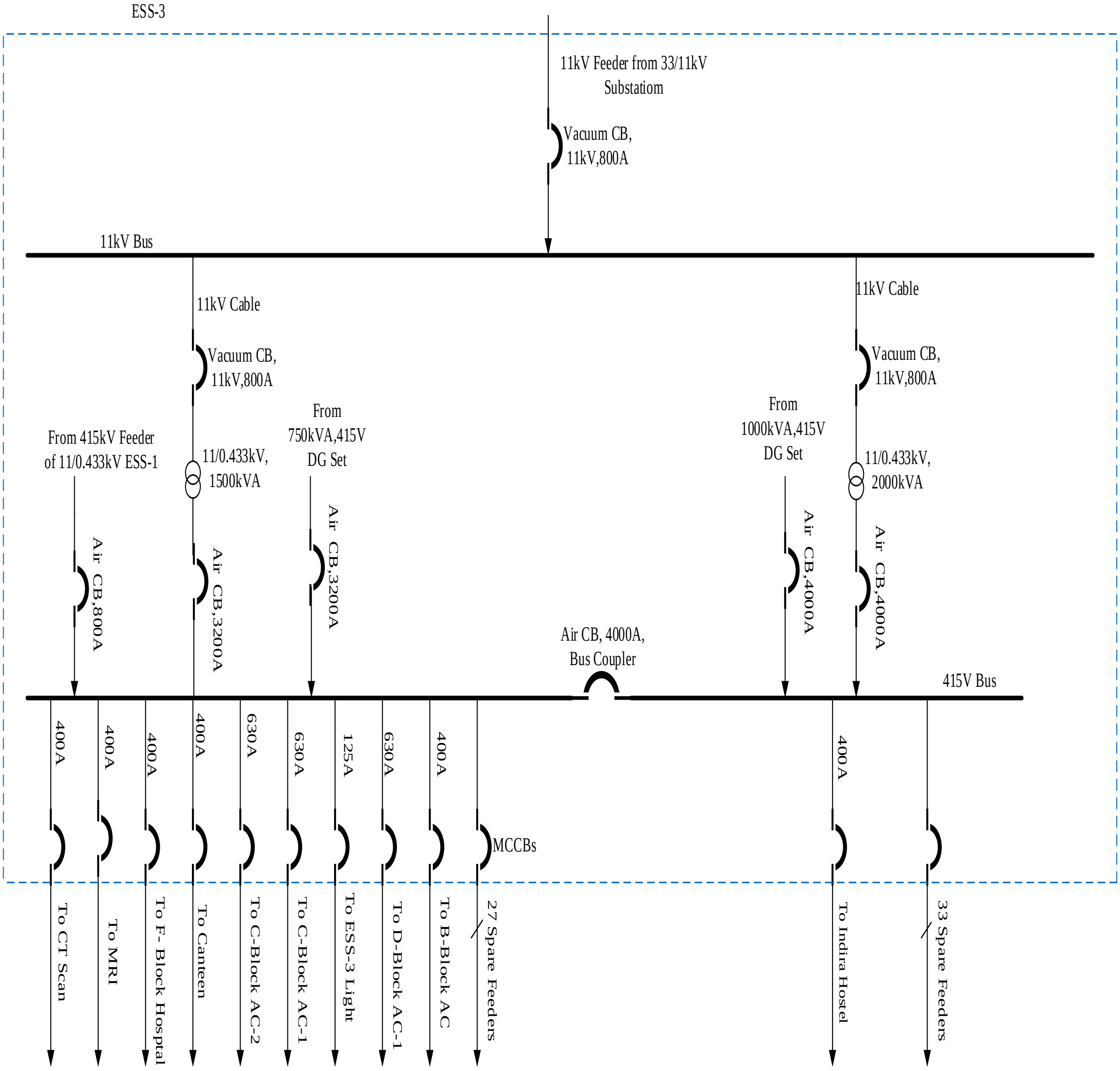


Single Line Diagram of 11/0.433kV ESS-1 (Contd)



Sheet No. DS-3/4

Single Line Diagram of 11/0.433kV ESS-3



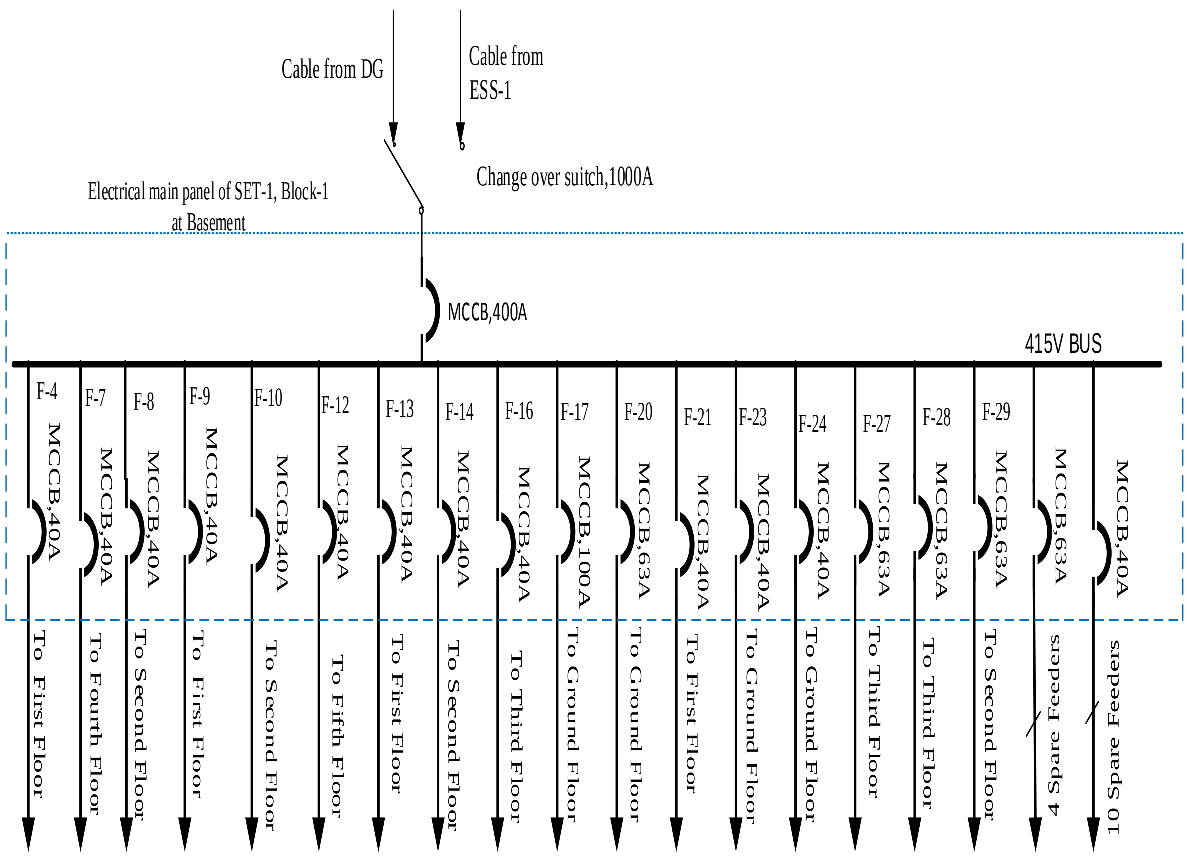
Sheet No. DS-4/4

Figure 4: SLD of distribution substations.

3.2.3: SLD of Distribution Boards in Block-1

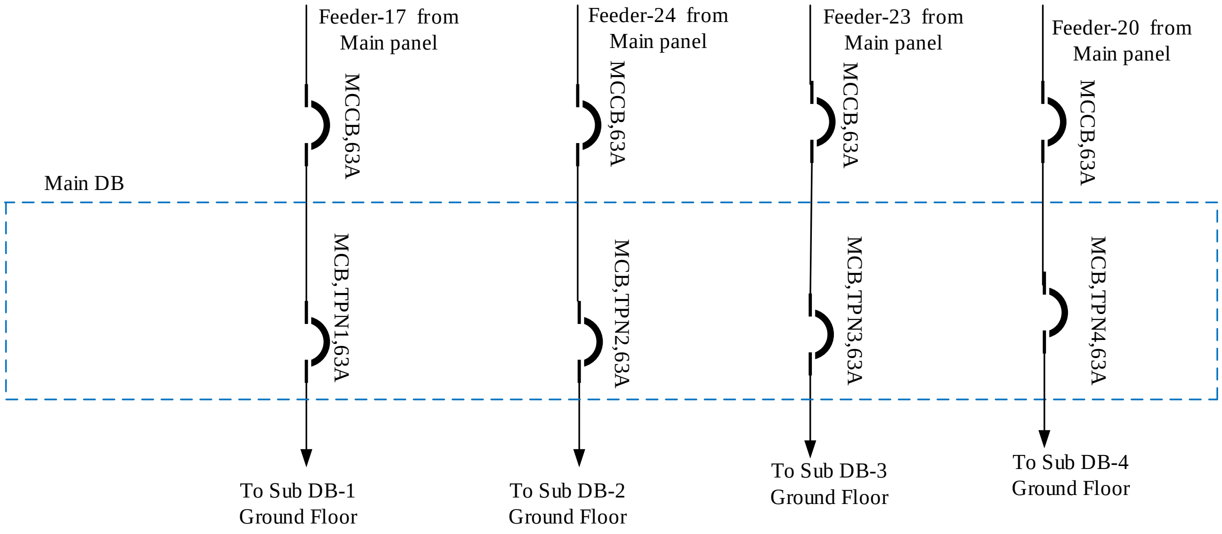
The power from Diesel Generators are used as spinning reserve in addition to the power from substation (SS-1) where by the help of change over switch, the operator can decide which among the two options he may connect depending on power availability and economic concerned. The power after passing through electrical main panel of block-1 located at ground floor, many power feeders are going to the floor Wise's Distribution Boards(DB's) through MCCB's before reaching different sub-DB's assigned to different sections of block-1. The following is the SLD of all four floors of SET-1 and SET-4 of blok-1.

Single Line Diagram of Electrical Main Panel of Block-1, SET-1

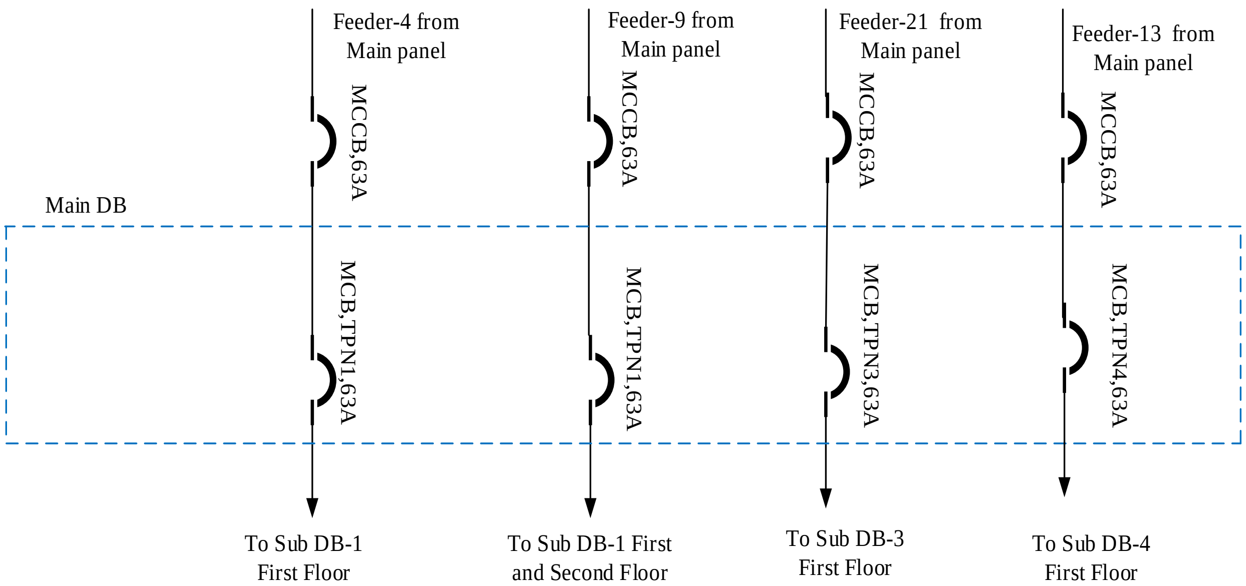


Sheet No. DBB1-1/8

Single Line Diagram of Main DB at Ground Floor of Block-1, SET-1

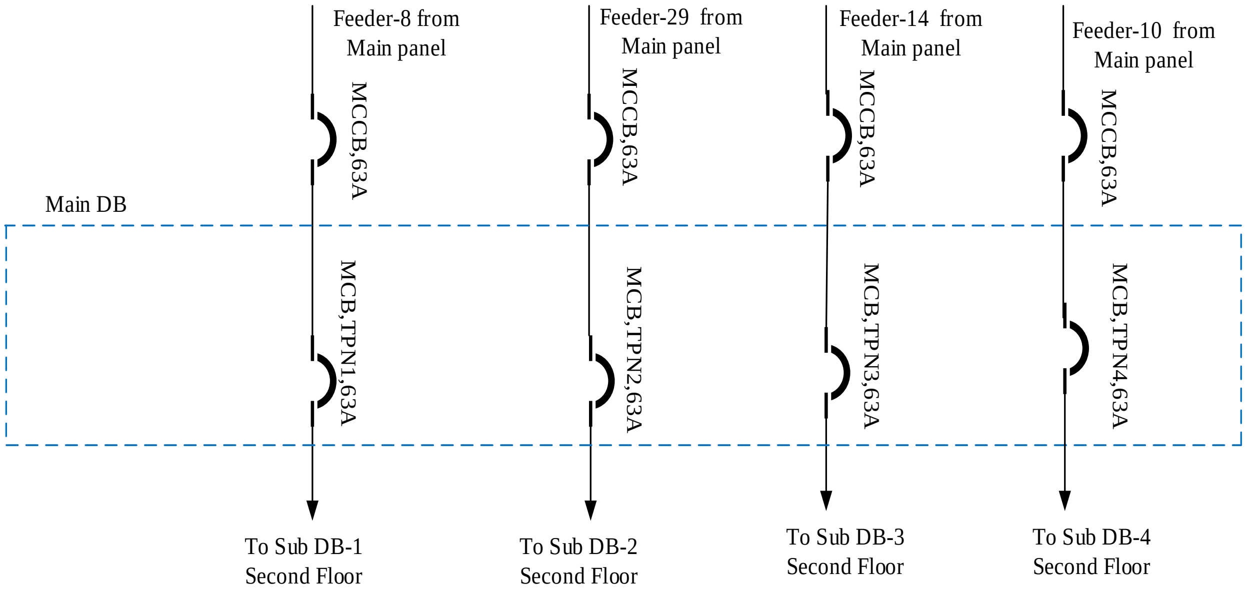


Single Line Diagram of Main DB at First Floor of Block-1, SET-1

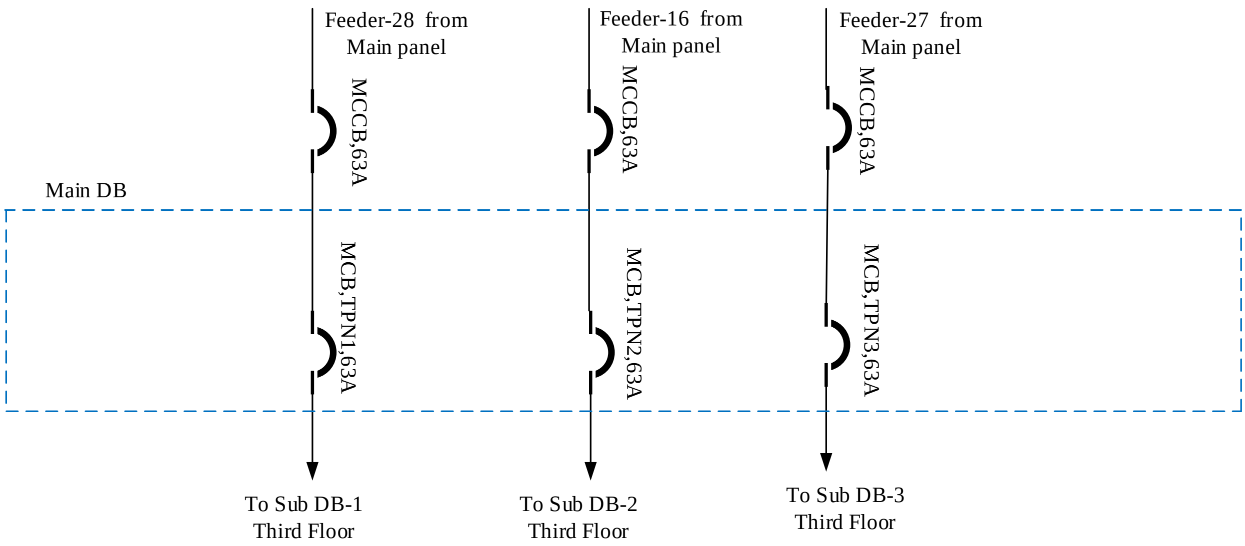


Sheet No. DBB1-2/8

Single Line Diagram of Main DB at Second Floor of Block-1, SET-1

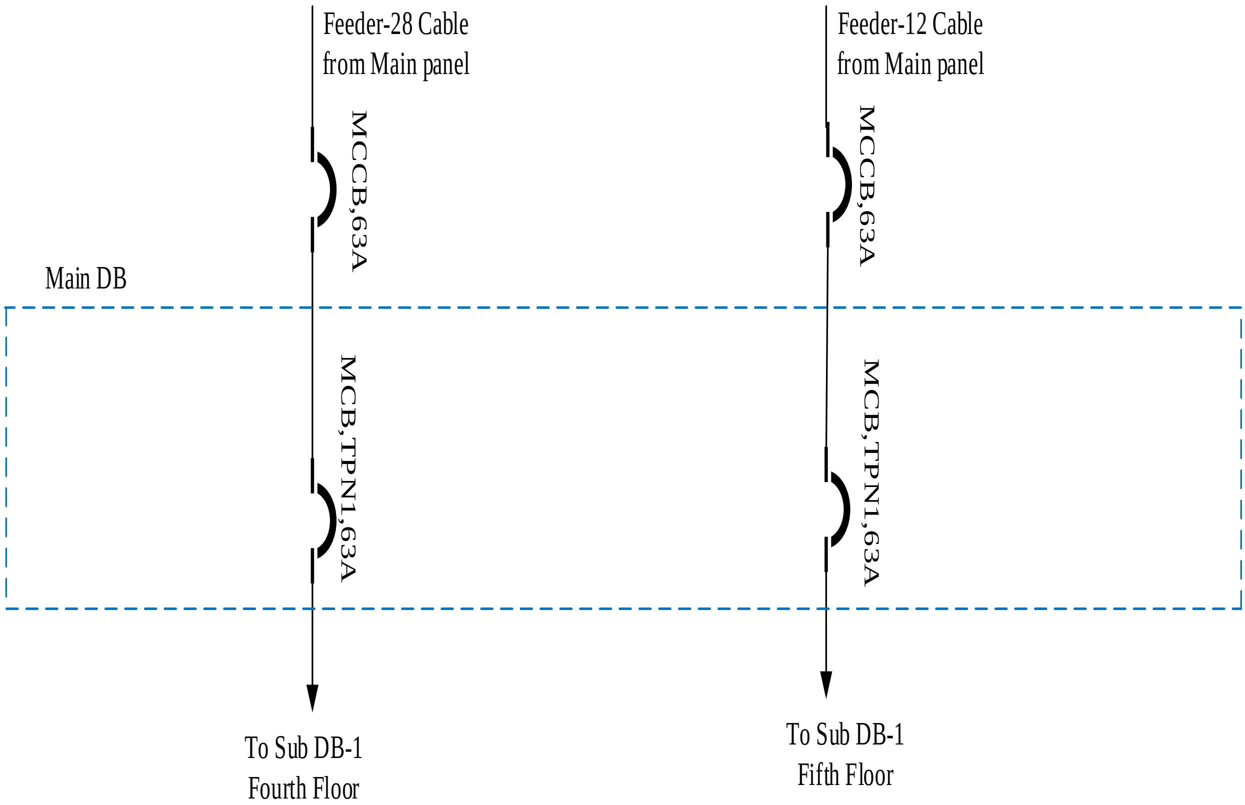


Single Line Diagram of Main DB at Third Floor of Block-1, SET-1



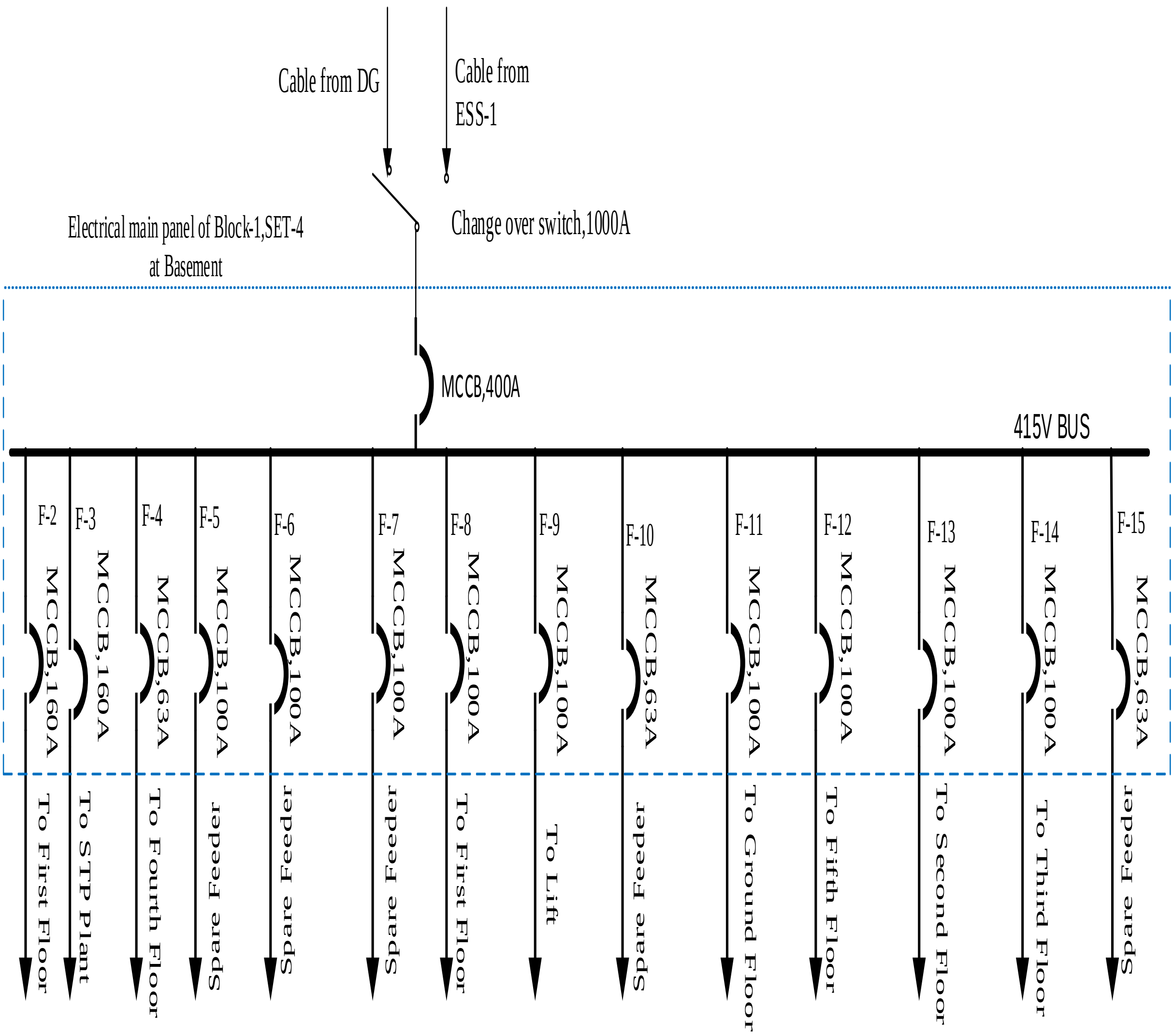
Sheet No. DBB1-3/8

Single Line Diagram of Main DB at Fourth Floor of Block-1, SET-1



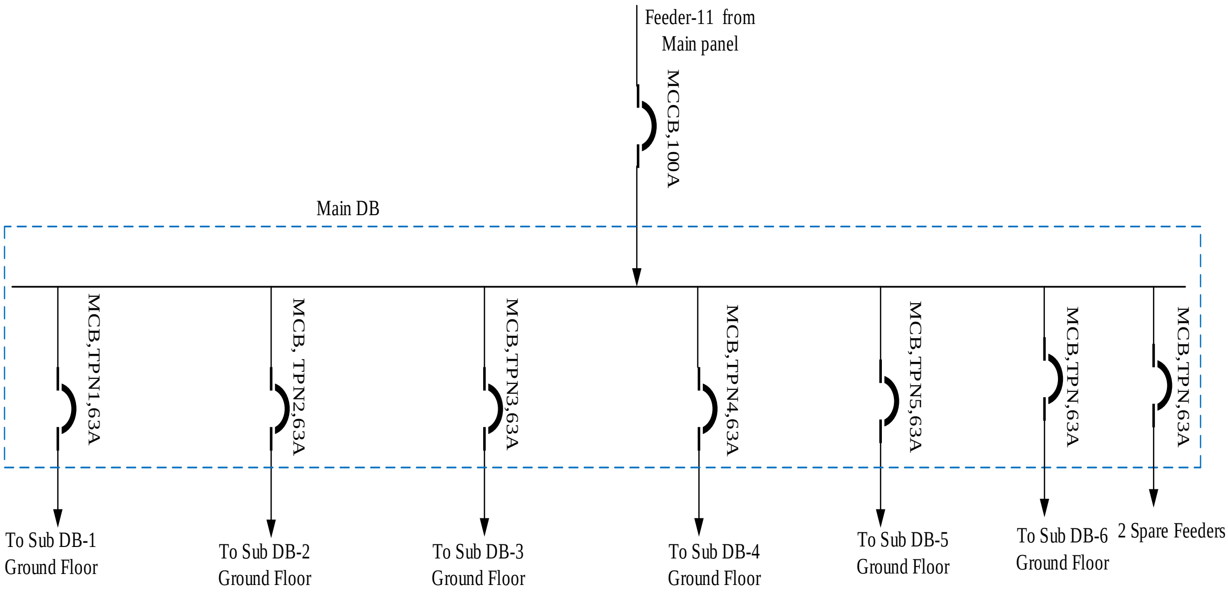
Sheet No. DBB1-4/8

Single Line Diagram of Electrical Main Panel of Block-1,SET-4

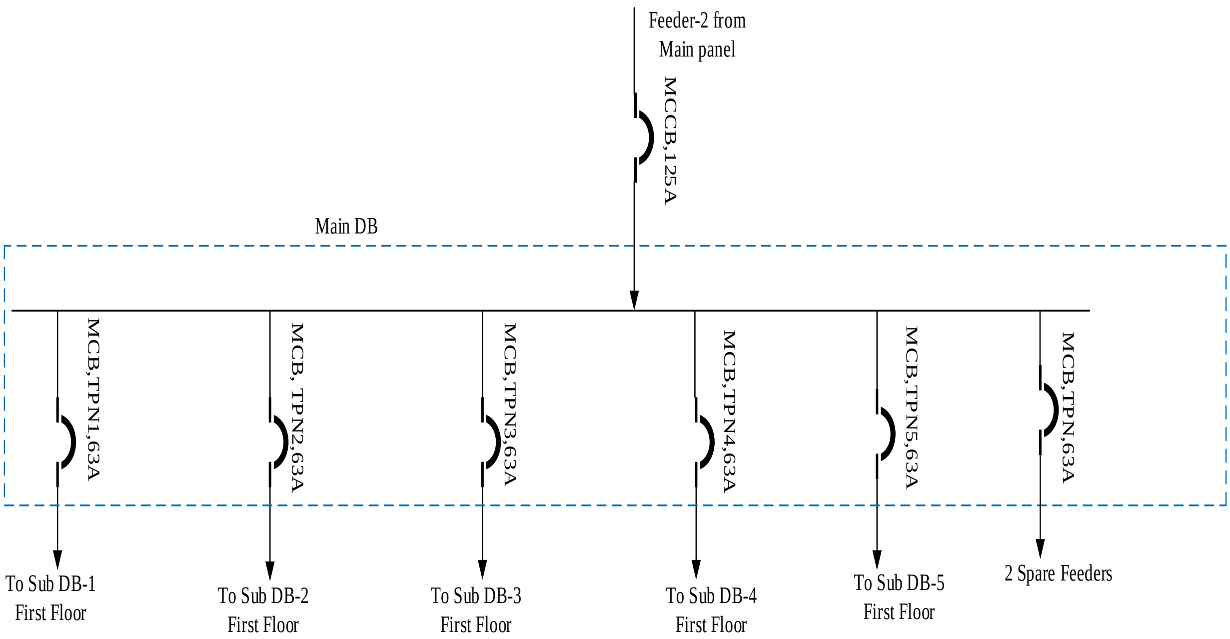


Sheet No. DBB1-5/8

Single Line Diagram of Main DB at Ground Floor of Block-1,SET-4

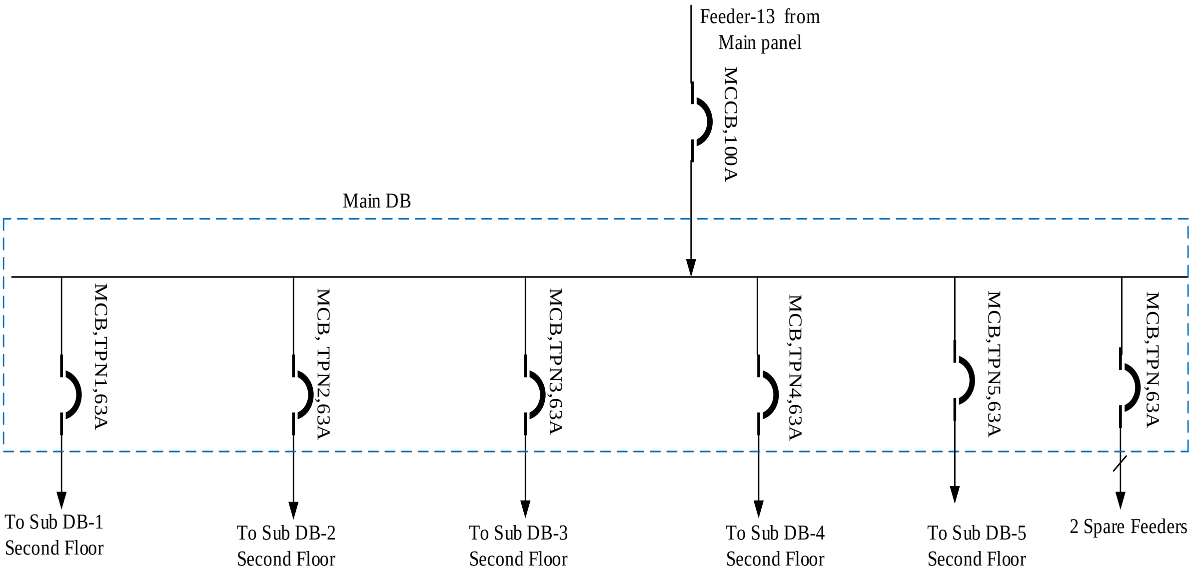


Single Line Diagram of Main DB at First Floor of Block-1,SET-4

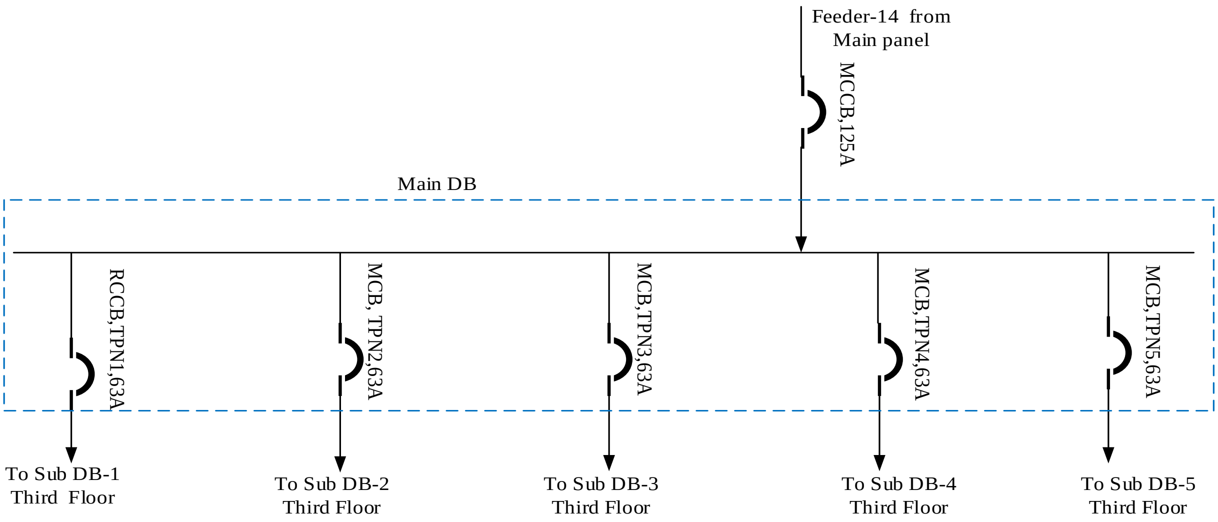


Sheet No. DBB1-6/8

Single Line Diagram of Main DB at Second Floor of Block-1,SET-4

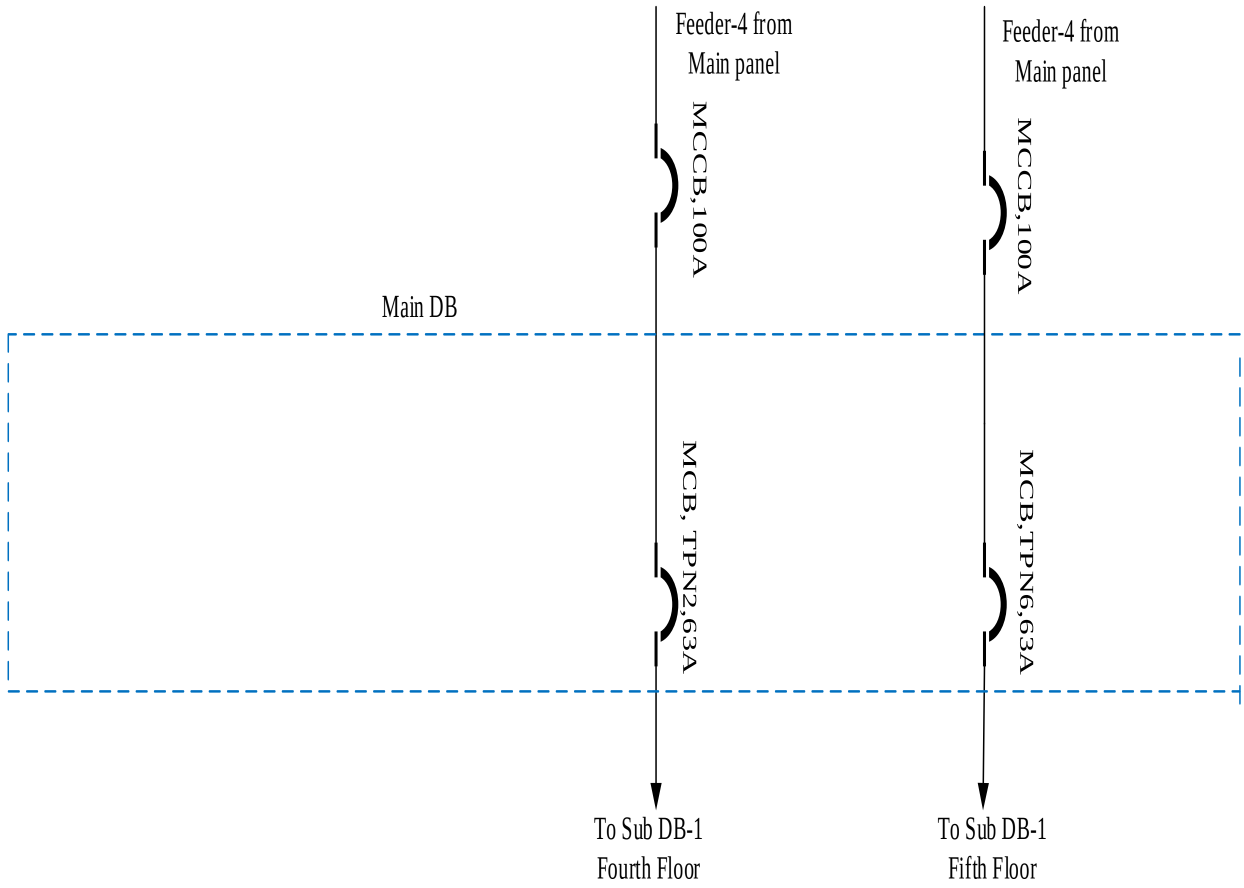


Single Line Diagram of Main DB at Third Floor of Block-1,SET-4



Sheet No. DBB1-7/8

Single Line Diagram of Main DB at Fourth Floor of Block-1,SET-4



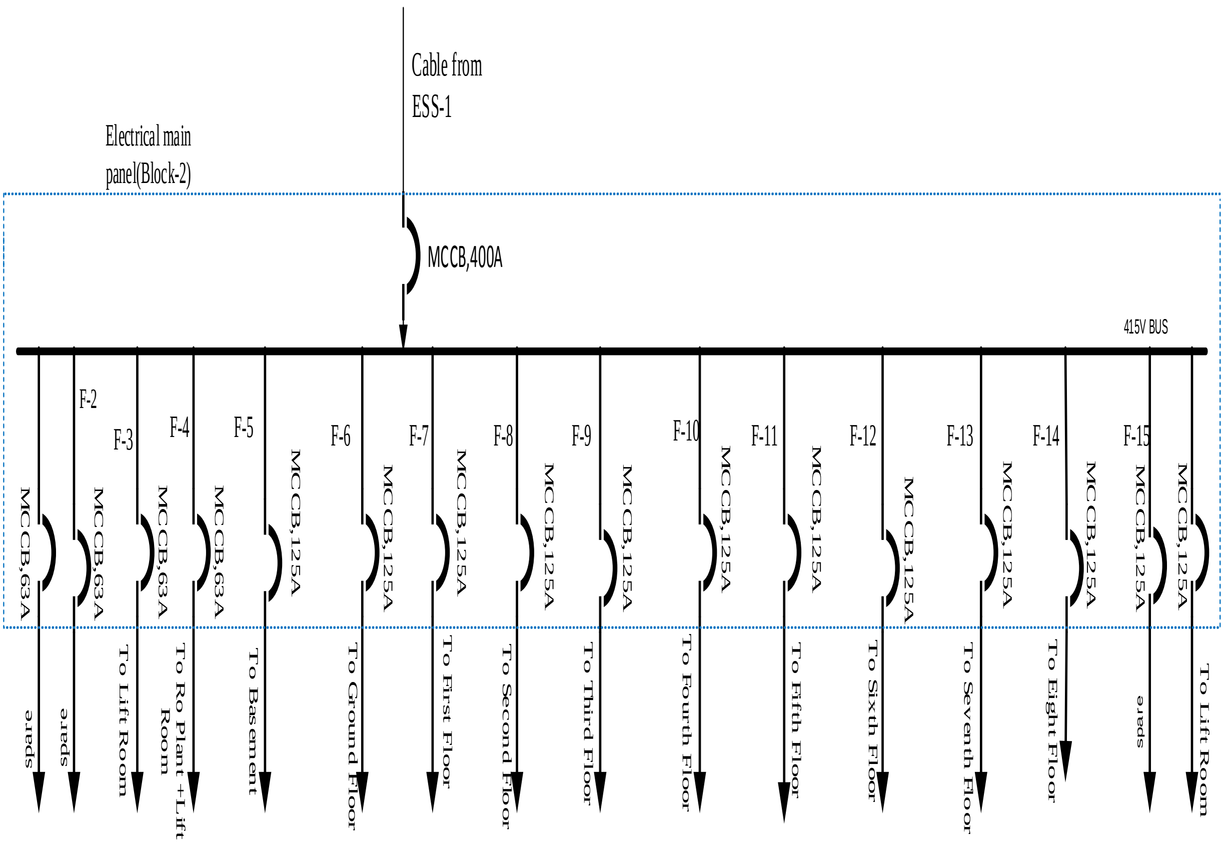
Sheet No. DBB1-8/8

Figure 5: SLD of distribution boards of block-1

3.2.3: SLD of Distribution Boards in Block-2

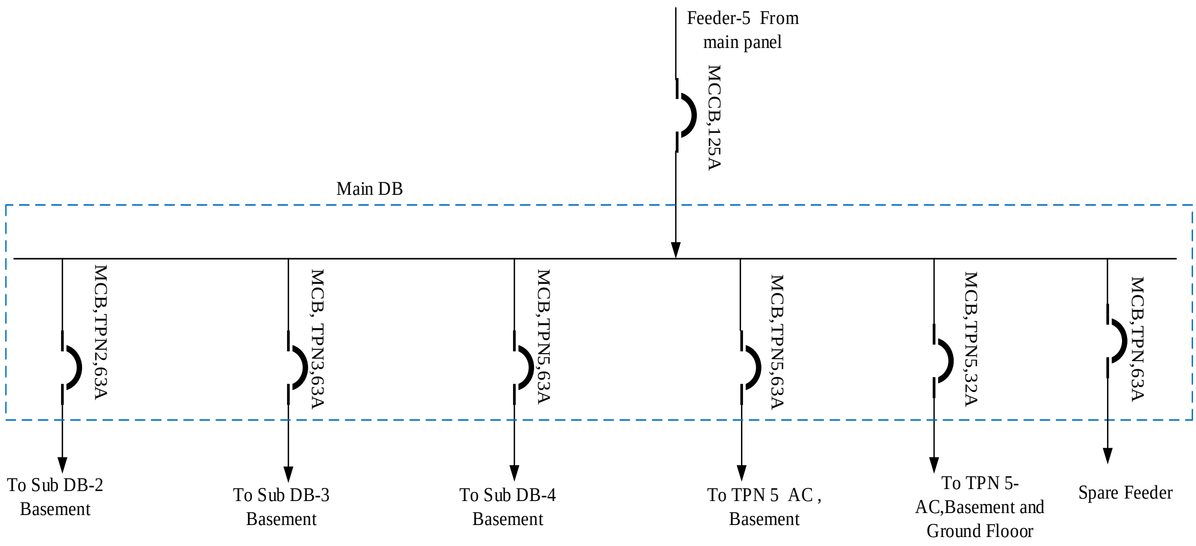
Through incoming MCCB, the power from substation (SS-1) is received at electric main panel of block-2 .The power after passing through electrical main panel of block-2, located at basement, many power feeders are going to the floor Wise's Distribution Boards(DB's) through outgoing MCCB's before reaching different sub-DB's assigned to different sections of block-2. The following is the SLD of all eight floors of block-2.

Single Line Diagram of Electrical Main Panel of Block-2

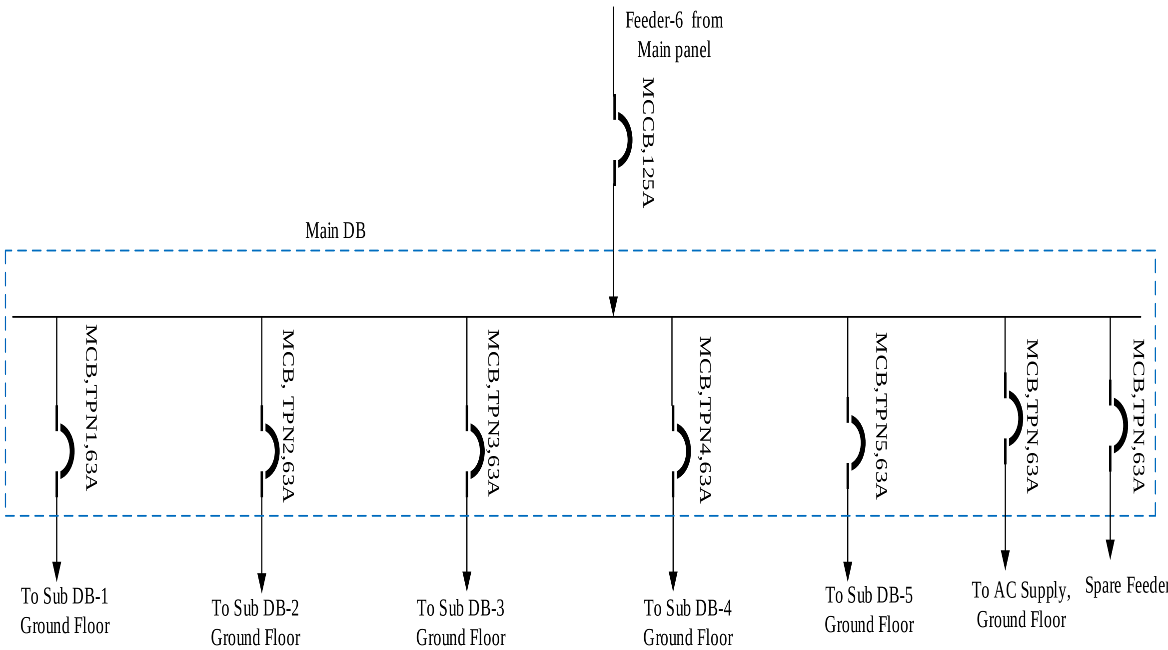


Sheet No.DBB2-1/6

Single Line Diagram of Main DB at Basement of Block-2

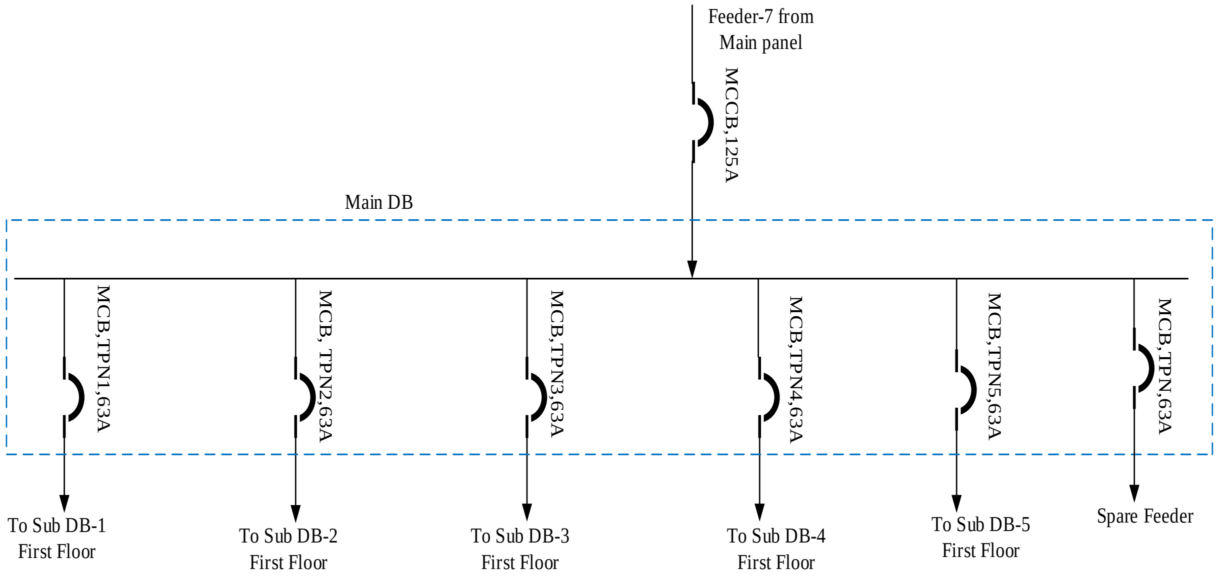


Single Line Diagram of Main DB at Ground Floor of Block-2

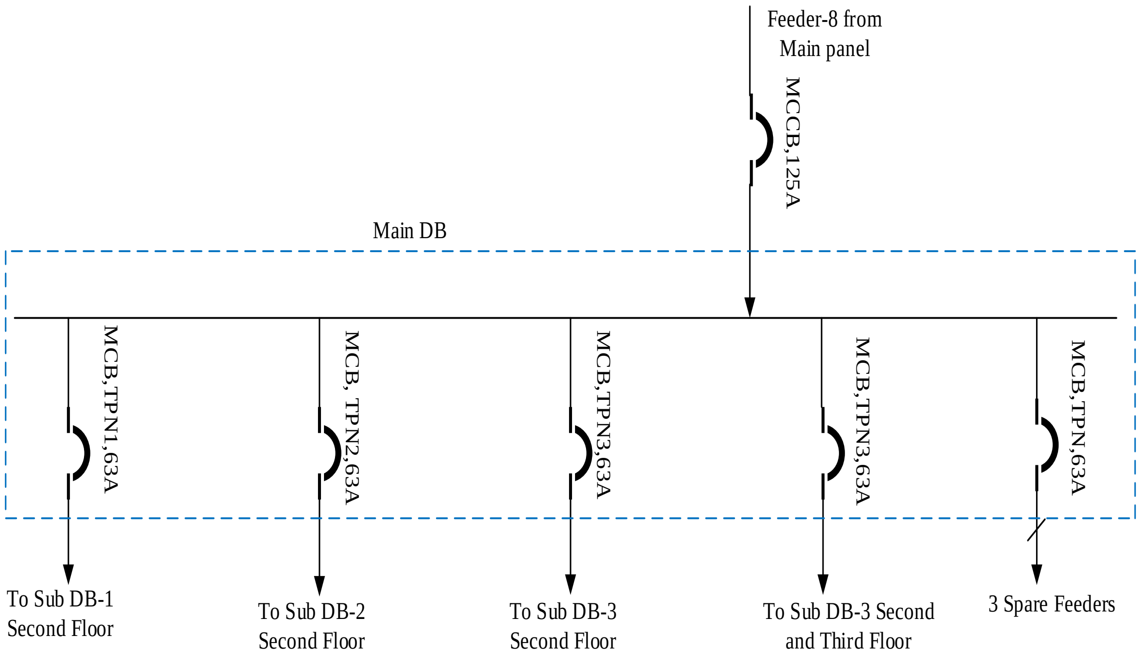


Sheet No.DBB2-2/6

Single Line Diagram of Main DB at First Floor of Block-2

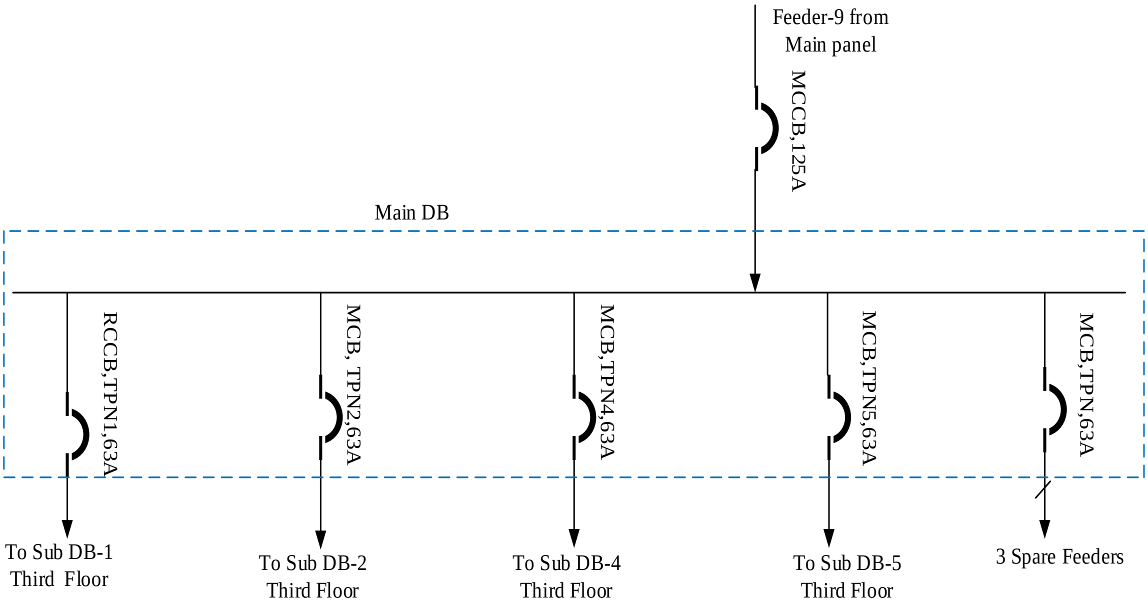


Single Line Diagram of Main DB at Second Floor of Block-2

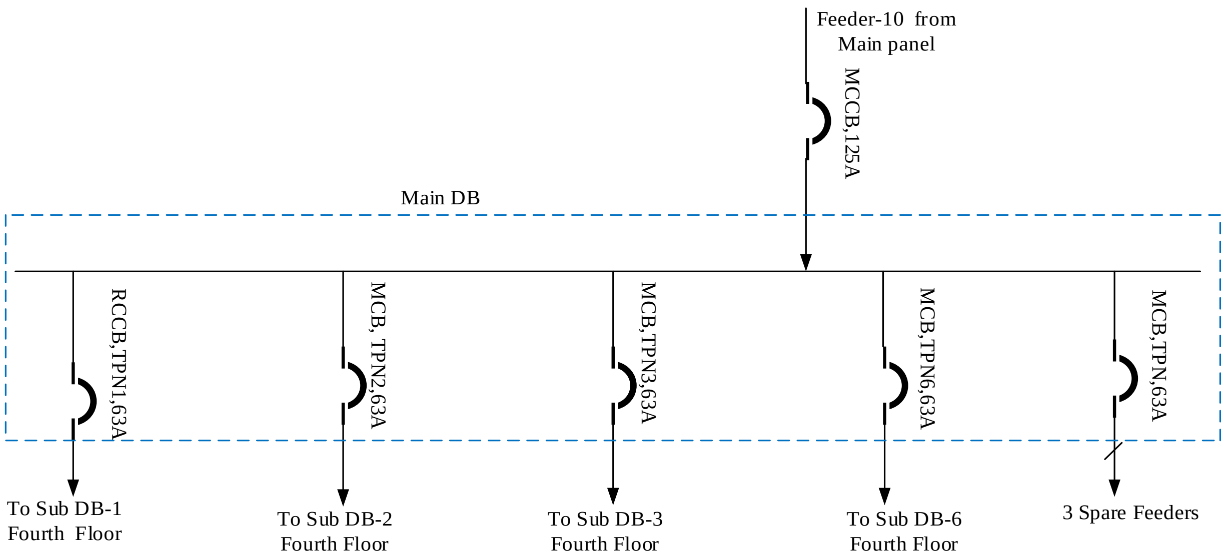


Sheet No.DBB2-3/6

Single Line Diagram of Main DB at Third Floor of Block-2

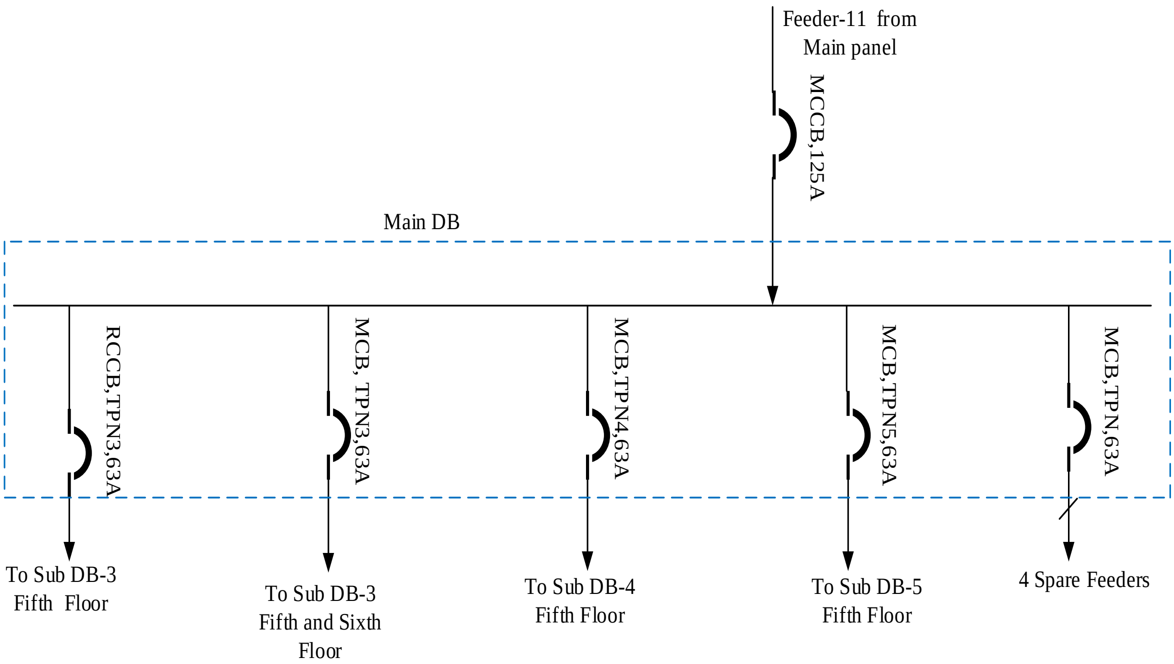


Single Line Diagram of Main DB at Fourth Floor of Block-2

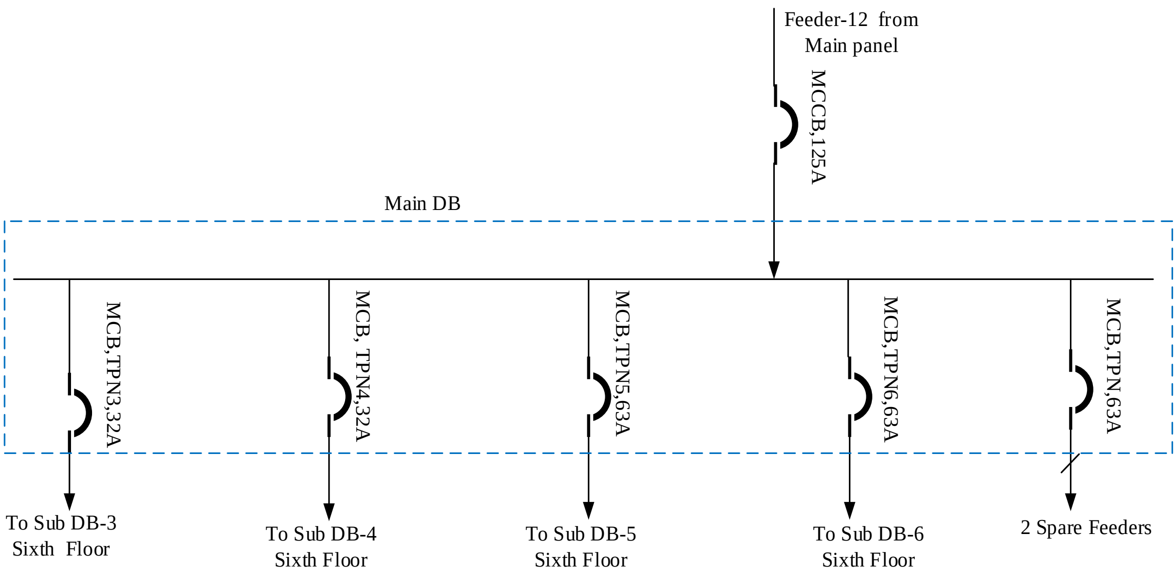


Sheet No.DBB2-4/6

Single Line Diagram of Main DB at Fifth Floor of Block-2

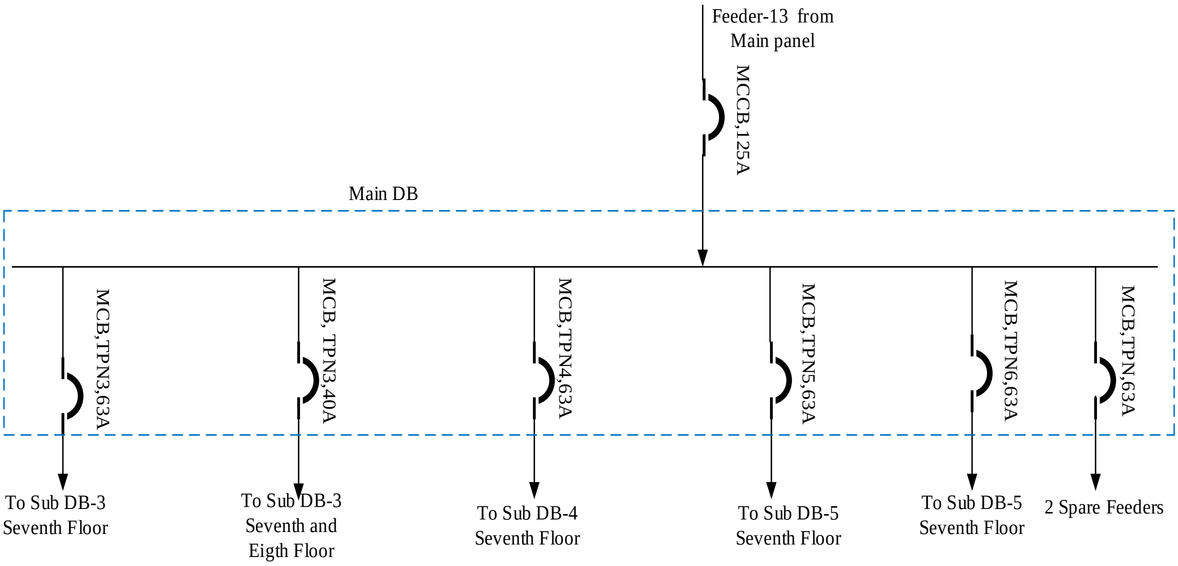


Single Line Diagram of Main DB at Sixth Floor of Block-2

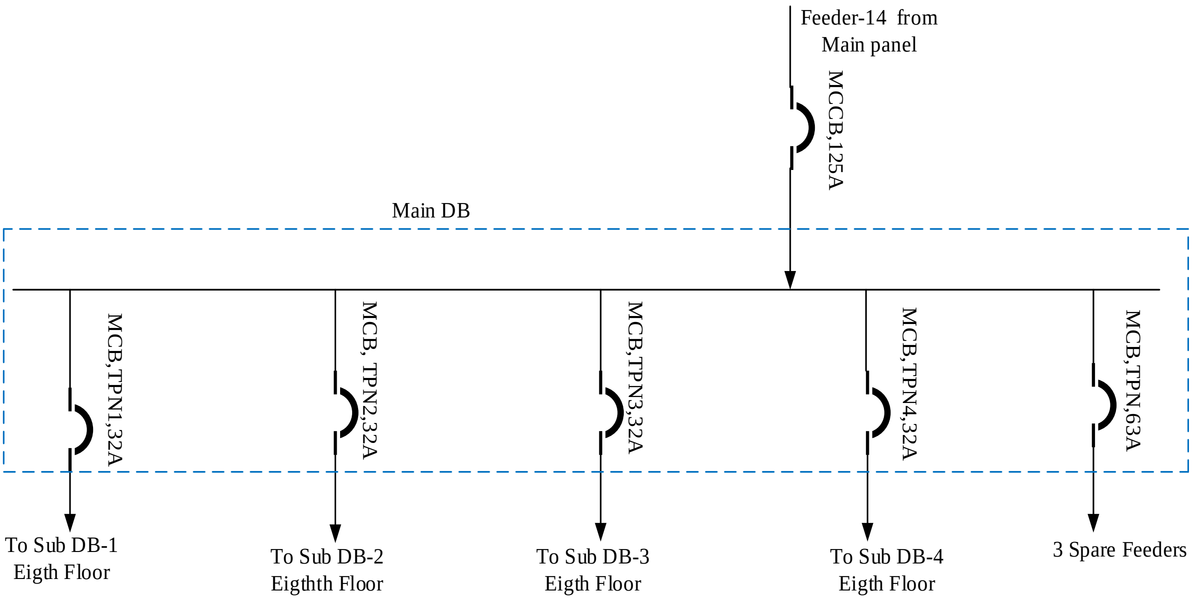


Sheet No.DBB2-5/6

Single Line Diagram of Main DB at Seventh Floor of Block-2



Single Line Diagram of Main DB at Eigth Floor of Block-2



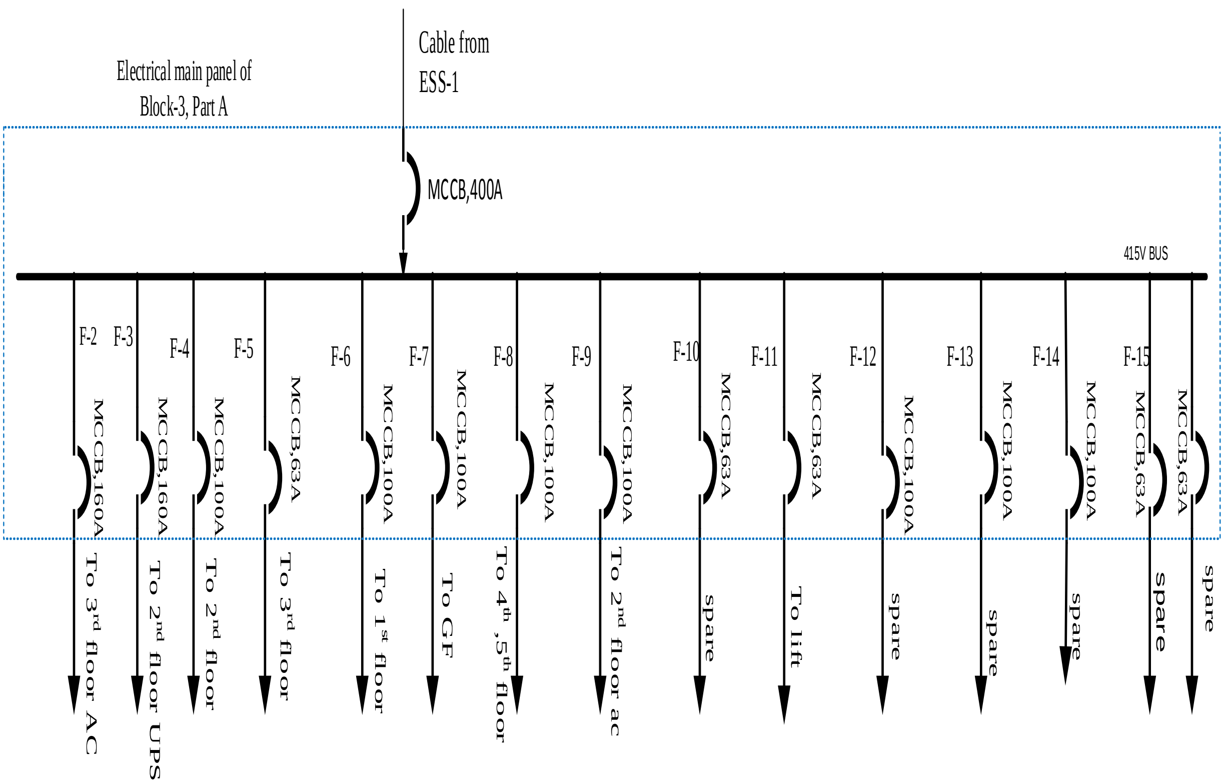
Sheet No.DBB2-6/6

Figure 6: Single Line Diagram of distribution boards of block-2

3.2.4: SLD of Distribution Boards in Block-3

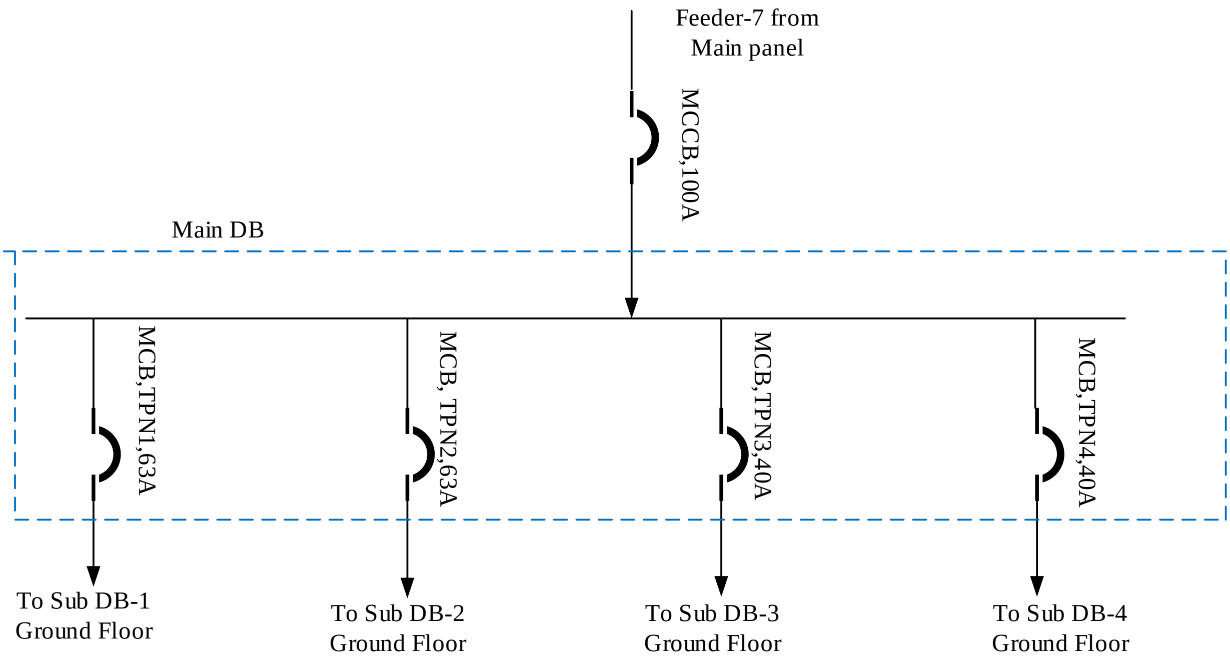
Through incoming MCCB, the power from substation (SS-1) is received at electric main panel of block-3.The power after passing through electrical main panel of block-3 located at ground floor, many power feeders are going to the floor Wise's Distribution Boards(DB's) through outgoing MCCB's before reaching different sub-DB's assigned to different sections of block-3. The following is the SLD of all four floors for Part A and Part-A of Block-3.

Single Line Diagram of Electrical Main Panel of Block-3, Part-A

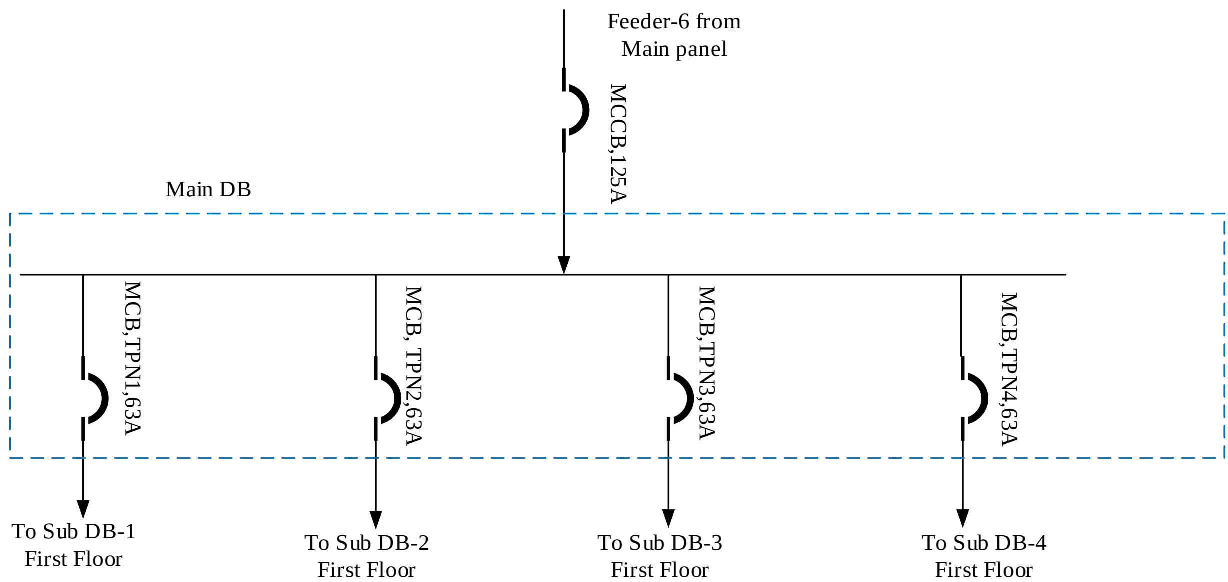


Sheet No.DBB3-1/8

Single Line Diagram of Main DB at Ground Floor of Block-3, Part-A

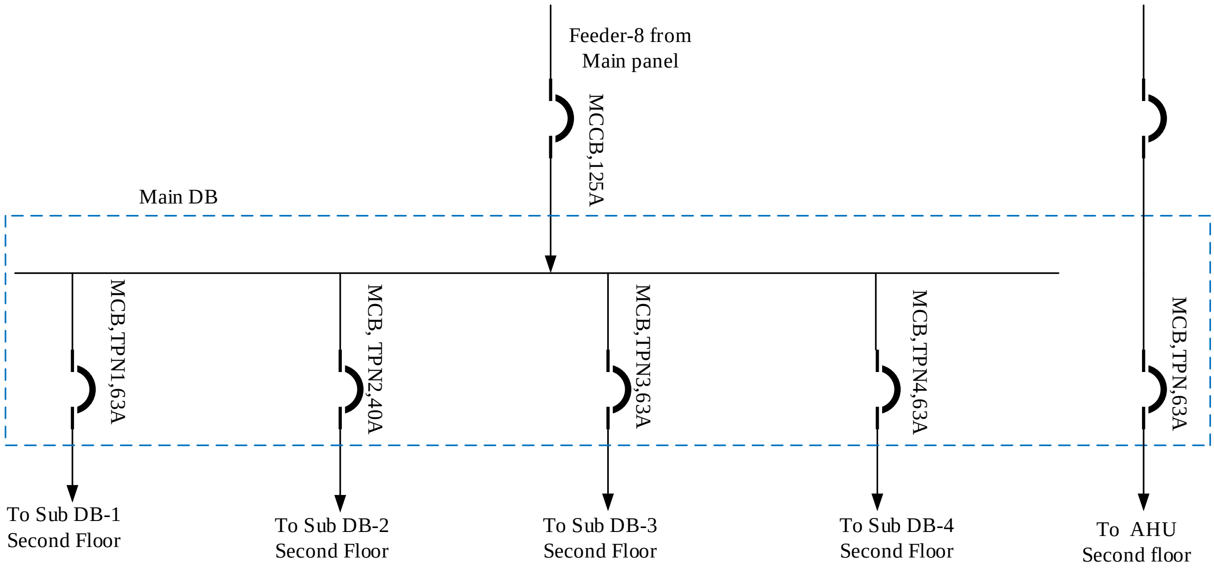


Single Line Diagram of Main DB at First Floor of Block-3, Part-A

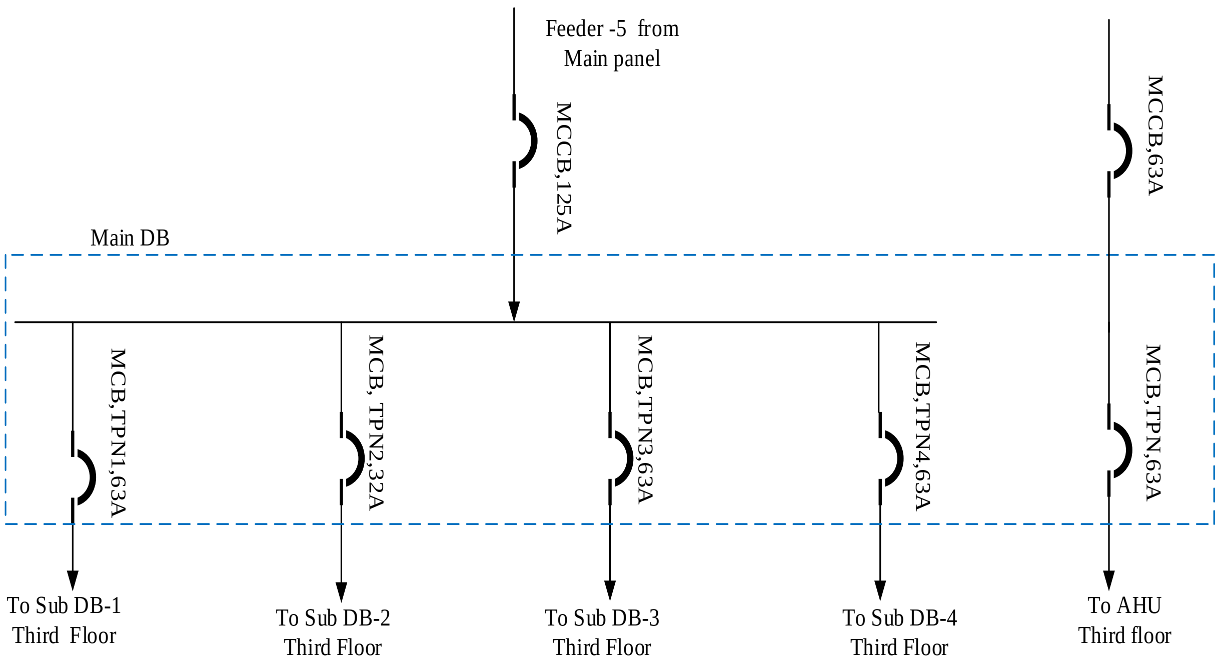


Sheet No.DBB3-2/8

Single Line Diagram of Main DB at Second Floor of Block-3, Part-A

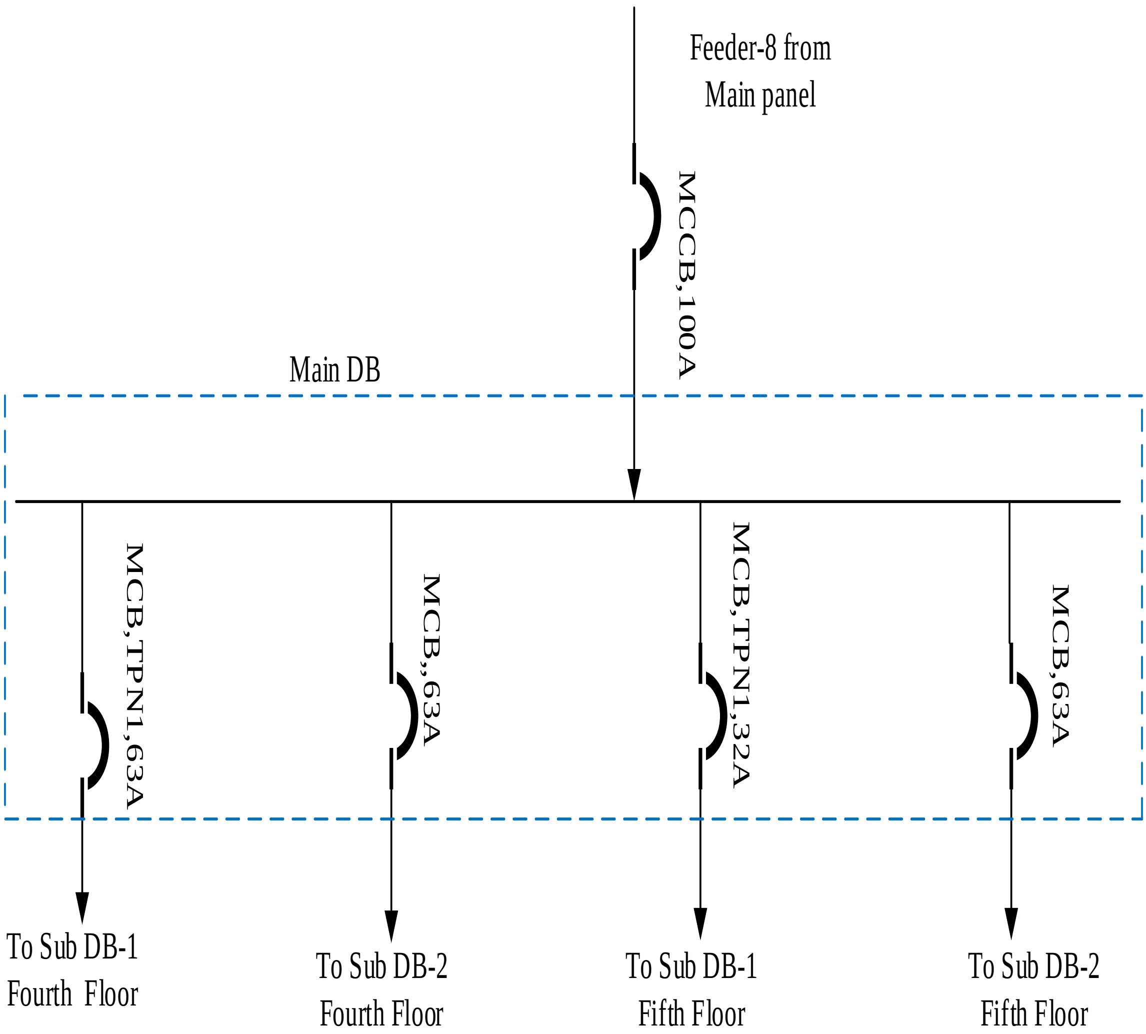


Single Line Diagram of Main DB at Third Floor of Block-3, Part-A



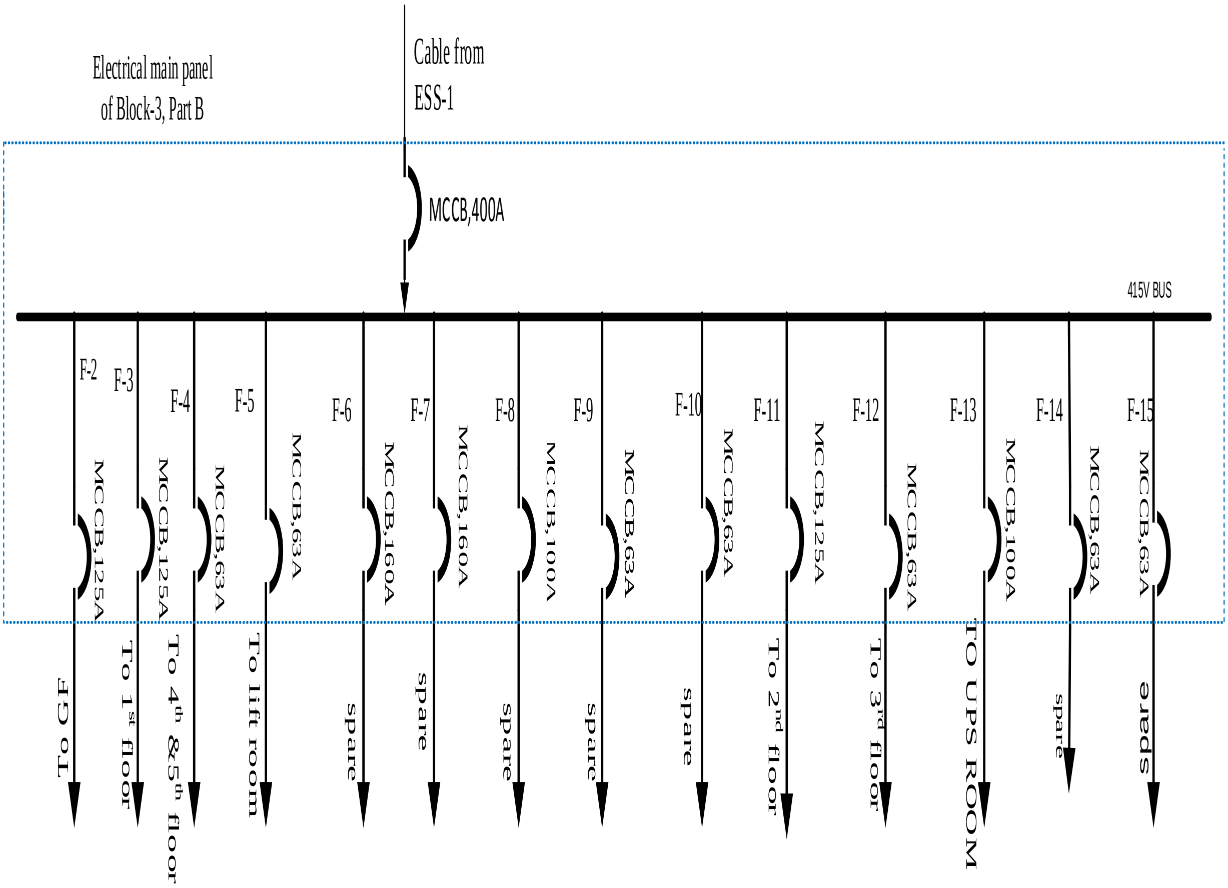
Sheet No.DBB3-3/8

Single Line Diagram of Main DB at Fourth Floor of Block-3, Part-A



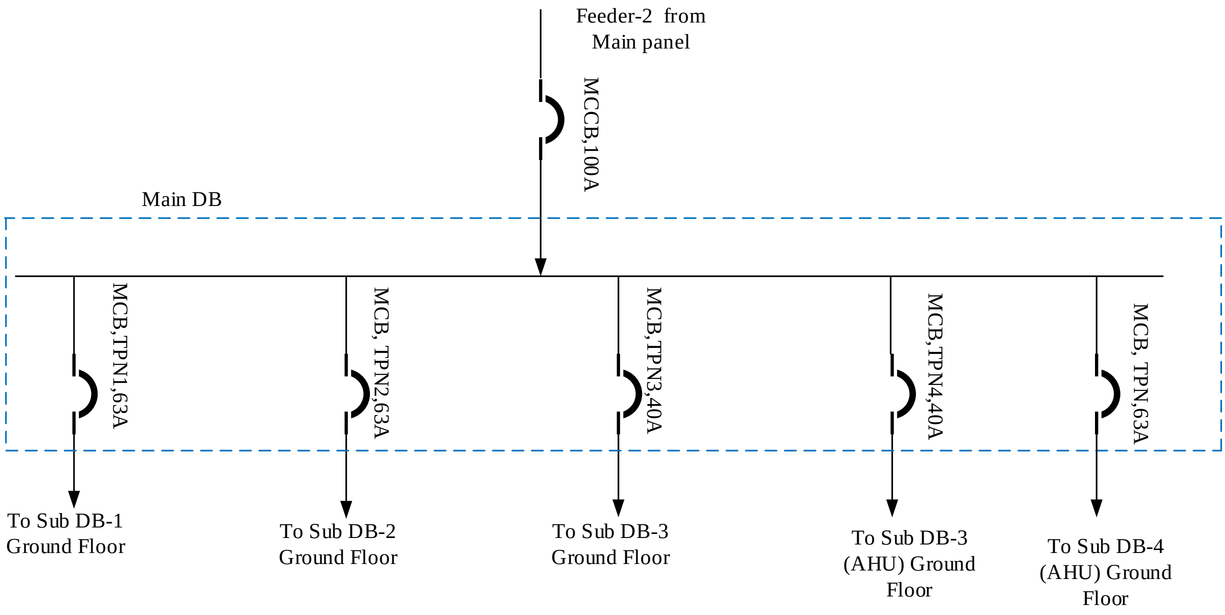
Sheet No.DBB3-4/8

Single Line Diagram of Electrical main Panel of Block-3 ,Part-B

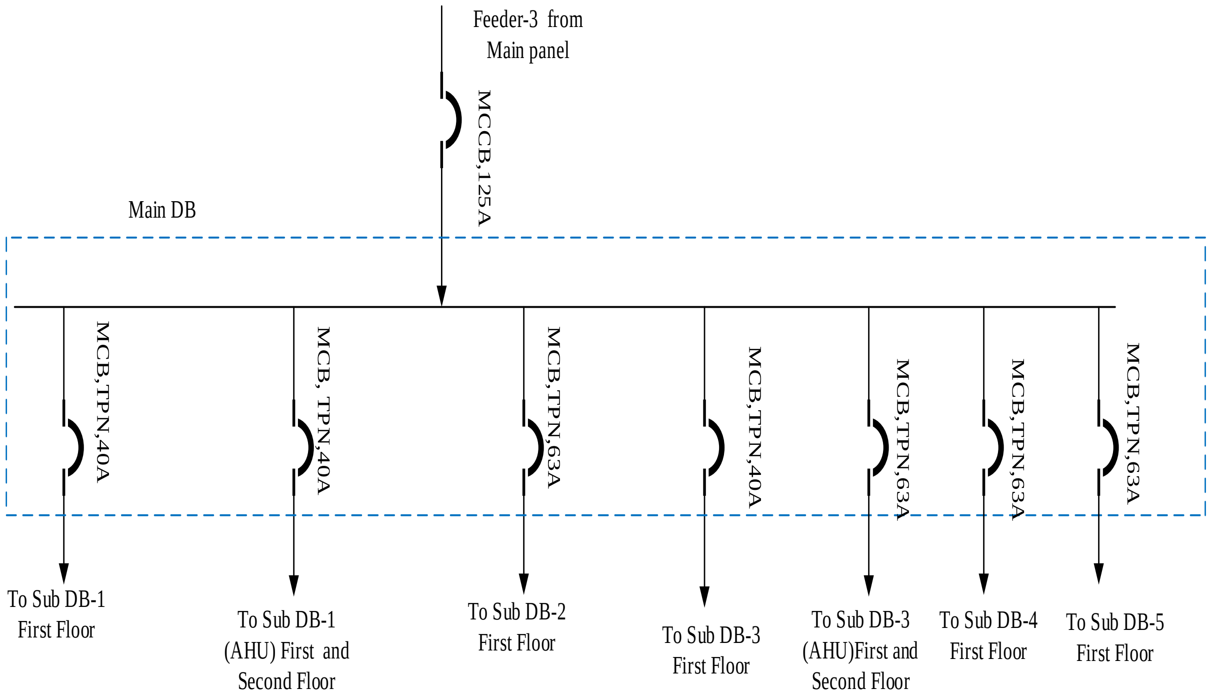


Sheet No. DBB3-5/8

Single Line Diagram of Main DB at Ground Floor of Block-3,Part-B

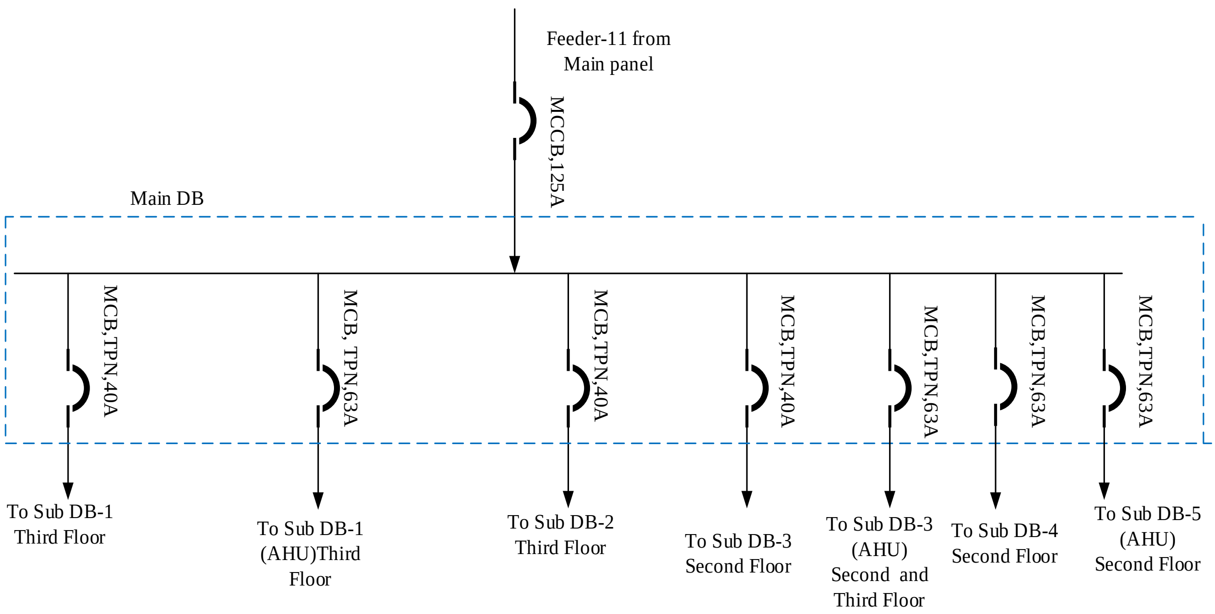


Single Line Diagram of Main DB at First Floor of Block-3,Part-B

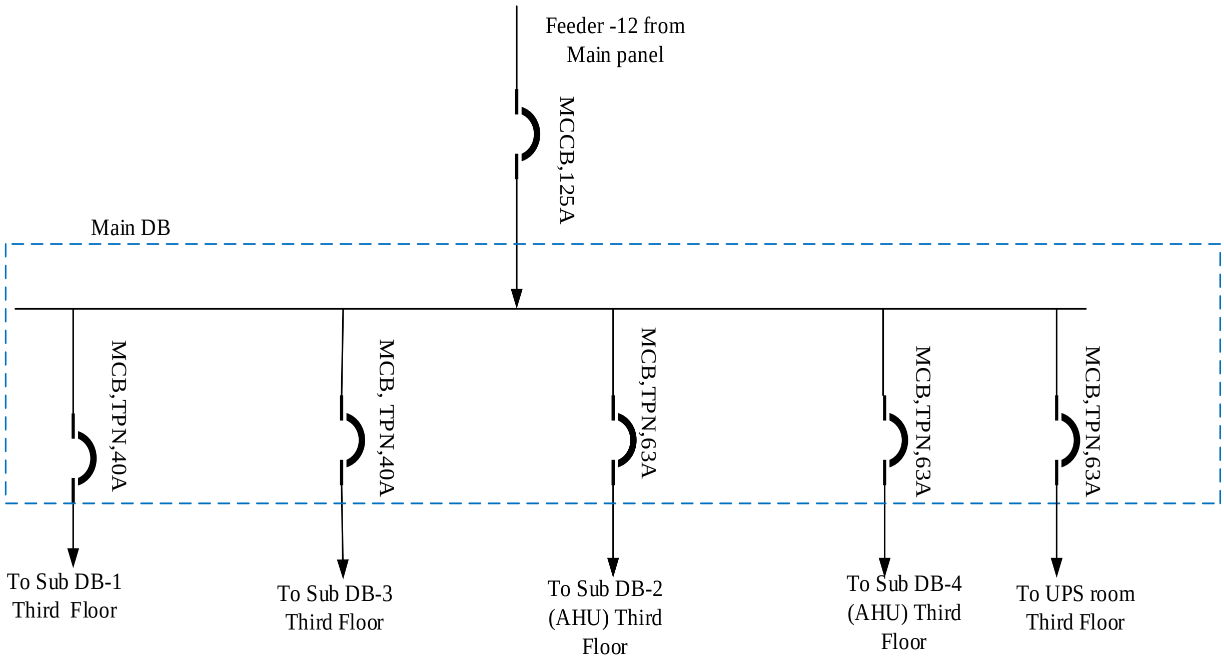


Sheet No. DBB3-6/8

Single Line Diagram of Main DB at Second Floor of Block-3,Part-B

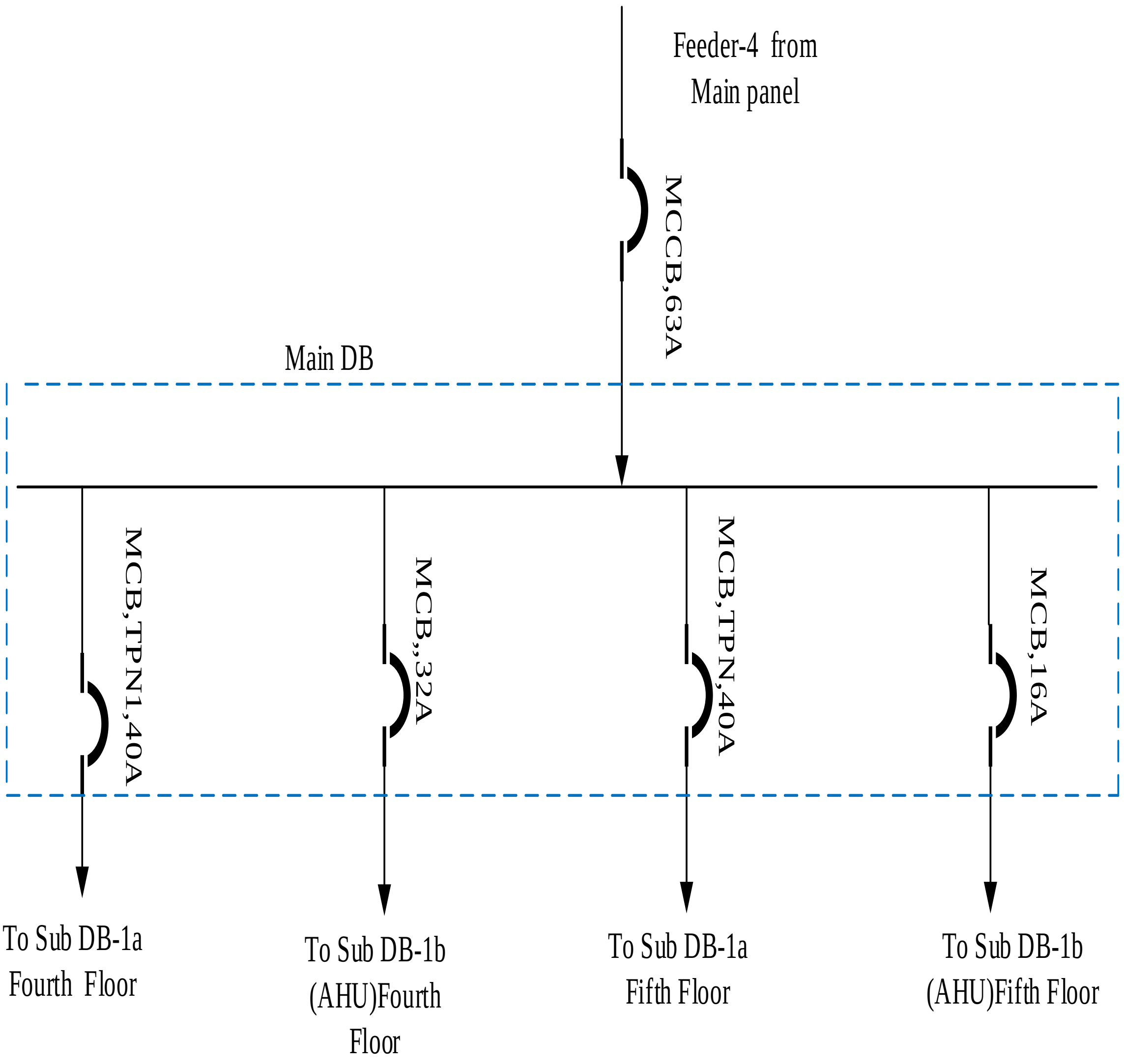


Single Line Diagram of Main DB at Third Floor of Block-3,Part-B



Sheet No. DBB3-7/8

Single Line Diagram of Main DB at Fourth Floor of Block-3,Part-B



Sheet No. DBB3-8/8

Figure 7: SLD of Distribution Boards in Block-3

3.3: PROPOSED DISTRIBUTED ROOF-TOP PV SOLAR PLANT .

The PV Units are located at the following buildings of Sharda University. The space availability and load has been considered for selecting the locations of PV solar plant units.

PV SP UNIT	LOCATION	CAPACITY
PV SP Unit -A	School of Engineering& Technology, Block-1	100kW$_p$
PV SP Unit -B	School of Engineering& Technology, Block-2	100kW$_p$
PV SP Unit -C	School of Engineering& Technology, Block-3	100kW$_p$
PV SP Unit -D	Hospital, Block-A	100kW$_p$
PV SP Unit -E	Hospital, Block-E	100kW$_p$
PV SP Unit -F	Mandela Hostel, Block-A	100kW$_p$
PV SP Unit -G	Mandela Hostel, Block-C	100kW$_p$
PV SP Unit -H	Tagore Boys Hostel	100kW$_p$
PV SP Unit -I	Vivekanand Boys Hostel	100kW$_p$
PV SP Unit -J	Indira Girls Hostel	100kW$_p$

Table 1: Locations of Proposed distributed roof-top PV Solar plant units

3.4: PROPOSED LAYOUT OF MICRO-GRID OF SHARDA UNIVERSITY

In this micro-grid, the space and loads has been considered for the locations of roof-top PV Solar Plant Units and all PV SP Units are connected to 415kV bus in electrical main panel. To achieve the energy management by sending electricity based on demand in such way that more power is send to high priority areas, less power to low demand, 3 tie lines will be added to the micro-grid. Here, one tie- line is for connecting SSS-1 to SS-2; second tie- line is for connecting SS-2 to SS-3 and third tie-line is for connecting SS-1 to SS-3.

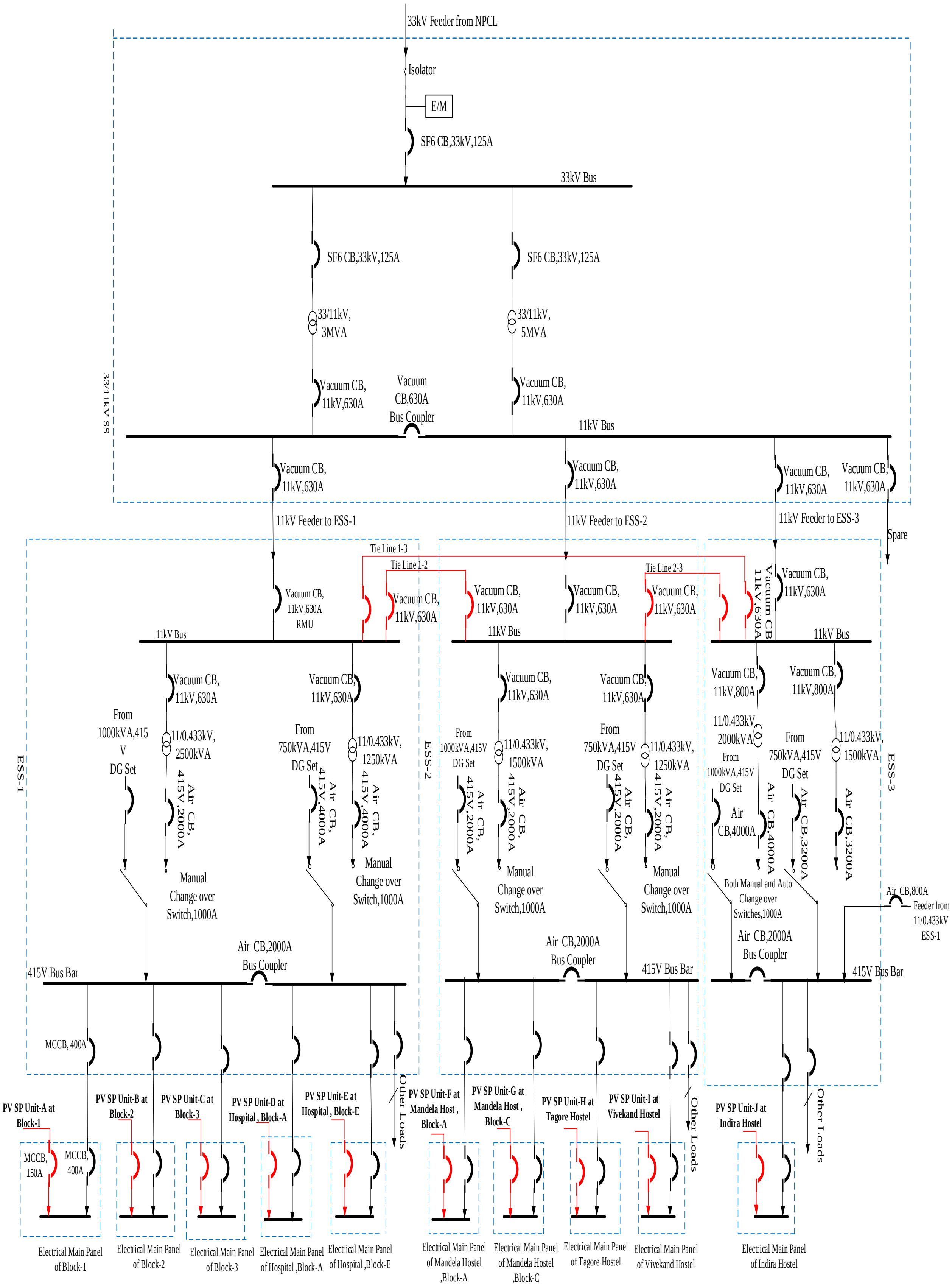


Figure 8: Layout of micro-grid of Sharda University

3.5: CONTROL LOGIC FOR MICRO-GRID

The control logic for micro-grid has the main objective of supplying the total energy from PV to the consumers. If PV energy exceeds the existing load, this excess is sent to the NPCL and for less PV energy generation, the load gap is taken from NPCL.

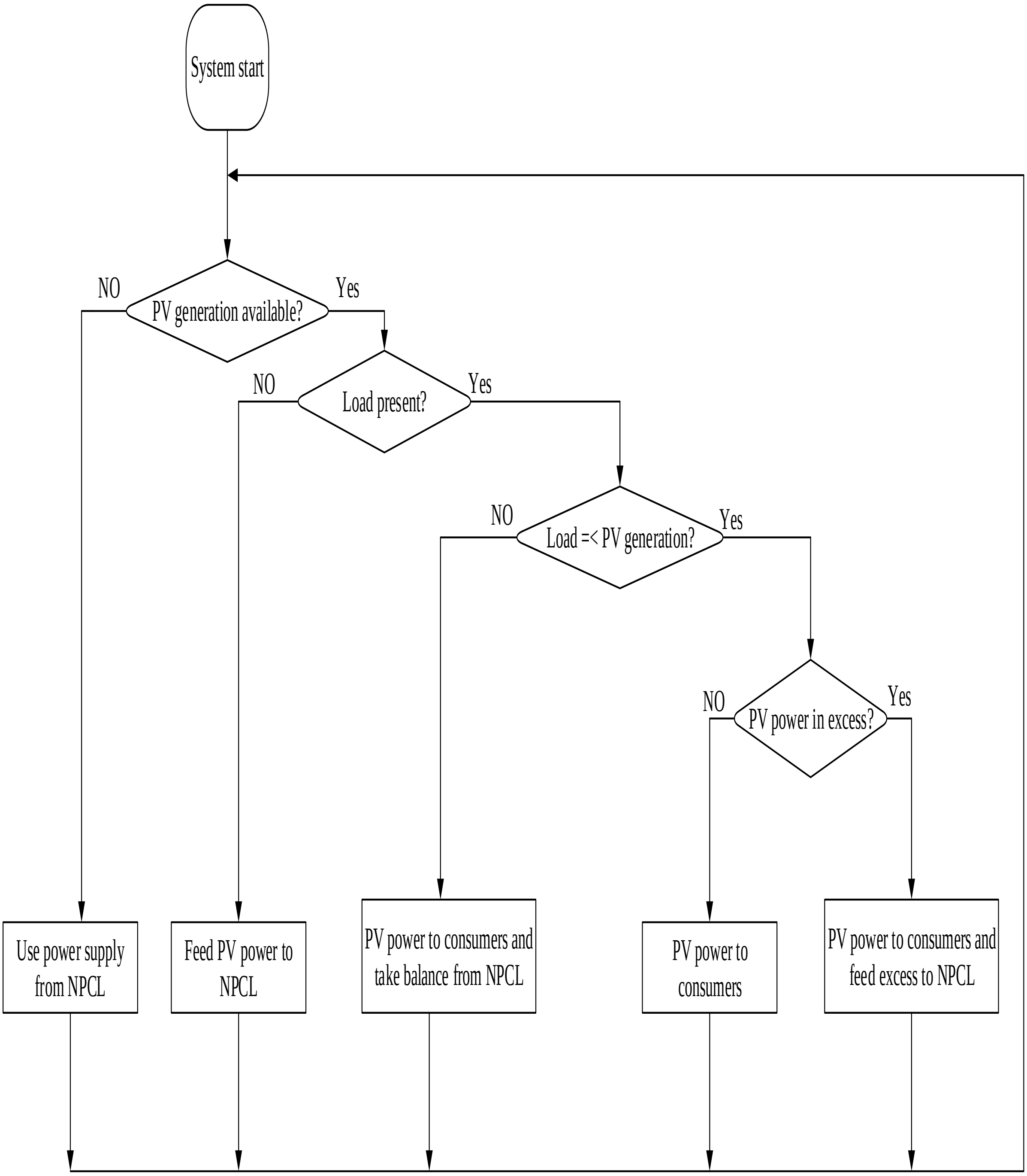


Figure 9: Control logic for Micro-grid.

CHAPTER 4 : DESIGN OF SCADA SYSTEM FOR MICRO-GRID

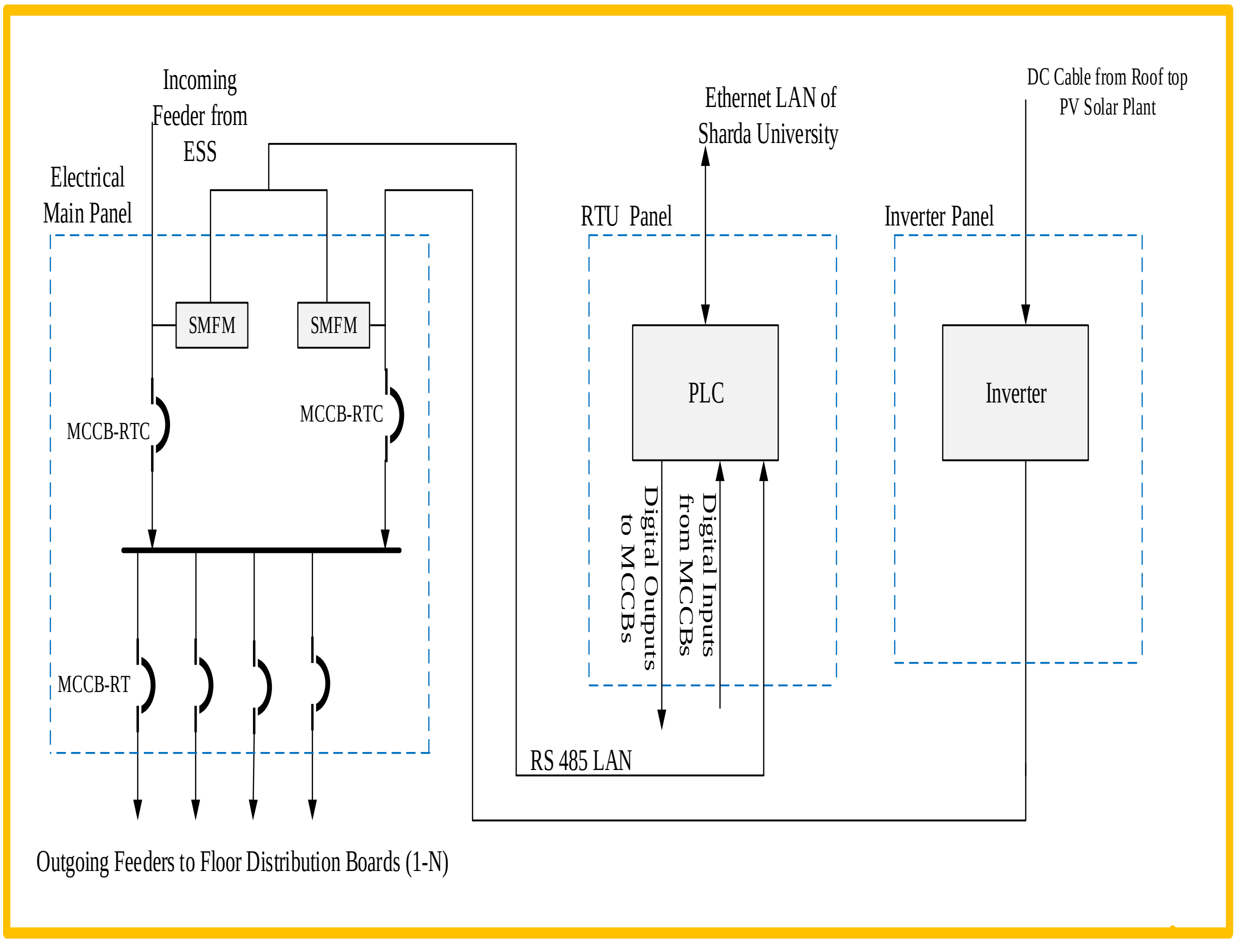
4.1: INTRODUCTION

In this design of the Supervisory Control and Data Acquisition (SCADA) system for micro-grid with distributed renewable resources with reference to Sharda University, the governing of the system is the Master Terminal Unit (MTU), which is a computer located in control room that will analyze real time information in the micro-grid and sent electricity out of demand. It will tell us what happened, why it happened and what we need to do. This MTU will be in bus data network for communication with Remote Terminal Units/Programmable Logic Controllers (RTUs/PLCs) /local controllers. A total of 14 RTUs are distributed to different locations at university. Here, 4 RTUs are assigned to 4 substations present at university and 10 RTUs are assigned for the 10 selected buildings at University. The RTUs will acquire data (status) from Fields Devices (FDs) and sent these to MTU and also transfer control commands from MTU to the Field devices.

The existing Ethernet LAN of Sharda University will be used for data network communication between RTUs and MTU, and the Remote Terminal Units (RTUs) will be in wired data network communication with Field devices. Here, 24V DC cables will be used for digital inputs (status) from Field Devices (FDs); 240V AC cable will be used for digital outputs (control commands) to Field Devices (FDs).

4.2: PANELS WITH INTERCONNECTIONS IN A BUILDING

During surveying at Sharda University distribution systems, it has been found that most of field devices (FDs)are manual in operation, so some remote trip and close arrangements for field devices has been added so that SCADA system functions can affects the operation of micro-grid through switching operations . In addition to this, Smart Multi Functions Meters (SMFM) has been paced at different building so that from the reading parameters, through SCADA, the energy management can be achieved. Note that the RS485 LAN will be used as data network for communication between Smart Multi Functions meters and Remote Terminal Unit (RTU).



Legend

MCCB- RTU : MCCB with Remote Trip and Close arrangements

MCCB-RT : MCCB with Remote Trip arrangements

SMFM : Smart Multi- Function Meter

Figure 10: Panels with interconnections in a building

4.3: LAYOUT OF SCADA SYSTEM

This SCADA System is composed with:

1. Mater Terminal Unit located in Control room which is the governing of the whole system.
2. 14Remote Terminal Units assigned for different parts of the micro-grid
3. Field Devices (different types of circuit breakers present at Sharda University distribution network)

4. Communication between MTU and RTU's: which is a two-ways communication with the help of Ethernet LAN of Sharda University.
5. Communication between RTU and Field Devices: This is the wired circuit.

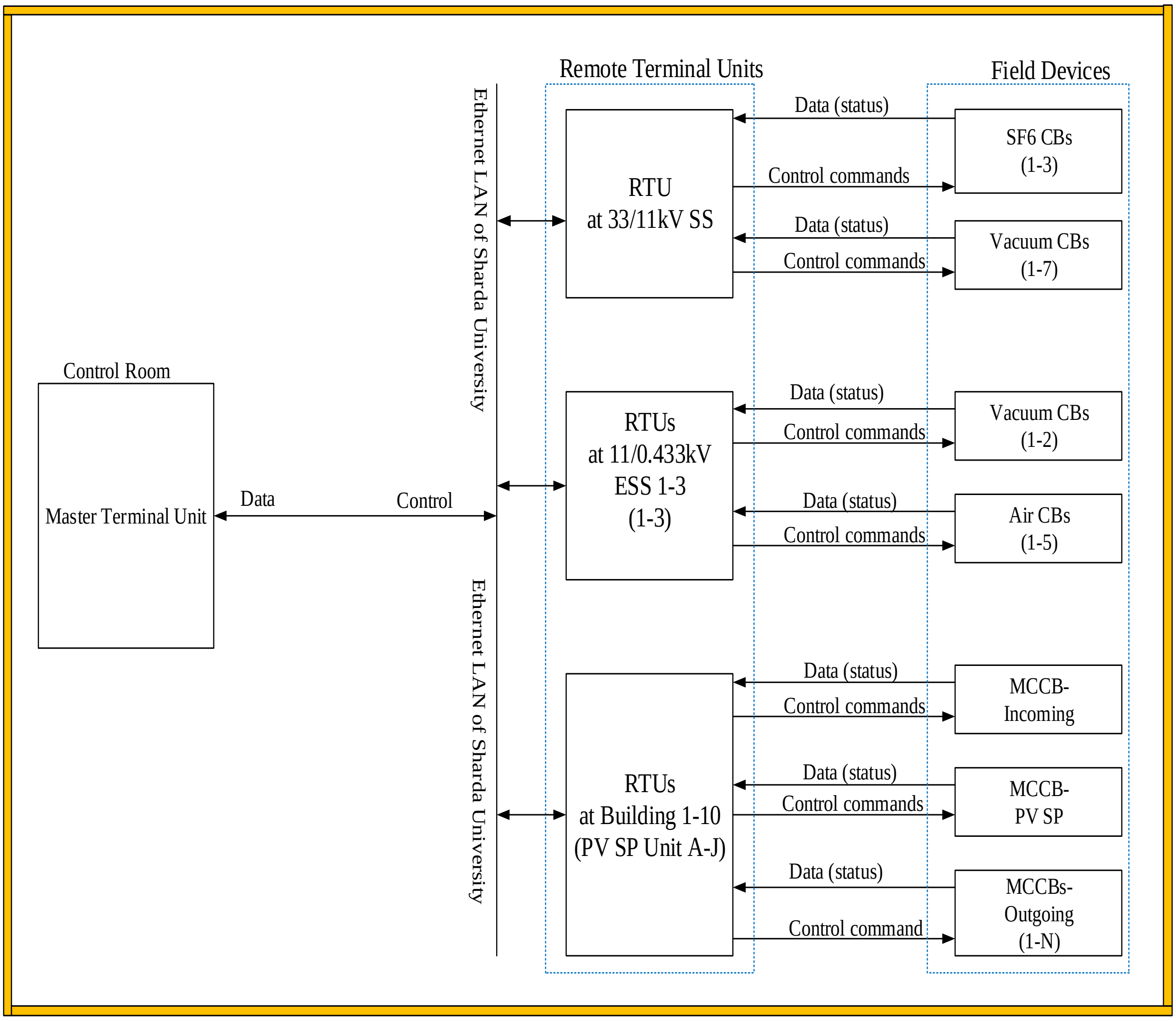


Figure 11: Layout of SCADA system for micro-grid of Sharda University

4.4: DESIGN OF MASTER TERMINAL UNIT

A central host or master (also called a master station, master terminal unit or MTU). The master station itself often consists of two separate subsystems.

- Work stations which process all the information and where the system operator/engineer can monitor and control the system
- A communication controller, which takes over the burden of real –time communication processing and network management.[12]

4.4.1: Layout of Master Terminal Unit in Control Room

In this MTU design, the two computers will be used as work station, where one of these will be for viewing and other for control. The mimic board will be there for simplified data show, and printer will be there to printouts some required information or report generation. Through Ethernet port all these devices will be in data communication with Remote Terminal Units (RTU's) assigned to different parts of micro-grid.

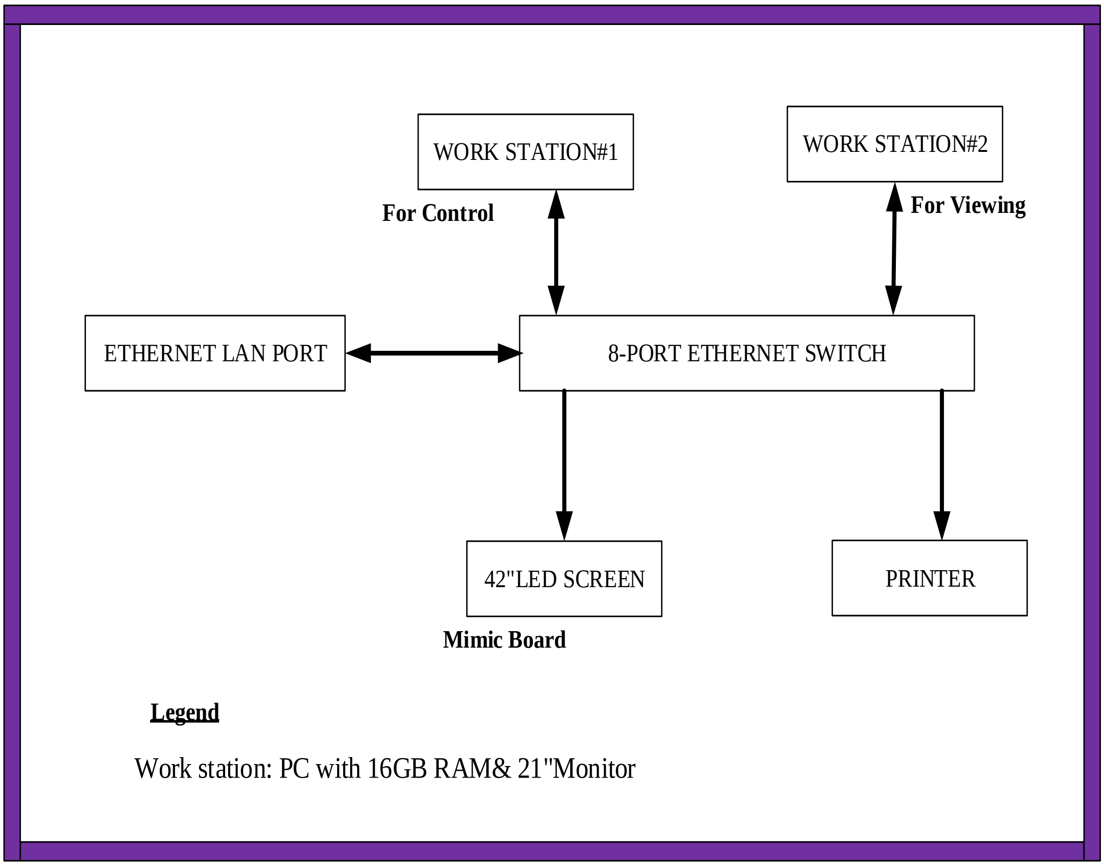
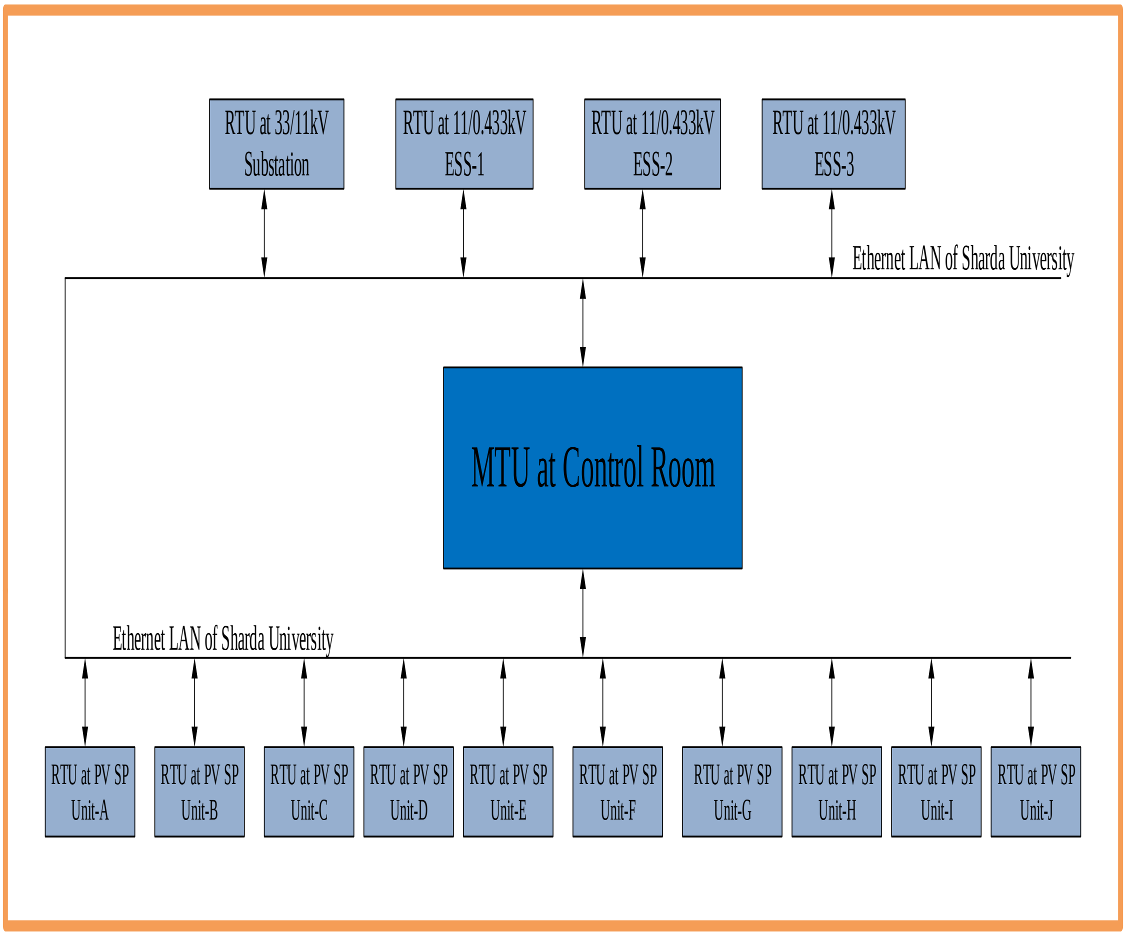


Figure 12: Layout of Master Terminal Unit in Control Room

4.4.2: Data Network for Communication between RTU's and MTU

The existing Ethernet LAN of Sharda University will be used data network for communication between RTUs and MTU, and the bus data network is suitable due to the university configuration.



Legend

ESS : Electric Substation

PV SP : Photo- Voltaic Solar Plant

RTU : Remote Terminal Unit

MTU : Master Terminal Unit

Locations (Tentative)

PV SP Unit-A : Block-1, SET-1

PV SP Unit-B : Block-2

PV SP Unit-C : Block-3, Part-A

PV SP Unit-D : Hospital, Block-A

PV SP Unit-E : Hospital, Block-E

PV SP Unit-F : Mandela Hostel, Block-A

PV SP Unit-G : Mandela Hostel, Block-C

PV SP Unit-H : Tagore Hostel

PV SP Unit-I : Vivekand Hostel

PV SP Unit-J : Indira Hostel

Figure 13: Data network for communication between MTU and RTUs

4.5: DESIGN OF REMOTE TERMINAL UNIT

One or more filed data gathering and control units or remote(also called remote stations ,remote terminal units or RTU's) .An RTU provide intelligent

Input/ Output collection and processing, such as reading input from switches, sensors, and transmitters, then arranging the representative data into a format that SACADA system can understand. RTU also converts outputs values provided by the SCADA system from digital form into that which can be understand by field controllable devices such as discrete(relay) and analog outputs (current or voltage).[12]

In this work, the RTU will acquire the digital inputs (status) from Field devices such as Manual trip; Remote trip; Under-voltage trip; Over-current trip. Also will transfer digital outputs (control commands) to the Field Devices such as trip /close or close. The Programmable Logic Controllers (PLCs) of Allen Bradley Micrologix-1400, with 20 digital inputs, 12 digital outputs, Ethernet port, RS485 Port has will be used, and some additional number of inputs and outputs will be provided.

4.5.1: Design of RTU for 33/11KV Substation

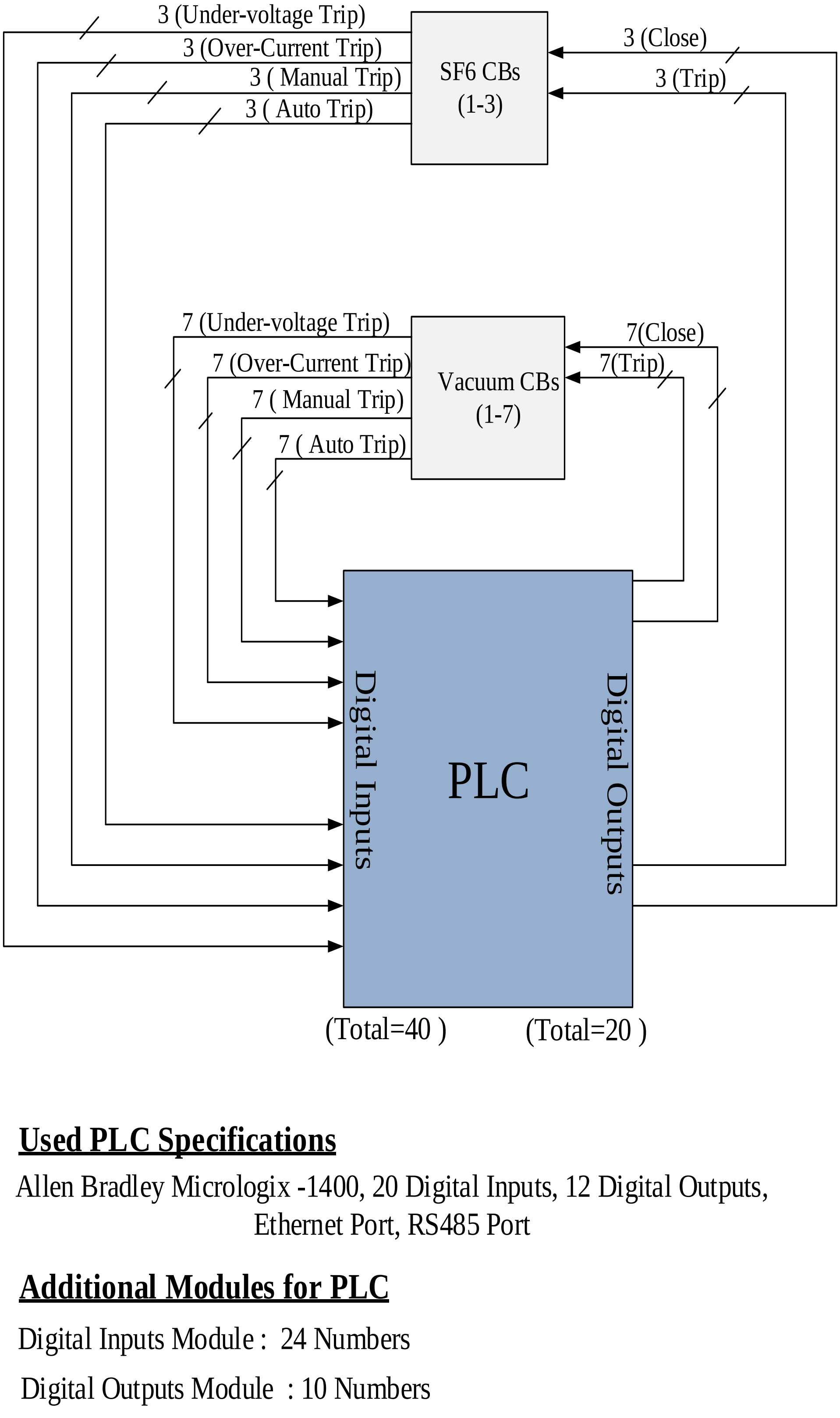
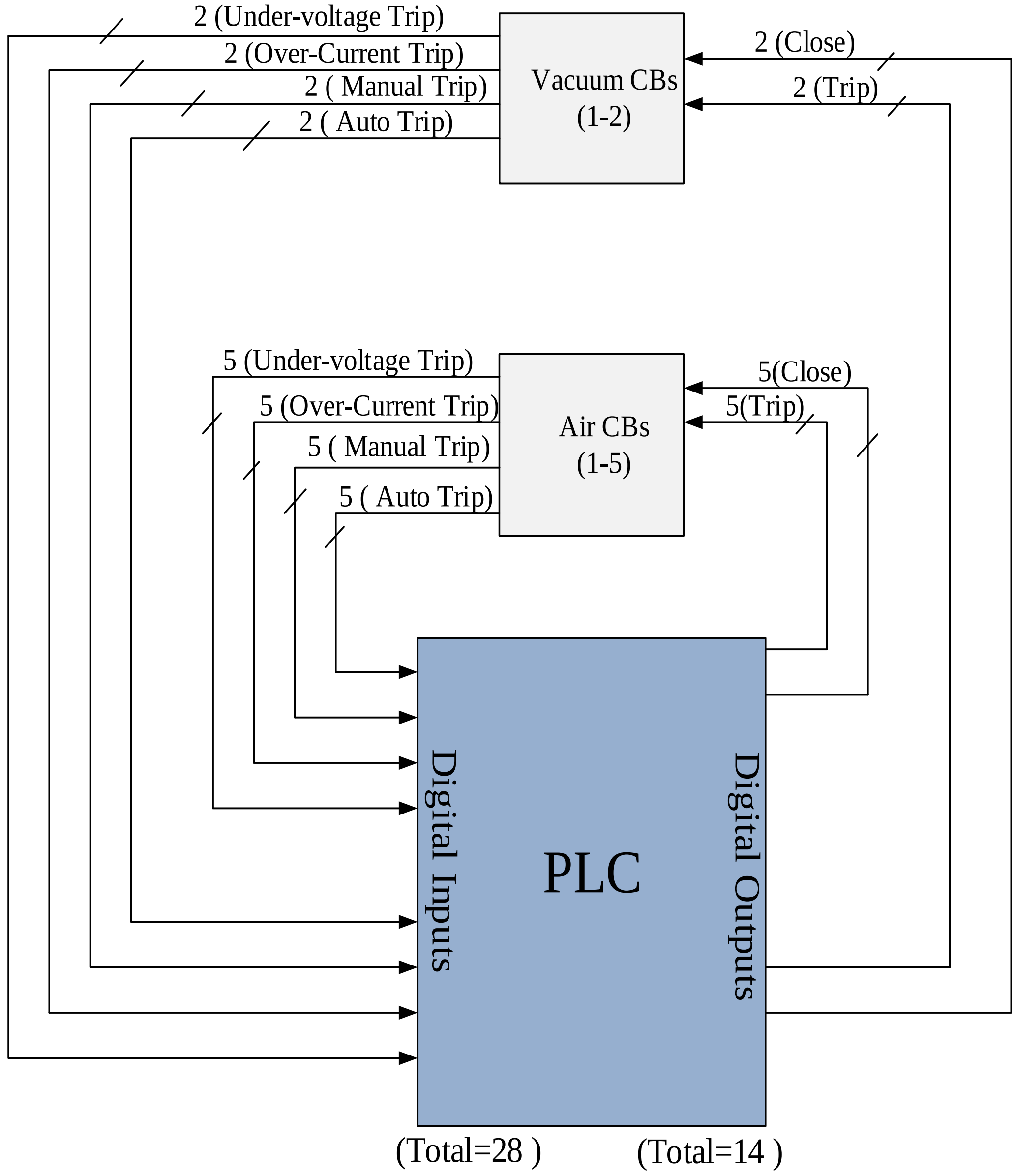


Figure 14: Design of RTU for 33/11kV Substation.

4.5.2: Design of RTU for 11/0.433KV ESS-1 to ESS-3.



<u>Used PLC Specifications</u>

Allen Bradley Micrologix -1400, 20 Digital Inputs, 12 Digital Outputs, Ethernet Port, RS485 Port

<u>Additional Modules for PLC</u>

Digital Inputs Module : 12 Numbers

Digital Outputs Module : 4 Numbers

Figure 15: Design of RTU for 11/0.433kV ESS1 to ESS-3

4.5.3: Design of RTU for Building-1 to 10 (PV SP Unit-A to J)

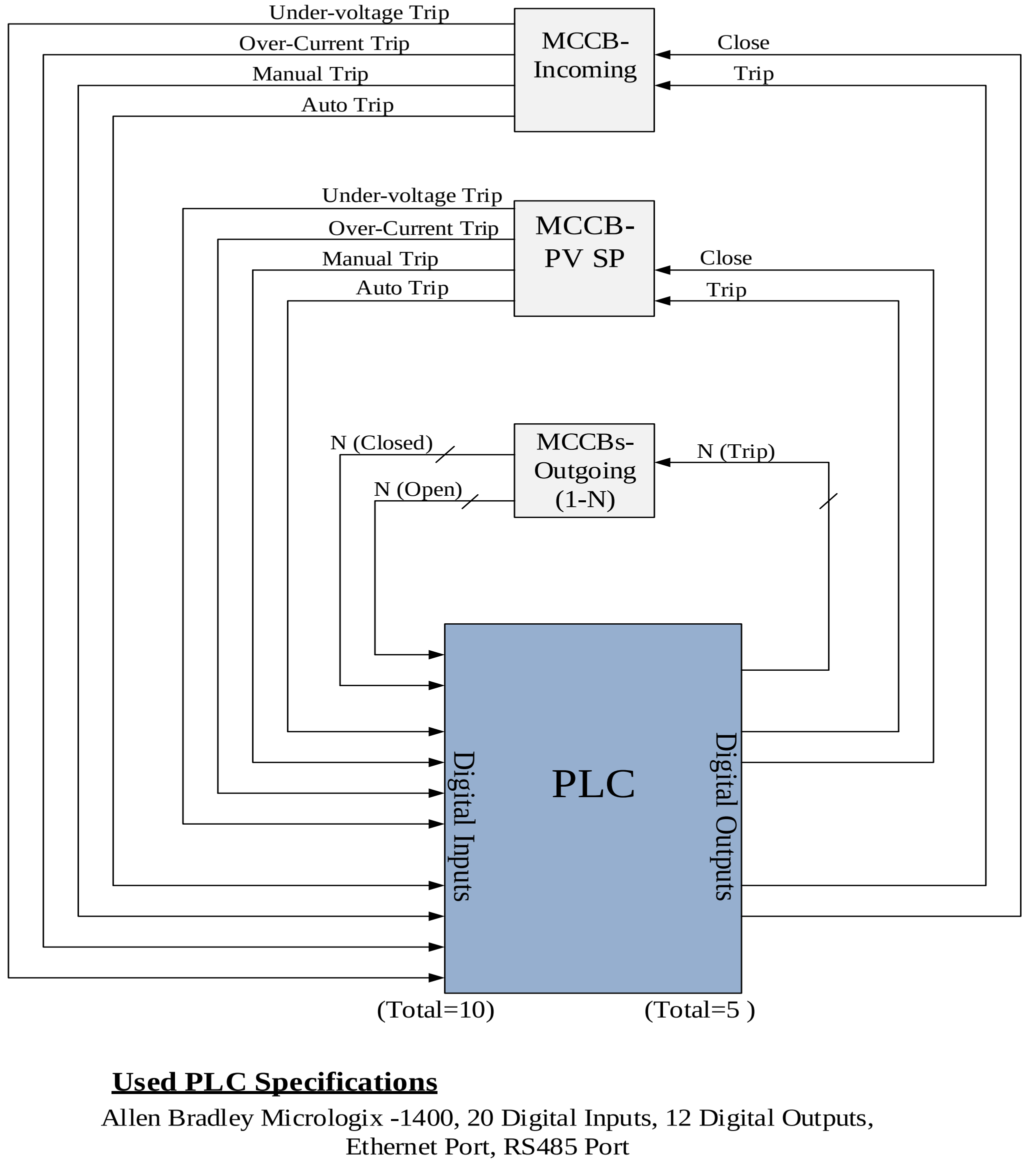


Figure 16: Design of RTU for building-1 to 10 (PV SP Unit-A to J)

4.5.4: Communication between RTU and FDs

a) For Data Inputs to RTU

Through wired circuit (24V DC cable), each RTU will acquire the digital inputs (status) from filed devices (different types of circuit breakers present at University distribution network). Also, through RS 485 LAN, the RTU will get different metered parameters (Line to line voltage, Line to Neutral voltage, frequency, current, power factor, and energy) from Smart Multi-Function Meters (SMFM) and RTU will transfer to MTU using Ethernet LAN of Sharda University.

b) For Control Commands to FD’s

Through wired circuit (240V AC cable), each RTU will transfer the digital outputs (control commands) to field devices (different types of breakers present at University distribution network).

CHAPTER 5: ISSUES RELATED TO CONNECTION OF PV SOLAR PLANT UNITS TO MICRO-GRID

5.1: INTRODUCTION

The huge amount of solar is available on the earth. Humans consume almost 15TW of solar energy [6]. Although solar energy is an infinity energy source derived from the environment, its supply is intermittent. Yet, its availability is less than predictable and outside human control as compared to conventional power plants [13]. Customers are interested in solar power due to low cost, environment friendly and flexible installation. But, constraints of solar generation are: high installation cost of solar panels, low capacity, uncertainty of solar irradiance and power fluctuation due to the intermittency behavior of sunlight [6]. Continuous research and development are going on to meet the challenges pertaining to solar power generation. From technologies used to manage challenges due to PV Grid-tied systems, the use of energy storage unit, distribute PV system on large geographic area in small units instead of large unit concentrating of one area are among many means to offset these challenges.

5.2: CHALLENGES WITH SOLAR PV INTEGRATION

5.2.1: Intermittent Generation

The intermittent nature of solar resource and limited dis-patchability require grid operator to maintain additional spinning reserves. Accurate hourly and sub hourly solar generation forecasting is required to help in unit commitment and spinning reserves, scheduling and dispatch[13]. The figure below shows the rapid PV output variations (ramping) that occur as clouds pass overhead [4]

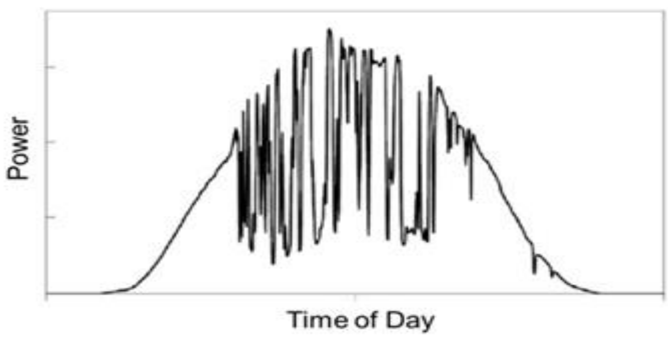


Figure 17: Rapid PV Power output variations (ramping) during a day [4].

5.2.3: Distribution System Issues

The increasing penetration of institutional and residential solar generations imposes challenges on the existing distribution infrastructure. Grid operators are facing shifts in peak demand, load pattern resulting in a scenario where generators are being called upon to ramp up their output than before and for which they may have not been designed[16]. To avoid this, new control strategies such as enhancing distribution automation, and micro-grid capabilities, voltage and VAR management are required.

5.2.4: Integrating Energy Storage

Usually, the electric energy storage is mainly used in standalone PV systems. But, as the percentage share of PVgenarated energy is increasing in the total basket, it is necessary to integrate energy storage with PV-Grid tied systems. Therefore, the integration will add value (Cost sharing) to the utilities and consumers through improved reliability, enhanced power supply and economic delivery of electricity.

5.3: VARIOUS SOLUTIONS OF PV SOLAR UTILIZATION

5.3.1: For Standalone Systems

Standalone PV systems are most relevant and successful in remote and rural areas having no access to grid supply. So, an excellent style of electric energy storage is mainly required for standalone PV systems.

Storage can be used to 'smooth out' variability that the grid must accommodate. For example, storage can be used to provide localized' ramping' service 'as depicted shown in the following figure [4].

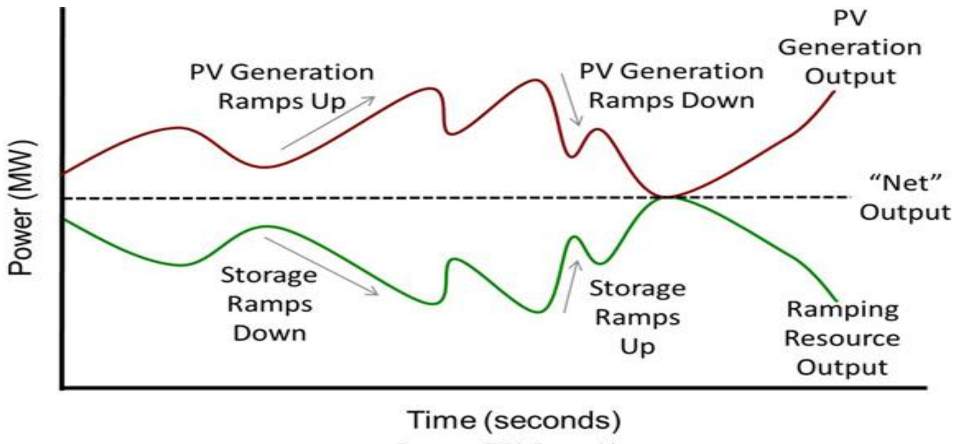


Figure 18: Storage to provide Ramping service [4].

5.3.2: For Grid Connected System

a) The Need for Energy Storage in High-Penetration PV System

The increase penetration of PV systems on local and regional utility grids is to achieve goals related to the emission reduction, energy independence, and improved infrastructure reliability. But, when PV penetration reaches high levels (e.g., 5 to20% of total generation) however, the intermittent nature of PV generation can start to have noticeable negative effects on the entire grid [14].

High PV integration may reduce intermediate fossil fuel generation by, without storage, will do little or nothing to reduce a utility's overall conventional generation because of higher spinning reserve requirements.

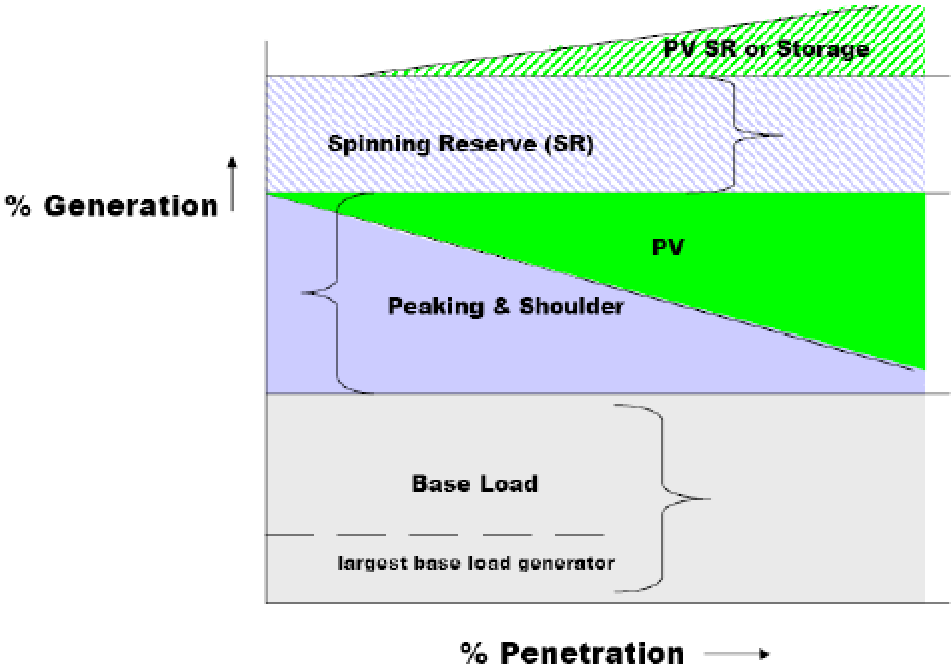


Figure 19: The need for additional spinning reserve or storage to back up intermittent PV generation at increased levels of Penetration [14].

The storage can be used for frequency regulation, voltage regulation by providing the following advantages:

i. **Peak shaving**: PV system require that PV provide above the threshold and if PV is not available then an adequate energy storage to fill the gap. Thus reliability of PV storage is a key element [14].
ii. **Load Shifting**: Many peak loads occur late in the day, after the peak for PV generation has passed. Storage can be combined with PV to reduce demand for utility power late-day; higher rate times by charging a storage system with PV generated energy early in the day or to support a load later in the day.
iii. **Demand Response**: This allows the utility to control selected high load devices such as heating, ventilation, and air conditioning and water heating during high demand periods.

iv. **Outage protection**: An important benefits of PV-storage system is the ability to provide to the residential or small commercial customers when power is unavailable (i.e., during outage).

b)The use of other Renewable Resources

In some cases, wind generation is diminishing as solar power is increasing in the morning and wind generation is increasing as solar power output is decreasing the evening. That can either lead to offsetting variation or variation that is additive. PV and wind generation diurnal variation is shown in following figure [4].

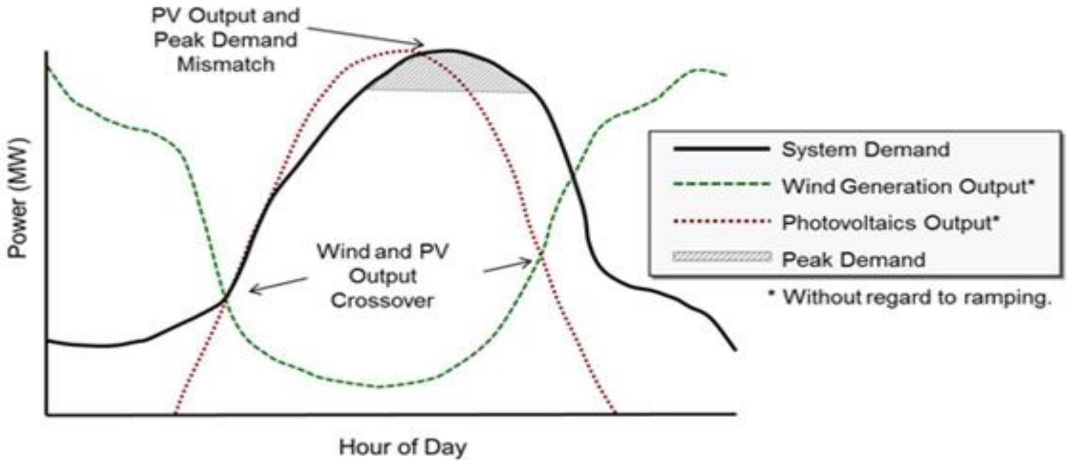


Figure 20: Diurnal PV and Wind generation variation [4].

5.3.3: For Micro-grid of Sharda University

In the micro-grid of the University, in addition to the power from Noida Power Company Limited, the Diesel Generators (DG sets), the 10 units (100KW for each) of distributed roof-top PV solar plant will be used to generate power. Therefore, by using change over switches present at university distribution system, the DG sets which work as spinning reserve will be used to manage the challenges due to the time variability of power from sunlight

5.4: CURRENT ELECTRIC ENERGY STORAGE TECHNOLOGIES

5.4.1: Battery Based Technologies

To date, the advantage of lead-acid technology, such as low cost and availability, has made it the default choice for the energy storage in most PV applications. But, other new technologies are established. The following show different battery technologies used storing PV energy.

TECHNOLOGY	ADVANTAGES	DISADVATANGES	APPLICATIONS
Flooded Lead-acid	• Cost effective • Mature technology • Relatively efficient	• Low energy density • Cycle life depends on battery design and operation strategies when deeply discharged • High maintenance • Environment hazardous materials	• Motive power(forklifts, carts,etc) • Back –up power • Short-duration peak reduction • Short-duration power quality
NiCd	• Good energy density • Excellent power delivery • Long shelf life • Abuse tolerant • Low maintenance	• Moderately expensive • "Memory effect" • Environment hazardous materials	• Air craft cranking, aerospace, military and commercial applications • Utility grid support • Stationary rail • Telecommunication back –up power
Na/S	• High energy density • No emissions • Long cycle life when deeply discharged • Low maintenance • Integrated thermal and environment management	• Relatively high cost • Requires powered thermal management(heaters) • Environment hazardous	• Utility –integrated renewable generation support • Commercial/industrial peak shaving • Commercial/industrial back up power

Na/S	• High energy density • No emissions • Long cycle life when deeply discharged • Low maintenance • Integrated thermal and environment management	• Relatively high cost • Requires powered thermal management(heaters) • Environment hazardous	• Utility –integrated renewable generation support • Commercial/industrial peak shaving • Commercial/industrial back up power
Vanadium Redox	• Good cycle life • Low temperature • Low maintenance	• Low energy density • Medium power density • Requires stripping cycle	• Firming capacity of renewable resources • Remote area power systems • Load management and peak shaving.

Table 2: Battery Technologies for Electrical Energy Storage in Residential and small commercial Applications[14].

5.4.2: Other Technologies

The non -battery technologies can be integrated with grid –tied distributed PV generation. Hybrid lead-carbon asymmetric capacitors are also targeting the peak shaving market while low-speed flywheels are currently being used in many UPS application. The table below shows some of non-battery technologies used for grid-tied distributed PV generation.

STORAGE TYPE	ADVANTAGES	DISADVANTAGES	APPLICATIONS
Lead-carbon asymmetric capacitors(hybrid)	• Rapid discharge • Deep discharge • High power delivery rates • Long cycle life • Low maintenance	• Lower energy density than batteries • Lower power density	• Peak shaving • Grid buffering
Electrochemical Capacitors	• Extremely long cycle life • High power density	• Lower energy density • Expensive	• Portable electronics • Utility power quality
Flywheels	• Low maintenance • Long life • Environment inert	• Lower energy density • High cost	• Aerospace • Utility power quality • Renewable support • UPS • Telecommunications.

Table 3: Non-Battery Technology for Electric Energy Storage in Residential and Small-commercial Applications[14].

CHAPTER 6: CONCLUSION AND FUTURE SCOPE

In this dissertation work, a survey on existing distribution system of Sharda university has been carried out, which was a lot of time consuming because data were not available due to the traditional system network configuration. From this survey, single line diagram of 4 electrical substations, block-1, block-2 and block-3 has been prepared along with details by using Electra E7 software.

Distributed PV solar plant units have been proposed to support the power from Noida Power Company Limited (NPCL) along with back up diesel generator sets present at university. The survey has been carried out by certified company who has proposed that 1MWpeak can be set up on roof-top of 10 selected buildings of the university. The proposed layout of micro-grid with 10 units of distributed roof-top solar plant connected to electrical main panel in each building and with tie-lines has been designed. The losses are minimized by selecting the location of solar plant units.

The Supervisory Control and Data Acquisition System (SCADA) has been designed which is composed with MTU which is a computer located in control room and work as the governing system. The unit controllers which comprise 4 RTUs assigned to 4 electrical substations and 10 RTUs assigned to 10 buildings with 10 units of distributed solar plant has been designed for acquiring data and sent control commands to FDs. The existing Ethernet of Sharda University has been chosen as data network for communication between RTUs and MTU. The RTU will acquire data from FDs through 24V DC cable and will send control commands to FDs through 240AC cable. The control logic which will be implemented by MTU for sending control commands to close and trip breakers of load and PV units has been clarified to increase the efficient of PV energy use.

The connection of PV solar plant result in problems with grid tied studies. To minimize fluctuations and intermittent problems of PV integration, the use of energy storage and use of other resources have been suggested in this dissertation work.

The following would be the future scopes:

- ✓ Programming of RTU and MTU
- ✓ Making development SCADA screens

- ✓ Actual problems due to PV connections to micro-grid
- ✓ Use of storage option at University rather than back up diesel generators
- ✓ Use of Smart Multi -Function Meters(SMFM) for improving energy management

REFERENCES

[1]. P.Nivedhitha. Power Scenario Prospects for Micro-Grid. IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE),Volume4, Issue6(March- April.2013), pp24-30

[2]. Yanning Chen, Wei Pei. Design and Implementation of SCADA system for Micro-grid. Information Technology Journal 12(24): 8049-8057, 2013. Asian Network for Scientific Information.

[3]. Solanke Tirupati U, Kulkarni Anant A. Effective Micro-grid Synchronization in Islanded Mode: Controlled Input/output PI-Fuzzy-PI Algorithm. International Journal of Computer Applications (0975 – 8887) Volume 75 – No.16, August 2013.

[4]. EnergyStorageAssociation.WashingtonDC,USA.http://energystorage.org/energy-storage/technology-applications/distributed-grid-connected-pv-integration.

[5]. Christian Dragos Dumitru, Adrian Gligor .SCADA based software for renewable energy management system. ScieVersa Science Direct, procedia Economics and Finance 3(2012) 262-267

[6]. Er.Mamatha Sandhu, Dr.Tilak. Issues, Challenges, Causes, Impacts and Utilization of Renewable Energy Sources-Grid Integration. Mamatha Sandhu etalInt.JournalofEngineeringResearchand.Applications.www.ijera.comISSN: 2248-9622, Vol.4, Issue 3(version1), Mach 2014, pp636-643.

[7]. S.Hasan Saeed, B.K. Sharma, Non-Conventional Energy Resources, Mc Graw Hill Education, 2ndEd, 2009.

[8]. European research commission. Integration of renewable resources and distributed generation in energy supply systems. European research commission. Office for Official Publications of the European Communities, 2001.Luxembourg: ISBN 92-894-0508-2.Internet: http://www.cordis.lu/eesd/.

[9]. Lisa Frantzis, Maya Chaudhari, Julie Blunden. Relative Merits of Distributed vs.Central Photovoltaic (PV) Generation .MOMERANDUM presented to California Energy Commission Renewable Energy Program April 7, 2004.

[10]. Sneha Kulkarni, Sunil Sontakke. Power System Analysis of a Microgrid using ETAP. International Journal of Innovative Science and

Modern Engineering (IJISME) ISSN: 2319-6386, Volume-3 Issue-5, April 2015.

[11]. Prof.H.K. Verma, Lecture notes on SCADA at, www.profhkverma.info accessed on 3rd March, 2016.

[12]. Christian Dragos Dumitru, Adrian Gligor .SCADA based software for renewable energy management system. ScieVersa Science Direct, procedia Economics and Finance 3(2012) 262-267

[13]. T.Kaur. Solar PV Integration in Smart-Grid: Issues and Challenges. International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering. Vol.4, Issue7, July, 2015

[14]. Dan Ton, Georgianne H.Peek, Charles Hanley, John Boyes. Solar Energy Grid Integration Systems- Energy Storage. Energy. Energy Efficiency and Renewable Energy.U.S Department of Energy.Program Concept Paper,2008.