Load Flow Analysis of IUT and Proposing a Better Infrastructure

by

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Declaration of Authorship

This is to certify that the work presented in this thesis is the outcome of the analysis and experiments carried out by Intiak Ahmed Orkey, Ishmum Monjur and Aftab Mahmud Sakib under the supervision of Prof. Dr. Rakibul Hasan Sagor, Faculty of Electrical and Electronic Engineering Department, Islamic University of Technology (IUT), Gazipur, Bangladesh. It is also declared that neither of this thesis nor any part of this thesis has been submitted anywhere else for any degree or diploma. Information derived from the published and unpublished work of others has been acknowledged in the text and a list of references is given.

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List of Acronyms

AC	Air Conditioner
ACB	Air Circuit Breaker
ATS	Automated Transfer Switch
BB	Bus Bar
BBT	Bus Bar Trunking System
BNBC	Bangladesh National Building Code
BREB	Bangladesh Rural Electrification Board
CB	Circuit Breaker
CBs	Circuit Breakers
CT	Current Transformer
DFC	Dropout Fuse
ETAP	Electrical Transient Analyzer Program
FACTS	Flexible AC Transmission System
HT	High Tension/High Voltage side
IEC	International Electrotechnical Commission
KCL	Kirchhoff's Current Law
kVA	Kilo Volt Ampere
kVAR	Kilo Volt Ampere Reactive
kW	Kilo Watt
LT	Low Tension/Low Voltage side
MCB	Miniature Circuit Breaker
MCCB	Moulded Case Circuit Breaker
MCO	Manual Change Over
MW	Mega Watt
MVA	Mega Volt Ampere
MVAR	Mega Volt Ampere Reactive
NEMA	National Electrical Manufacturers Association
ONAN	Oil Natural Air Natural
PF	Power Factor
PLC	Programmable Logic Controller
PLF	Probabilistic Load Flow

PT	Potential Transformer
RM	Radial Meter
SP	Single Pole (Circuit Breaker)
TP	Triple Pole (Circuit Breaker)
TV	Tele Vision
VCB	Vacuum Circuit Breaker

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Abstract

The significance of the electrical industry is visible in Bangladesh's present employment economy. Furthermore, load flow analysis is one of many power engineers' most typical concerns. We generally undertake load flow analysis on different power plants, networks, and substations. The substation at IUT is largely powered by the Bangladesh Rural Electrification (Palli Biddyut in Bangla) Company grid situated in Rural region-1. The major purpose of this research is to undertake a detailed load flow analysis of the IUT substation. Other key tasks include giving the required assistance for building excellent cables and identifying the suitable cable rating on the LT side of the substation. Our purpose is to study the HT side of the three feeders (three uppers and three lowers) and the three neutral lines from the rural electrification grid. Through our study, we will also aim to identify the many sorts of defects that may arise owing to erroneous cable rating on the LT side. We will also establish a means to change the current IUT substation structure by evaluating load flow analysis using the suitable software and providing sophisticated and appropriate methods for load flow analysis using the software.

The other objectives of this project also include to do load flow analysis of entire IUT. This project also focuses on the to give important remarks on the modifications that is necessary to ensure efficient power flow. The project also aims in proposing a better substation design, designing the substation accordingly and simulation of the proposed model showing the optimal power flow than the current or existing model. This project is mainly a simulation based project which will be used for the comparison and analyzation and is done by using a power system simulation software ETAP.

Chapter 1

Introduction

1.1 Definition

Load flow analysis is the most critical and essential approach to investigating power system operating and planning problems. Load flow analysis solves the steady operation state with node voltages and branch power flow in the power system based on a specified generating state and transmission network structure[1].

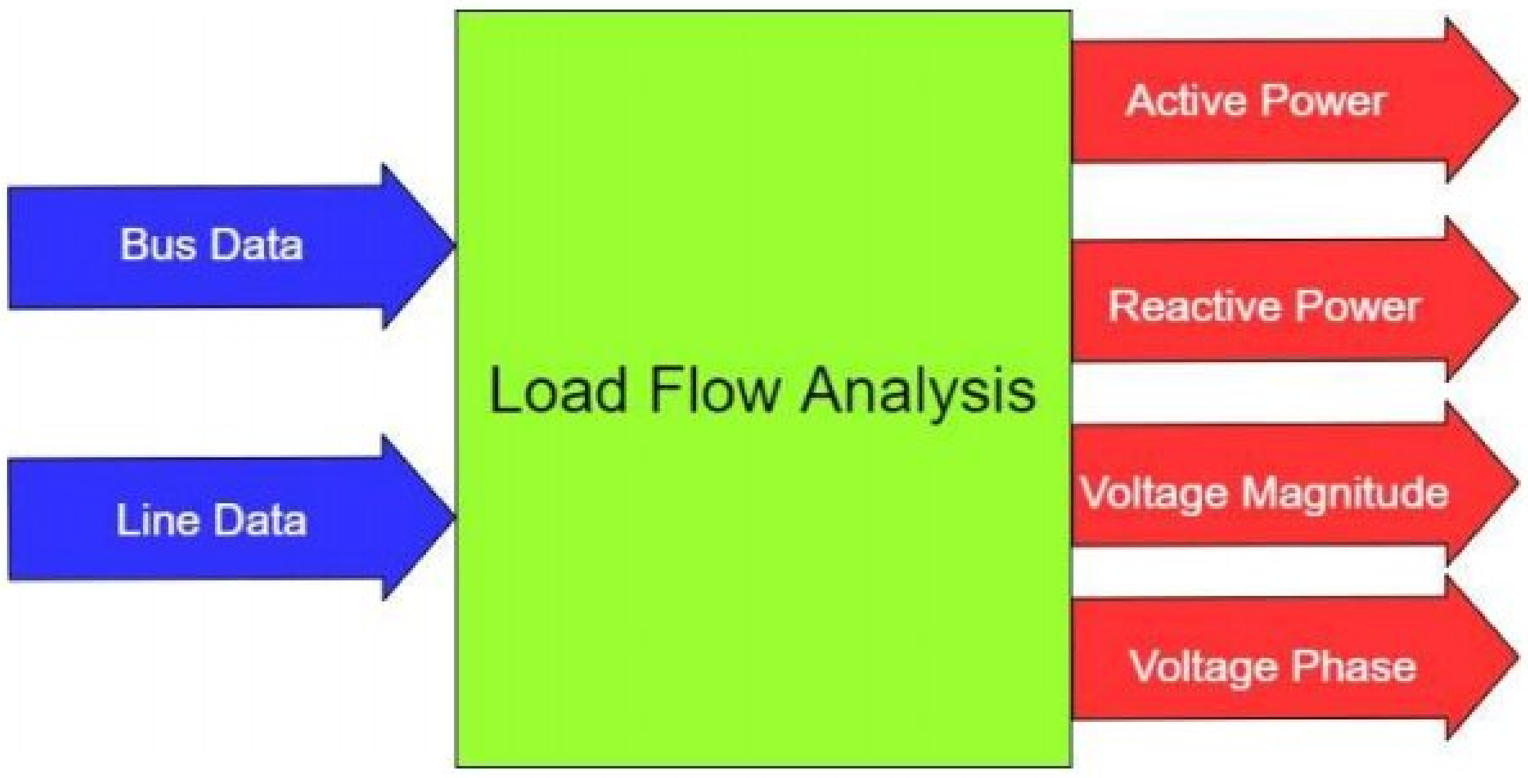


Figure 1.1: Block Diagram Showing Load Flow Analysis

1.2 Basic concept of load flow analysis

Load flow analysis mainly calculates the real power P and reactive power Q throughout all the electrical components in a power system. Load flow solutions are among the most frequently performed power network calculations for the power system's steady-state operating conditions. Load flow simulations must be extremely computationally efficient to be of exceptional value to operators in the operational context[2].

The expression below shows the expression of the real and reactive power for the load buses present within an electrical network in a power system. When the real and reactive power is injected into the buses, like generator buses, the natural and reactive power will have positive values, and if these real and reactive powers flow away from the bus, which is seen in the case of load buses, the real and reactive power will have negative values[3].

$$(P_i)^{K+1} = \mathrm{Real}[(V_i)^{*(K)}\{(V_i)^K \sum_{j=0}^{n} Y_{ij} - \sum_{j=1}^{n} Y_{ij}(V_j)^k\}]\ , j \neq i \text{ and}$$
$$(Q_i)^{K+1} = \mathrm{Imaginary}[(V_i)^{*(K)}\{(V_i)^K \sum_{j=0}^{n} Y_{ij} - \sum_{j=1}^{n} Y_{ij}(V_j)^K\}],\ \ j \neq i \ldots\ldots\ldots\ldots (\mathbf{1.2.1})[\mathbf{4}]$$

Where Y is the admittance between two nodes i and j and V is the supply voltage of the required bus.

The process of load flow analysis is mainly done based on the following algorithm:

1. Start reading the bus data (bus voltage and current).
2. The data taken will check whether the solution converges or not.
3. If the solution does not converge, then the system will assume the initial values of the base values (initial voltage and current values).
4. Based on the reading of the initial values, the system will determine the effective load (for our case, lumped load) on each of the buses.
5. Based on the effective load, voltage magnitude, voltage phase angle, real power, and reactive power will be calculated.
6. After that, there will be the calculation of the initial power losses and current of all the switches, circuit breakers, fuses, cables, wires, busbars, etc., that are present within the power system.
7. Again, the system will check the convergence of the solution obtained from the load flow analysis. If the solution converges, i.e., within a specific limit, the system stops the process and shows the output results in this case.

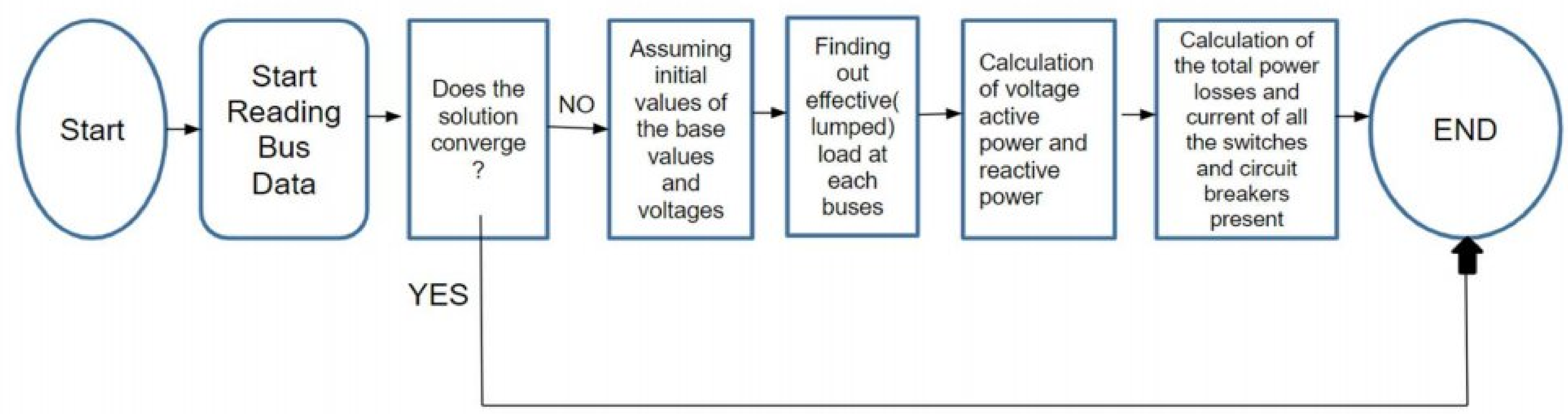


Figure 1.2: Flowchart showing load flow analysis

1.3 Reason to perform load flow analysis

The load-flow analysis is used in functional studies to guarantee that each generator operates at its optimal operating point, that demand is fulfilled without overloading facilities, and that maintenance programs may occur without jeopardizing the system's security[5]. It also aids in the steady-state analysis and operation of the station by solving a series of non-linear equations.

1.4 Quantities to be measured through load flow analysis

Mainly load flow analysis gives a broad analysis of the following quantities within a power distribution network:

1. Load flow research is the steady-state examination of a power system network.
2. Load flow research establishes the system's operational condition for a particular loading.

3. Load flow solves a set of simultaneous nonlinear algebraic power equations for the unknown variables ($|V|$ and $\angle\delta$) at each node in a system.
4. To solve nonlinear algebraic equations, it is vital to have quick, efficient, and accurate numerical techniques.
5. The outcome of the load flow analysis is the voltage and phase angle, real and reactive power (both sides of each line), line losses, and slack bus power[6].

1.5 Literature review

Load flow analysis is essential for analyzing power flow over large-scale or small-scale distribution networks. As a result, various types of research have been conducted to ensure the optimal power flow within either a small or large transmission and distribution network. In many cases, the optimal power flow was ensured using different simulation software, as, through field visits or surveys, we could not accomplish such types of calculations. So, out of the many papers that we have gone through, we observed that the load flow analysis was done using ETAP software simulation. ETAP is an effective software for simulation, design, monitoring, control, operator training, optimizing, and automating power systems[7]. So we have gone through several conferences and journal papers to have an idea of the software and tried how to take readings of each electrical component, do the optimal load flow, identify and analyze faults, and propose appropriate solutions based on the simulation results.

The first paper that we reviewed is mainly the load flow analysis of a typical 132/11 kV Grid Station in the Bhawalpur Region of Pakistan that is done through simulations and propositions for the voltage improvement through FACTS[8] (Flexible AC Transmission System) devices (FACTS are mainly the devices having an alternating current transmission system using power electronic-based and other static controllers to improve controllability and boost power transfer capabilities). The paper also discusses using the Newton-Raphson Method for the load flow case study for the load flow simulation using ETAP due to its high convergence rate and fewer iterations.

The second paper that we reviewed reviews PLF (probabilistic load flow) approaches along with PLF approach applications in many sectors of power systems, and also steady-state analysis are also highlighted[9]. That is because as we cannot obtain all the loads connected, connection given to each load and hence an optimal power flow within a network, we need to predict the load flow through each network in some cases that the paper successfully mentions, which helped us a lot in our load flow analysis of the IUT substation.

The third paper that we have reviewed shows the design of the electrical system, which is based upon the load flow analysis that has been done using the ETAP software for IEC projects[10]. The paper mainly mentions the input power requirements for modeling any electrical system, like the grid input, generator input, transformer input, lump load input, busbar input, study case input (like Newton Raphson or Gauss Seidal Method) etc. The paper also mentions the ETAP simulations showing the optimal power flow for generator and transformer operation in parallel.

1.6 Background and motivation

IUT was established in 1983, and our IUT substation was designed based on the needs and requirements of that time, but as time went by, the number of students and departments kept increasing, hence the load. However, we still use that same substation from 1983, which can barely handle such a huge load. As a result, our substation is working under critical conditions, and if necessary modifications are not made, it might end up dangerously.

So, we want to do a proper load flow analysis of the entire IUT, considering each load and providing solutions based on our research.

1.7 Objectives of load flow analysis in IUT

Our objective is to do a load flow analysis of the entire IUT (every single load) and give introductory remarks on the necessary modifications to ensure efficient power flow. Suppose we want to discuss these objectives elaborately. In that case, we want to do a complete load flow analysis of every academic building of IUT that is connected to the IUT substation at the distribution side by taking the collected current, voltage, and power ratings of each of the electrical components like generators, transformers, circuit breakers, cables, lumped loads (like light, fans, AC), LT panels, etc. through a field survey and simulating all of these in ETAP to obtain the following components like:

1. Active/Real Power
2. Reactive Power
3. Voltage in each bus in terms of both magnitude and phase.
4. Overall load consumption
5. Apparent losses
6. Load demand
7. Reactive compensation (through a capacitor)

Moreover, based on all of these readings, we want to also propose a new model of the IUT substation, which will also be accomplished based on load flow analysis of this proposed substation on the ETAP software by calculation of the exact quantities mentioned above (from points 1 up to 7).

Chapter 2

Overview of a Typical Substation

2.1 Introduction

A typical power substation mainly contains of the following parts:

1) Main Grid from the power generating plant or powerplant.
2) Generators
3) Busbars
4) Cables or Wires
5) Circuit Breakers
6) Fuses
7) Motor loads
8) Lumped Loads
9) Transformers

2.2 Explanation of the overall parts of the substation

An overall discussion of all of these parts are given below in details as subsections:

2.2.1 Main grid

The electrical grid is the network of the electrical power system that mainly consists of the producing plant, or powerplant, transmission lines, substations, transformers, distribution lines, and consumers. Here the substation remains on the consumer side[11].

Figure 2.1: Typical Electrical Grid

2.2.2 Generators

These are mainly the machines that are used to convert the mechanical energy that comes from the burning of diesel fuel or any other fuel to electrical energy that is mainly used to supply power to the whole substation during load shedding or for maintenance purposes when the main grid is disconnected from the substation. There may be one or more generators connected to a substation.

Figure 2.2: Generators

2.2.3 Busbars

A busbar is mainly a rectangular metallic bar in a switchgear panel that transports electric power from incoming feeders (the direction where the current is entering) to outgoing feeders (the direction denoting the coming out of the current)[12].

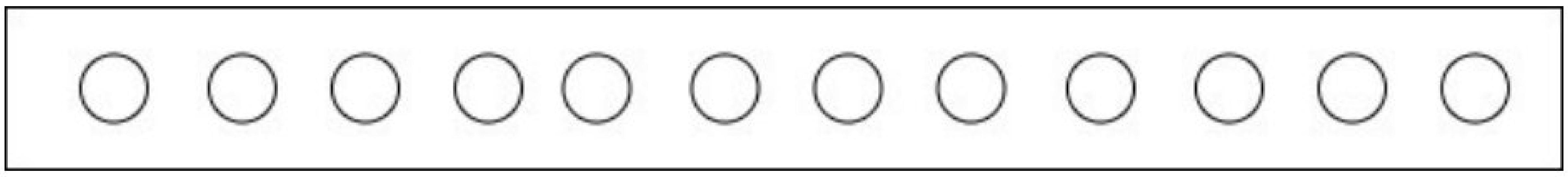


Figure 2.3: Typical View of a busbar (2D)

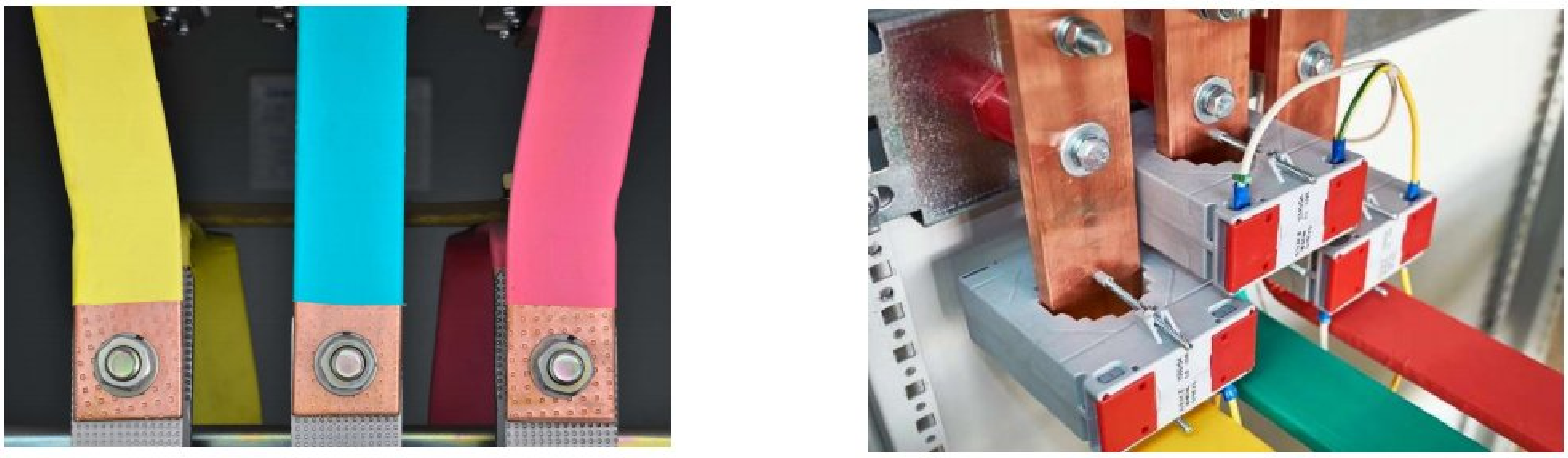


Figure 2.4: Busbars

The current rating of a busbar is mainly dependent upon the width (Here denoted as 2" in scale in the figure) and thickness of the busbar. The current rating of the busbar gradually decreases as more holes and of greater diameters (mentioned on the 1" length on the figure) produced on it.

Types of busbars: Mainly there are three types of power system buses. These are:

i) Generation Bus
ii) Slack Bus
iii) Load Bus

The detailed description of each of the buses is as follows:

1. **Generation bus:** The bus in which the real power (P) and the voltage magnitude (|V|) are known is called the generation bus. By injecting reactive power, the magnitude of the voltage is kept constant at a predetermined value. The reactive power generation Q and voltage phase angle must be calculated.
2. **Load Bus:** The bus where the magnitude (|V|) and (∠δ) phase angle of voltage can be determined is called the load bus. The active power P and reactive power Q are provided here, and the load bus voltage can be allowed to vary within a reasonable range, i.e., 5%. The phase angle of the voltage, i.e., ∠δ, is not critical for the load.
3. **Slack bus:** This is also called a swing bus or reference bus. The standard type of bus in which the real power (P) and reactive power (Q) can be calculated is called a slack bus. There is no load on the slack bus. The magnitude and phase angle of the voltage are provided on this bus. The voltage's phase angle is normally adjusted to zero. The active and reactive power is often determined by solving equations.
   The slack bus is a fictitious term in load flow studies that develops when the system's losses are not known precisely in advance for the load flow calculation. As a result, the total injected power cannot be defined for each bus. Typically, the phase angle of the voltage at the slack bus is used as a reference or zero.

Table 2.1: Summary showing all the bus types[13]

Bus type	**Quantities Specified (for ith iteration)**
Generation bus/P-V bus	P_i, $\|V_i\|$
Load bus/|V|-∠δ bus	P_i,Q_i
Slack bus/swing bus	δ_i, $\|V_i\|$

2.2.4 Cables or wires

These are the conductors with the presence of insulation through which current flows. Within a substation, the cable sizes are mainly obtained as RM sizes (used mainly here in the IUT substation), where RM stands for Round Conductor Multiwire Cable. According to this RM size, the current rating of the cable is also determined.

Figure 2.5: Cable

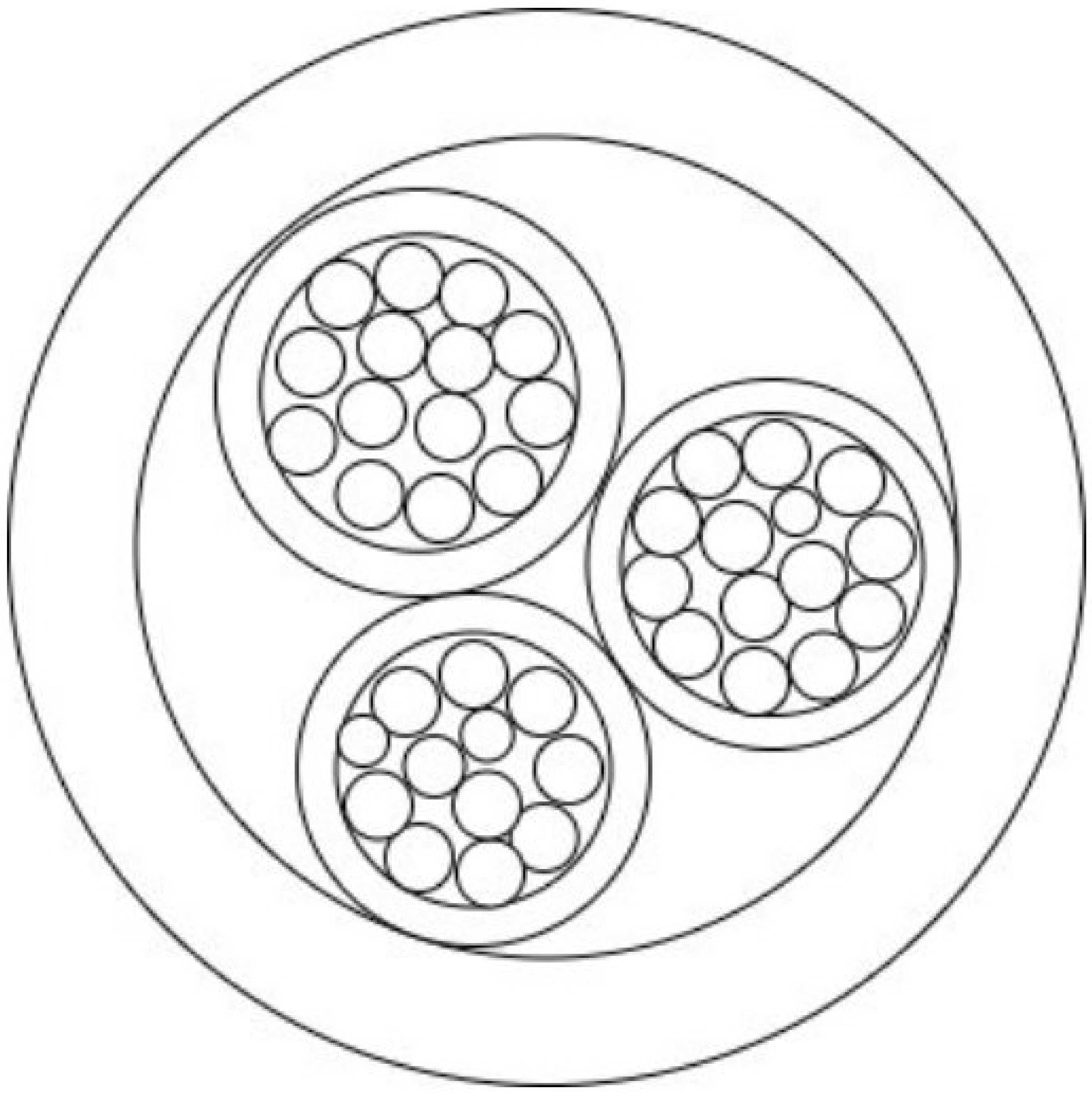


Figure 2.6: Cross Sectional View of RM cable[14]

2.2.5 Circuit breakers

An *electrical circuit breaker* is a switching mechanism used to manually or automatically disconnect an electrical power supply during a failure[15].

An electrical circuit breaker can detect a fault related to short circuits by constantly comparing it with a rated current value. The breaker isolates the whole network when the current flow is greater than the rated value.

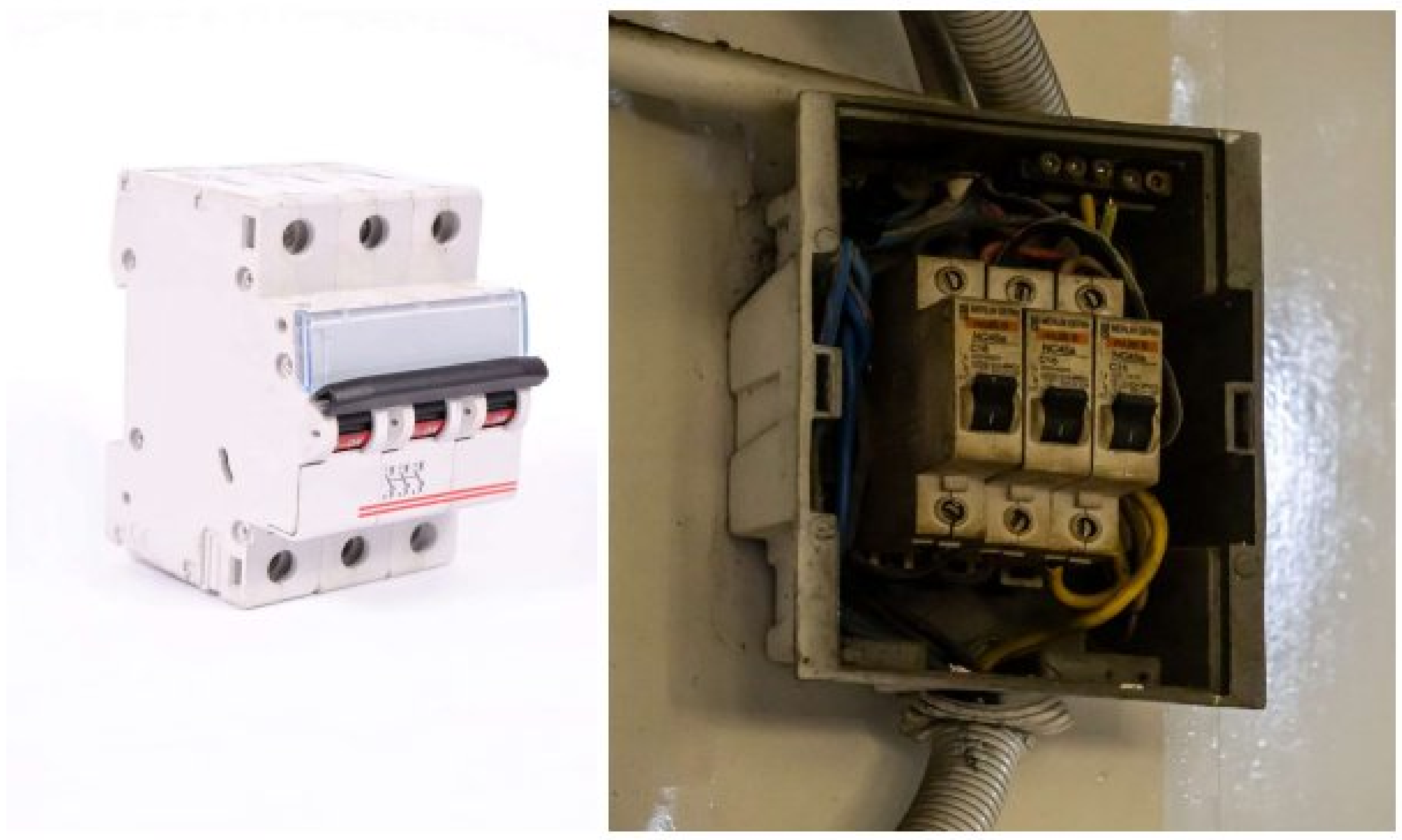


Figure 2.7: Circuit Breakers

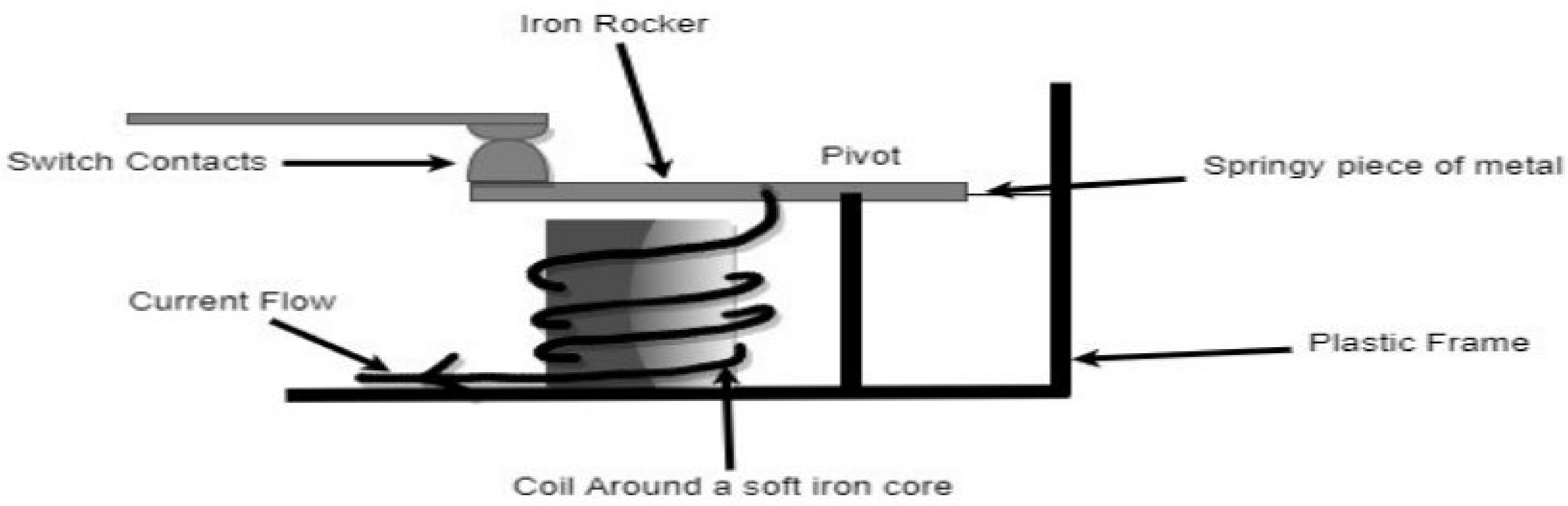


Figure 2.8: Internal Structure of a circuit breaker[15]

The above figure shows the internal operations of a circuit breaker. We can conclude that a circuit breaker has both permanent and moveable contacts from the figure. When the circuit breaker is in the closing position, mechanical pressure applied to the moving contacts connects these two contacts physically. The circuit breaker's operating mechanism includes a system for storing potential energy released when the switching signal is supplied to the breaker[15].

Potential energy can be stored in the circuit breaker in various ways, including by deforming a metal spring, compressing air, or hydraulic pressure.

Types of circuit breakers:

There are many types of circuit breakers used within a substation. Some of the commonly used circuit breakers are:

i) Vacuum Circuit Breaker (VCB)
ii) Air Circuit Breaker (ACB)
iii) Moulded Case Circuit Breaker (MCCB)
iv) Miniature Circuit Breaker (MCB)

Among all of these circuit breakers, mainly the VCB and ACB are used in the HT side of the substation and MCCB and MCB are used on the LT side of the substation.

MCB and MCCB circuit breakers are again be classified into many types. Among them the most commonly used circuit breakers are:

a) Single Pole (SP) Circuit Breaker
b) Triple Pole (TP) Circuit Breaker

a) **SP circuit breakers:** These are circuit breakers where the switching and protection are only affected in one phase of a single-pole MCCB. Exchange and insurance are impacted at a single step in Single Pole MCCB.

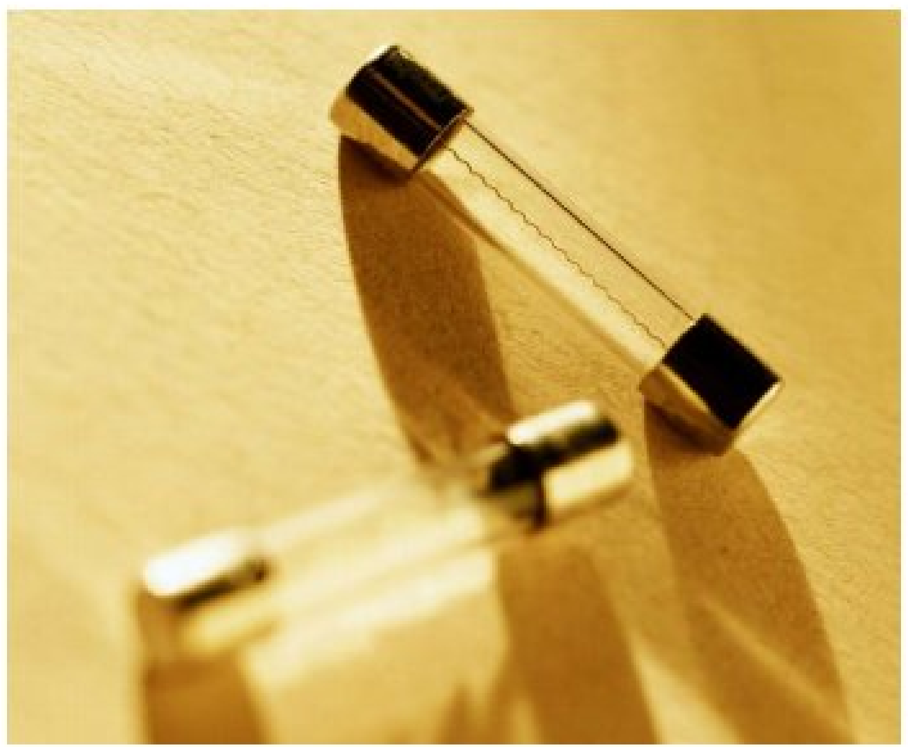
The applications of such circuit breakers are the areas that are given below:
1) Single Phase supply to break the phase, as it were.
2) Most houses and small businesses are connected to the power grid of a local utility company, which provides two AC (alternating current) voltages, notably 120-volt and 240-volt supplies. Most household electrical outlets provide 120-volt power to lamps, refrigerators, televisions, radios, computers, etc. Some appliances, however, require a higher voltage, 240 volts, to work since they consume a lot more energy[16].

b) **TP circuit breakers**: These are the circuit breakers in which switching and protection are only affected in three stages of a three-pole MCB, and the neutral wire is not included.

The applications of these circuit breakers are those areas where a three-phase supply is used only once, and no neutral wire is used at the same time.

2.2.6 Fuses

Fuses are mainly one of the types of protective equipment used in a power system. They are mainly safety mechanisms intended to safeguard household electronics or lumped loads such as lights, fans, ACs, TVs, refrigerators, and computers from harm caused by excessive voltage.



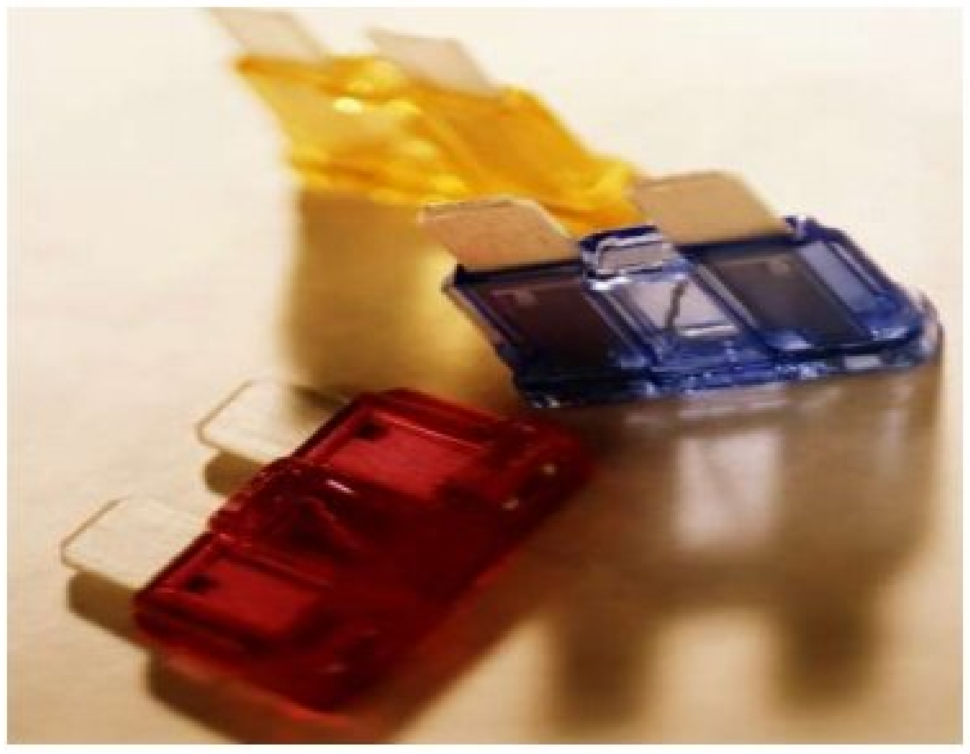


Figure 2.9: Fuses

Working function of a fuse:

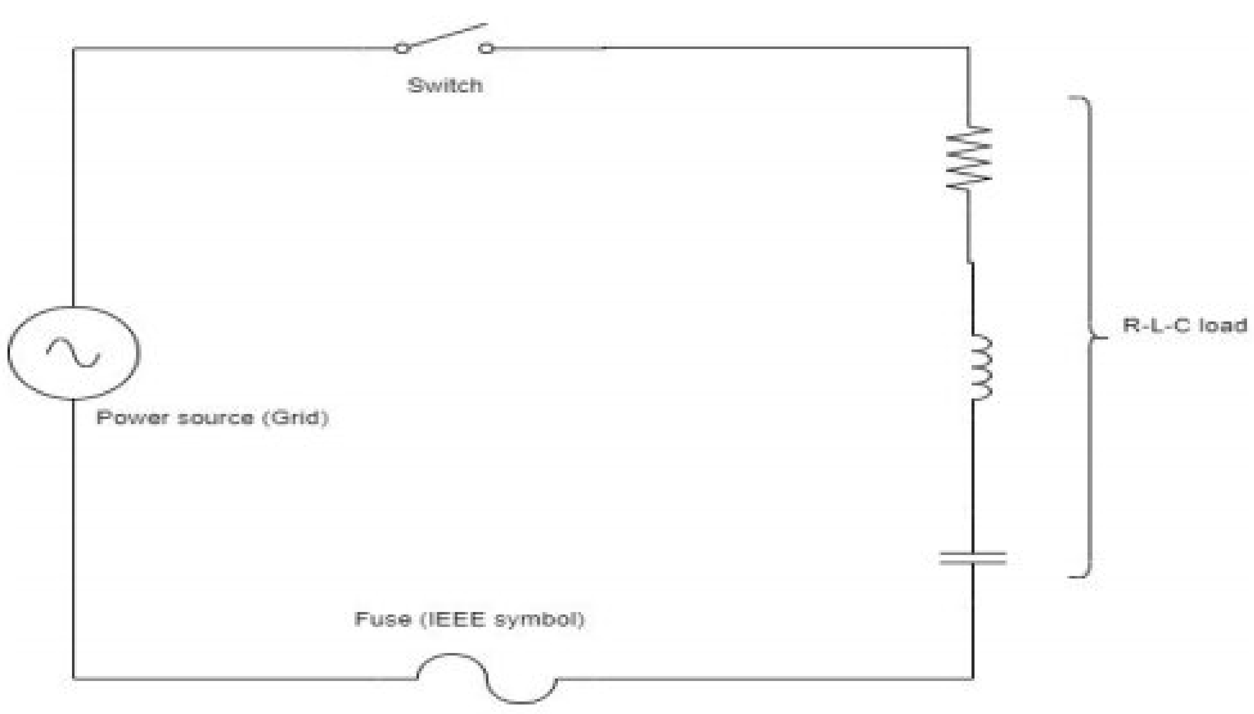


Figure 2.10: Circuit Diagram of a fuse

The above shows the circuit diagram of a fuse. When a large quantity of current or an excessive current flow is present in an electrical circuit, the fuse above melts and opens the circuit, disconnecting it from the power source. This melting of the fuse occurs due to the low melting point of the element with which the fuse is being made and, as a result, opens the circuit so that no current can flow[17, 18].

2.2.7 Motor loads/motor

These are mainly the electrical machines that convert electrical energy into mechanical energy and have similar types of construction to that of the generators, which are other types of electrical machines used within the power system. They are mainly used when loads are like lifts or elevators, pumps, escalators, etc.

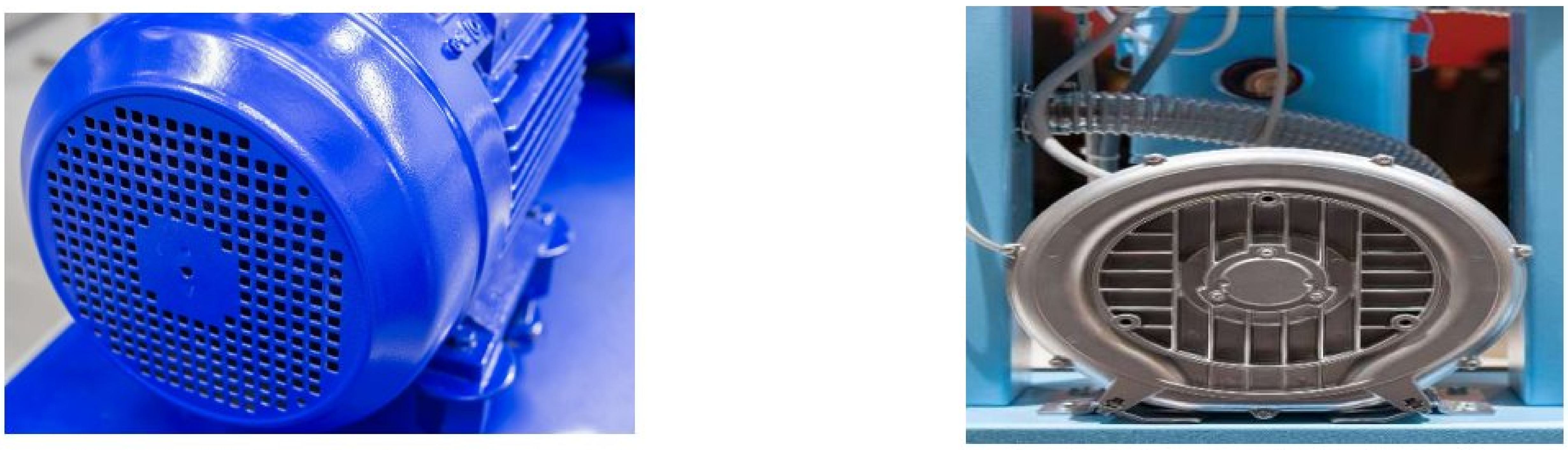


Figure 2.11: Motors

2.2.8 Lumped loads

These are mainly the household loads that can either be resistive (incandescent lamps, electric heaters, electric kettles) or a combination of resistive-capacitive (condensers) or resistive-inductive (iron, refrigerator, energy-saving lamp, air conditioner, washing machine, fans) or a combination of all of these three.

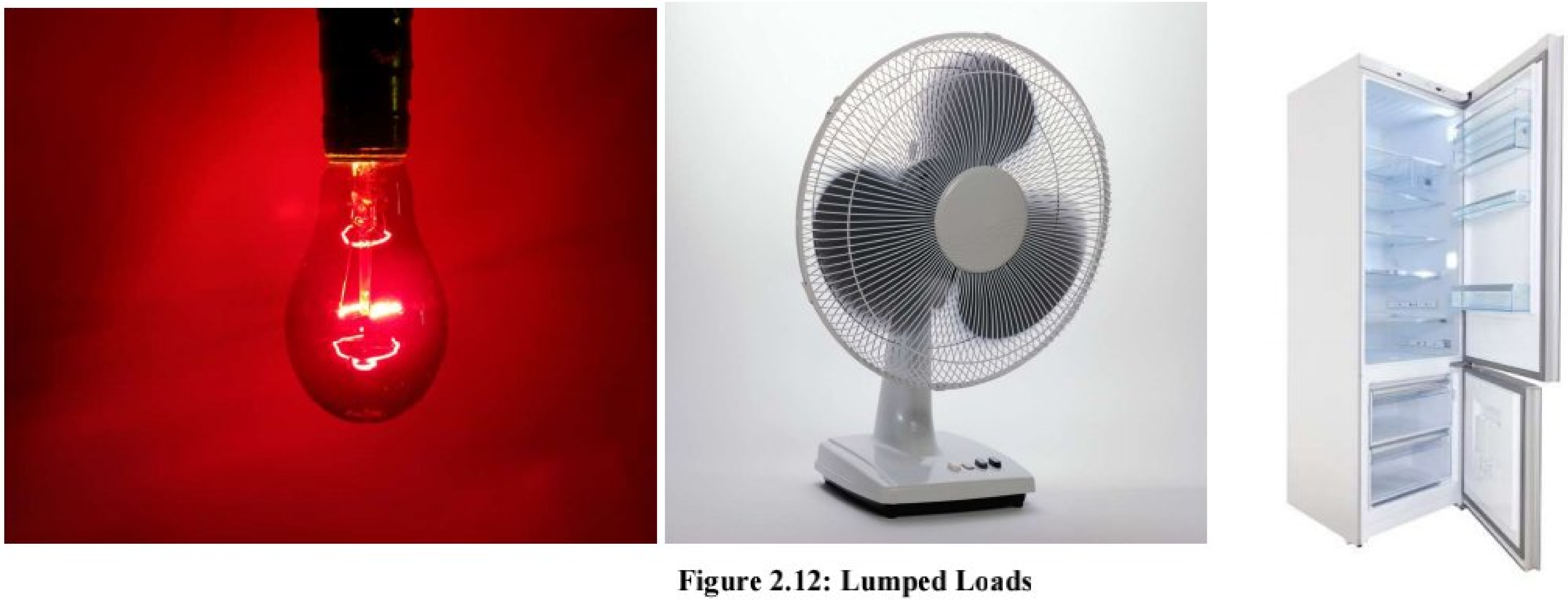


Figure 2.12: Lumped Loads

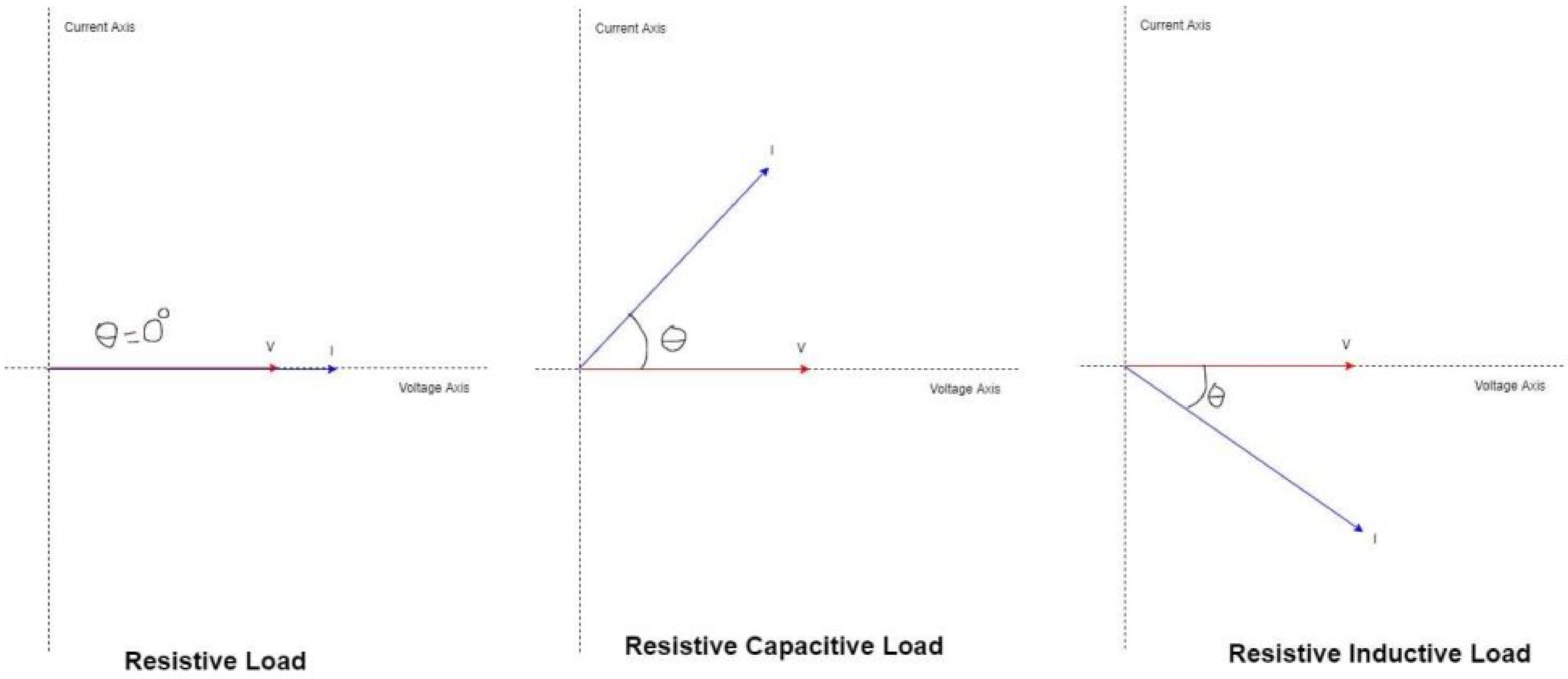


Figure 2.13: Phasor Diagram for different types of loads

2.2.9 Transformers

They are mainly the electrical devices that mainly steps up or steps down a certain amount of voltage as well as power as required within the different distribution sides of a substation. The windings of the transformer can be $\Delta - \mathrm{Y}$ (Delta − Star), $\Delta - \Delta$ (Delta − delta), $\mathrm{Y} - \Delta$ (Star − Delta) or $\mathrm{Y} - \mathrm{Y}$(star − star) that depends upon the construction of the windings at the primary and secondary side of the transformer as well as phase angle.

Overall, the HV and LV winding configuration of the transformer is categorized based on the IEC (International Electrotechnical Commission) method along with phase which is called vector group[18].

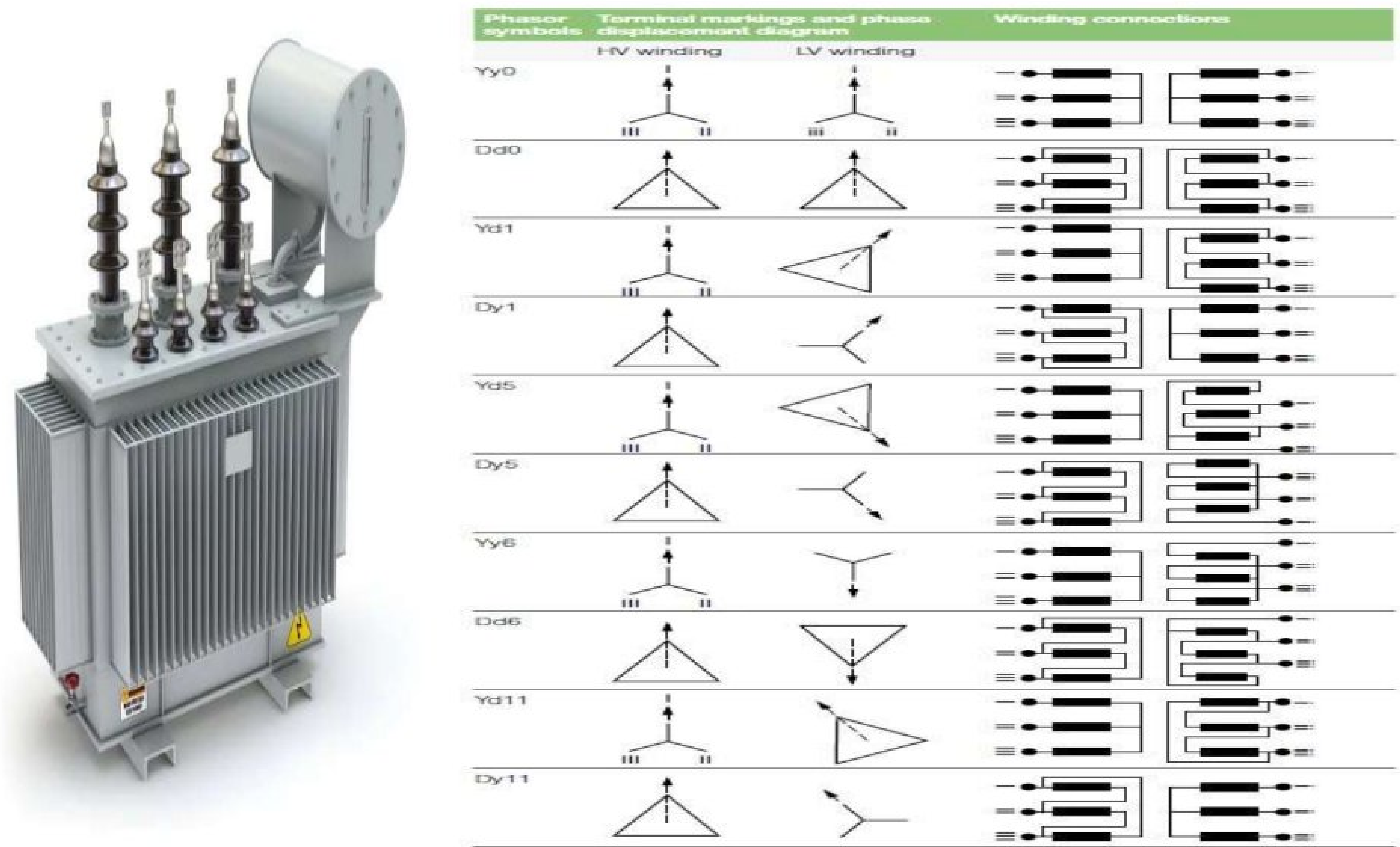


Figure 2.14: A typical transformer and vector group of transformers[18]

2.3 Overall single line diagram of a substation

The figure 2.15 shows the overall single-line diagram of a typical substation containing the main grid, generators, transformers, cables, circuit breakers, fuses, busbars, and lumped loads. It is to be mentioned here that fuses may or may not be present within a substation that is usually replaced with a circuit breaker. The lumped loads here are also considered individual loads and have been shown by drawing light, fan, air conditioner, and motor load to differentiate them individually. The transformer here shown is a changing tap transformer in which the tap can be changed on the secondary side.

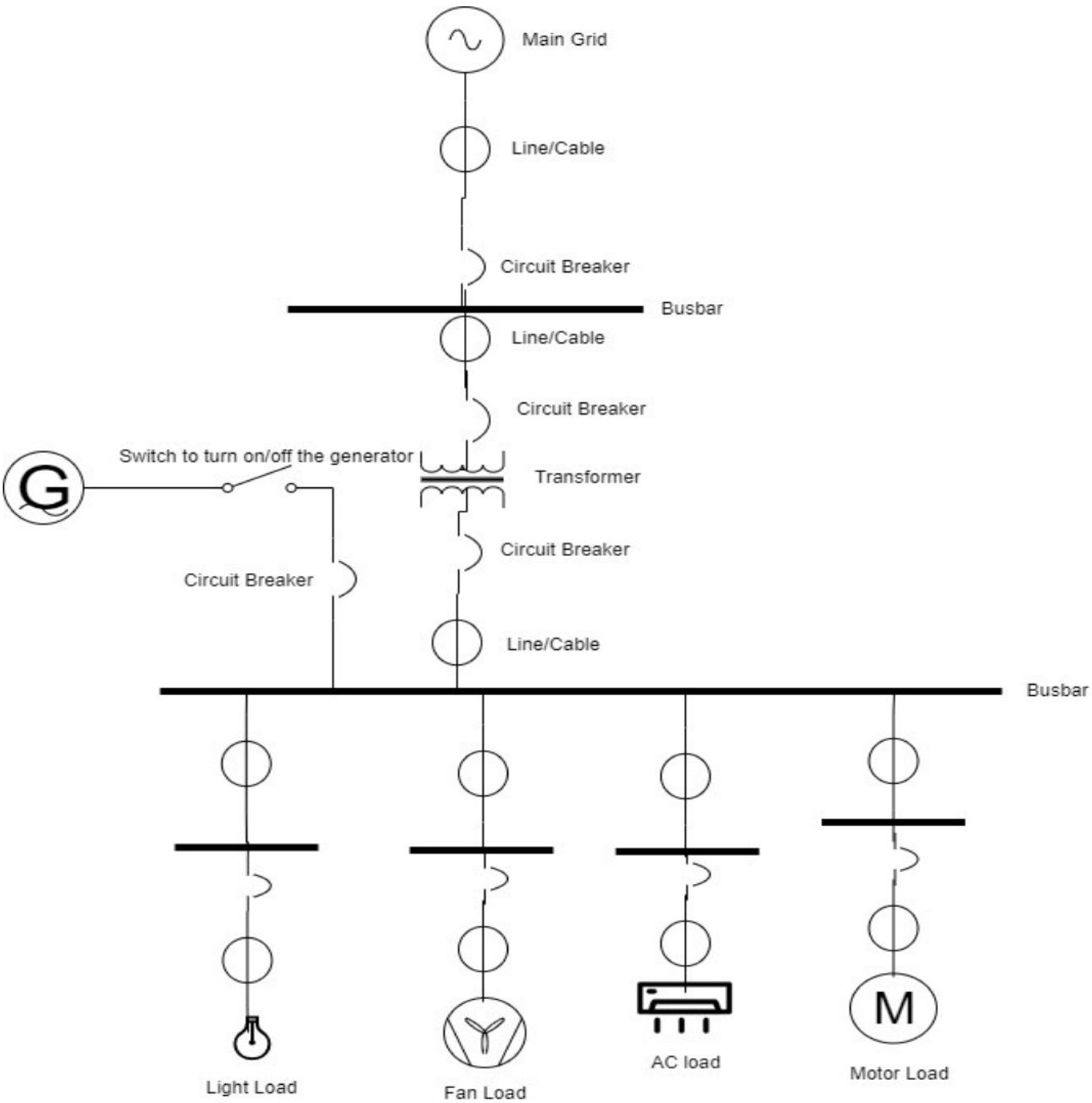


Figure 2.15: Overall single line diagram of a typical substation

Chapter 3

Brief Explanation of Load Flow Analysis

3.1 Introduction

Mainly load flow analysis is the process to identify different types of real power, reactive power, voltage, and current flow and to determine various types of faults within a power system, such as short circuit faults, voltage arc faults, ground faults, insulation faults, etc. It is mainly a fundamental and heavy tool used for power system analysis, both for planning a new power station or analysis of the load flow result. The load flow analysis mainly deals with the steady-state applicable for a specific load and generation values. The most common method of the load flow analysis is the DLF approach, in which the whole power system condition can be represented in a snapshot of time. In other words, the load flow value can be known for any particular instant of time, i.e., using some deterministic values[19].

3.2 Load flow analysis of a simple power system

Here the figure 2.14 there is given the impedance diagram of a simple power system along with mentions the per unit impedance of each of the components, i.e, of the generator, line, busbars and loads, and the corresponding figure 2.15 shows the admittance diagram of this simple power system which is done by inverting each of the lines impedances i.e, admittance between bus i and j, in this case, will be:

$$Y_{ij} = \frac{1}{Z_{ij}} \text{ where } Z_{ij} \text{ is the impedence between bus i and j}$$

Here, the total voltage angle and magnitude data are mainly obtained for each bus by some measurement instruments in a power system. When we know all of this data, we can obtain the real and reactive power through each branch of the network and generator reactive power output.

In Figure 2.14 and Figure 2.15, the impedances are expressed as per unit on a common MVA base. It is worth mentioning that KCL has been applied at each node of the impedance network to obtain the required results[3].

From the system obtained as an admittances network in the power system, applying KCL at the nodes and then simplifying the equations, the following matrix is determined:

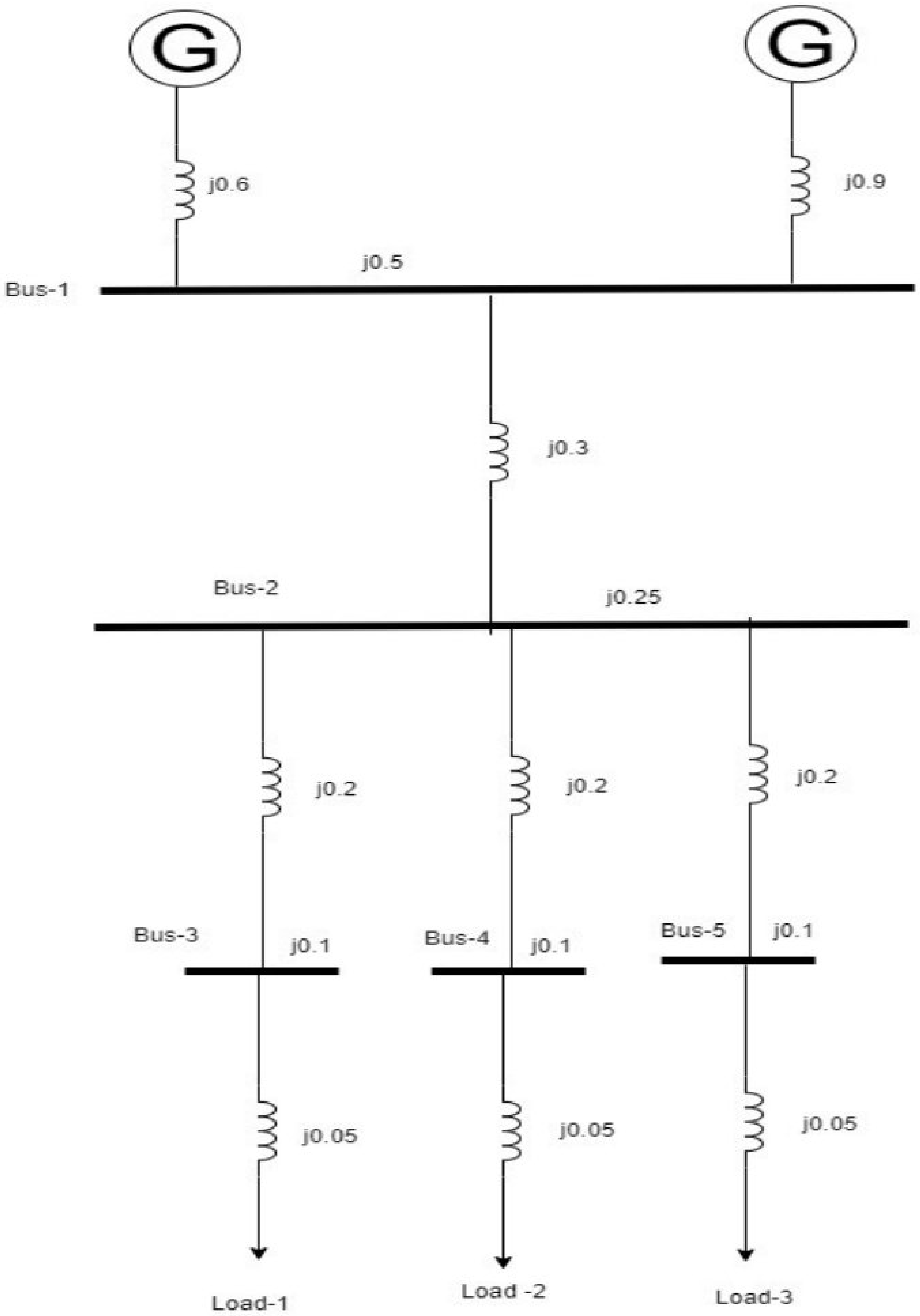


Figure 3.1: Impedance diagram of a simple power system[3]

$$\begin{bmatrix} \mathbf{I_1} \\ \vdots \\ \mathbf{I_n} \\ \vdots \\ \mathbf{I_r} \end{bmatrix} = \begin{bmatrix} \mathbf{Y_{11}} & \cdot\cdot & \cdot\cdot & \mathbf{Y_{1n}} & \cdot\cdot & \mathbf{Y_{1r}} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \mathbf{Y_{n1}} & \cdot\cdot & \cdot\cdot & \mathbf{Y_{nn}} & \cdot\cdot & \mathbf{Y_{nr}} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \mathbf{Y_{r1}} & \cdot\cdot & \cdot\cdot & \mathbf{Y_{rn}} & \cdot\cdot & \mathbf{Y_{rr}} \end{bmatrix} \begin{bmatrix} \mathbf{V_1} \\ \vdots \\ \mathbf{V_n} \\ \vdots \\ \mathbf{V_r} \end{bmatrix} \qquad (3.2.1)$$

Or we can express as:

[I]=[Y] . [V][3] **(3.2.2)**

Where [**I**] is the current through each node, [**V**] is the voltage drop in each node and [**Y**] is the admittance matrix obtained from each of the buses.

This required equation mainly gives us an idea of determining the current through each node which is obtained by solving the above equation for the nodal voltages [**V**] by which we can obtain the required value for each of the buses here present

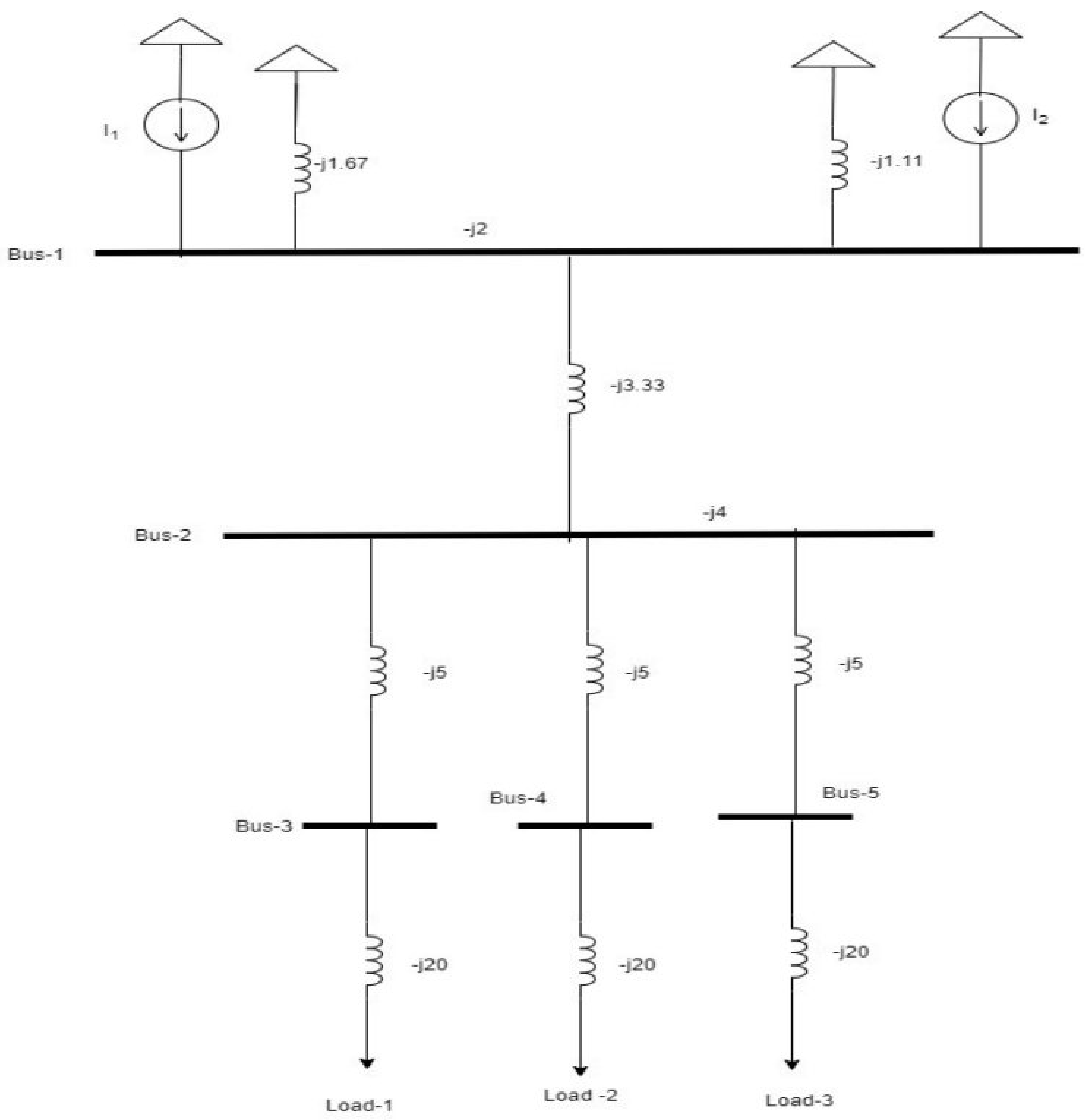


Figure 3.2: Admittance Diagram of the corresponding simple power system as given above[3]

Here, the equation 3.2.1 can also be expressed in terms of bus value of current, admittance and voltage as:

$$\mathbf{I_{bus} = Y_{bus}V_{bus}} \qquad [3] \qquad \textbf{(3.2.3)}$$

Where I_{bus} is the vector for the injected bus currents. Here, the current is positive when flowing towards the bus. On the other hand, the current is negative if it is flowing away from the bus. V_{bus} is the vector of bus voltages measured from the reference node (i.e., node voltages), whereas Y_{bus} is called the bus admittance matrix in this case. For the admittance matrix again we can see two types of admittance matrices which are self-admittance/driving point admittance (The on-diagonal elements of the admittance matrix) and the other is the mutual admittance or transfer admittance (The off-diagonal elements of the admittance matrix)[3]

Here, the self-admittance or driving point admittance is expressed as

$$Y_{ii} = \sum_{j=0}^{n} y_{ij} \text{ , } j \neq i \qquad [3] \qquad \textbf{(3.2.4)}$$

And the mutual admittance or transfer admittance expression is expressed as

$$Y_{ij} = Y_{ji} = -y_{ij} \qquad [3] \qquad \textbf{(3.2.5)}$$

Now, if the bus currents are known, then from the equation 3.2.3 we get the expression for nth bus voltage as:

$$\mathbf{V_{bus} = Y_{bus}^{-1} I_{bus}}\textbf{[3]} \qquad \textbf{(3.2.6)}$$

3.3 Case study solutions for load flow analysis

Generally, there are mainly two general types of methods that are used in case of obtaining solutions for load flow analysis. These two processes are:

i) Newton- Raphson Method

ii) Gauss-Seidel Method

These two highly used case study load flow analysis methods are discussed below:

3.3.1 Newton-raphson method

The Newton-Raphson method is one of the most accepted methods for the load flow solution. This method is widely accepted due to its stability and fast convergence capabilities. Each iteration of obtaining the different quantities using this method entails a computationally demanding process of LU factorization[2].

Mathematically, if we want to explain the Newton- Raphson method, it is a method of successive approximation based on an initial estimate of the unknown and the use of Taylor's series expansion.

If we consider the solution of the one-dimensional equation given by the expression

$$f(x) = c \qquad [3] \qquad \textbf{(3.3.1)}$$

Now if we consider $x^{(0)}$ is an initial estimate of the solution, and Δx^0 is a small deviation from the correct solution, we must have the following expression of

$$f(x^0 + \Delta x^0) = c \qquad [3]$$

Now expanding the left side of the above equation in Taylor's series about x^0 gives us the expression below:

$$f(x^0) + \left(\frac{df}{dx}\right)^0 \Delta x^0 + \frac{1}{2!}\left(\frac{d^2f}{dx^2}\right)^0 (\Delta x^0)^2 + \cdots = c \qquad [3] \qquad \textbf{(3.3.2)}$$

Now assuming the error Δx^0 as very small, the higher order terms can be neglected so it will result in the following equation:

$$\Delta c^0 \cong \left(\frac{df}{dx}\right)^0 \Delta x^0 \qquad [3] \qquad \textbf{(3.3.3)}$$

Where $\Delta c^0 = c - f(x^0)$ **(3.3.4)** is to be put in the above equation.

Now adding $\Delta x^0$to the initial estimate the approximate value of x will be

$$x^1 = x^0 + \frac{\Delta c^0}{\left(\frac{df}{dx}\right)^0} \qquad \textbf{(3.3.5)}$$

Now by doing the successive use of the procedure as mentioned in the above equation give us the final Newton-Raphson algorithm which is:

$$\Delta c^k = c - f(x^k) \quad [3] \qquad (3.3.6)$$

$$\text{and } \Delta x^k = \frac{\Delta c^k}{\left(\frac{df}{dx}\right)^k} \quad [3] \qquad (3.3.7)$$

And the final equation expression can be expressed as:

$$\Delta c^k = j^k \Delta x^k \qquad (3.3.8)$$

$$\text{Where } j^k = \left(\frac{df}{dx}\right)^k \; [3] \qquad (3.3.9)$$

3.3.2 Gauss-Seidal method

The method in which there is the successive substitution of the variables one after another until a convergence in case of the solution is achieved. Here, the substitution of the variable is done by substituting the equations obtained from each node of a network one after another. Unlike the Newton-Raphson Method, this case study method of load flow analysis also focuses on solving a set of nonlinear equations that are obtained from each node of a power system. Here, the nonlinear mismatching equations obtained are solved for each bus containing unknown voltage values, either in terms of magnitude or phase angle. Here the convergence phenomenon mainly means that the iteration process will be stopped, and there will be a final solution of real and reactive power unless the difference between the obtained solution and the desired solution has a difference less than the given criteria as obtained from the calculation.

For the initial iteration, the voltage magnitude of the slack and voltage-controlled buses is set a specified value but the phase angle of all of the load and voltage-controlled buses are assumed to be 0^0. Finally, the voltage magnitude of the load buses are set in p.u (per unit) as 1 p.u[4].

Mathematically, if we consider a non-linear equation as

$$f(x) = 0 \qquad (3.3.10)$$

Now this above function can be expressed as

$$X = g(x) \qquad (3.3.11)$$

Now if x^k is an initial estimate of the variable x, then the following iterative approach is performed in every case:

$$x^{k+1} = g(x^k) \quad [3] \qquad (3.3.10)$$

Now the final solution will be obtained if the difference between the absolute value of the successive iteration is less than a specified accuracy, which can be specified mathematically as,

$$\left|x^{k+1} - x^k\right| \le \epsilon \quad [3] \qquad (3.3.11)$$

Where ϵ is the desired accuracy as need to be obtained through continuous iteration using this process[3].

3.3.3 Other study cases for load flow analysis

Based on several types of research and processes, several other modified case studies have also been obtained for the load flow analysis. These are devised to get a more optimal load flow analysis within each node of a network. The study cases are modified Newton- Raphson method[20], Newton-Raphson method through complex Jacobian form[21], adaptive Newton-Raphson method, Newton-Raphson method using LU decomposition[2], gaussian elimination, inverse matrix technique, etc.

Chapter 4

Methodology

4.1 Introduction

We have mainly divided our whole work into a couple of groups or processes. However, our whole work is mainly divided into four main steps. These four main processes are:

a) Field Survey, i.e., observation of each of the electrical components within the substation, collecting the data from each component like the current or voltage rating, and noting down each of the readings in our notebook.

b) Simulations, i.e., simulating all the network components obtained from the field survey part by making a single line diagram and placing the components on it on the ETAP software and running thorough simulations in the software to obtain correct results.

c) Analysis, i.e., analysis of the simulation output through trial and error.

d) Proposing a plan, i.e., proposing a suitable model of the substation that can replace the present/conventional substation with a new one with fewer apparent power losses, less demand, and more reactive power compensation than it can presently.

4.2 Explanation of all the steps

Below there will be discussed all the steps/methods that we have followed in accomplishing our research works:

4.2.1 Field surveying

4.2.1.1 Observations from the BREB line

At first we observed the BREB line that came from Gazipur rural region-1. We observed that,

- The 5th and 7th feeder came from the BREB to IUT. We also were able to know that 3 feeders(3 upper and 3 under) and 3 neutral Substation from BREB came to IUT using underground line, though Gazipur rural region-1 has 3 thin overhead lines for transmission to our substation. We also saw that to transmit power to the IUT substation, the BREB have used 33 KV cable of size 70 RMA (3X70 RMA in broader sense). Each phase is supplying 11 KV. The 4th and 7th no feeder coming to IUT has 0.95 to 1 power factor limit
- There has been used instrumentation transformers like CT or PT which are labeled as BREB meter.
- There is a DFC (Dropout Fuse) that is available as one for each phase of the BREB line.
- The corner line contains PT and the middle line contains CT.
- There is seen no presence of neutral wire on the line coming from BREB but in the IUT substation this problem is solved as there is used earthing in the IUT substation.
- No 11kv fault detector present.
- The grid has a generation capacity 1600 kw that contains 3 thin phase wire to the IUT panel below (that works as the HT switchgear).

Figure 4.1: Power Connection from BREB Gazipur Rural Region-1 to IUT substation

Figure 4.2: Three phase connection with 3 DFCs (Drop Out Fuses)

4.2.1.2 The HT side

From the observation of the HT side, we found out the following information:

- There is presence of a manual isolator to stop the HT panel at the IUT load reading there is LT side or LT panel. This manual isolator mainly isolates the whole IUT substation from the grid when there is any maintenance work or during any fault.

- There can be done load modification between the HT to the LT side, where there is substation.

- The transformer receives HT side line that comes after several modifications from the BREB rural region-1. The distribution of the LT side of the transformer is done in such a way that there is stepped down voltage from 11kv to 0.44kv (mainly 0.44 KV/440 V per phase)

- The connection of transformer is such that a phase to neutral is connected and using center tap process of transformer made 230 V From HT panel we receive 11 KV line and place a transformer

- There also has a VCB (vacuum circuit breaker) for fault prevention when the line comes from the HT side to the transformer.

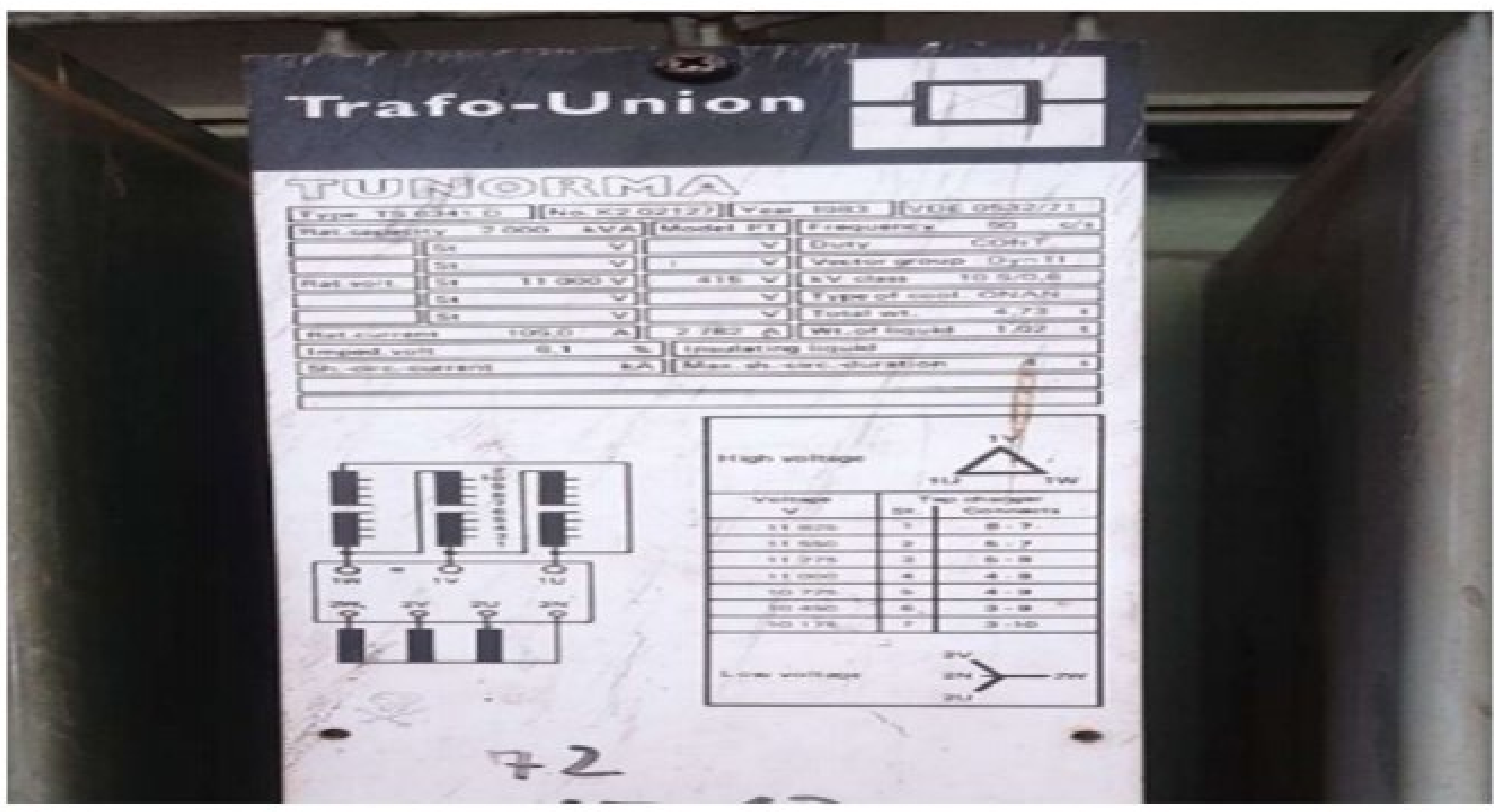


Figure 4.3: Nameplate of the 11/0.44 KV delta-star Transformer present in the substation with center tapping

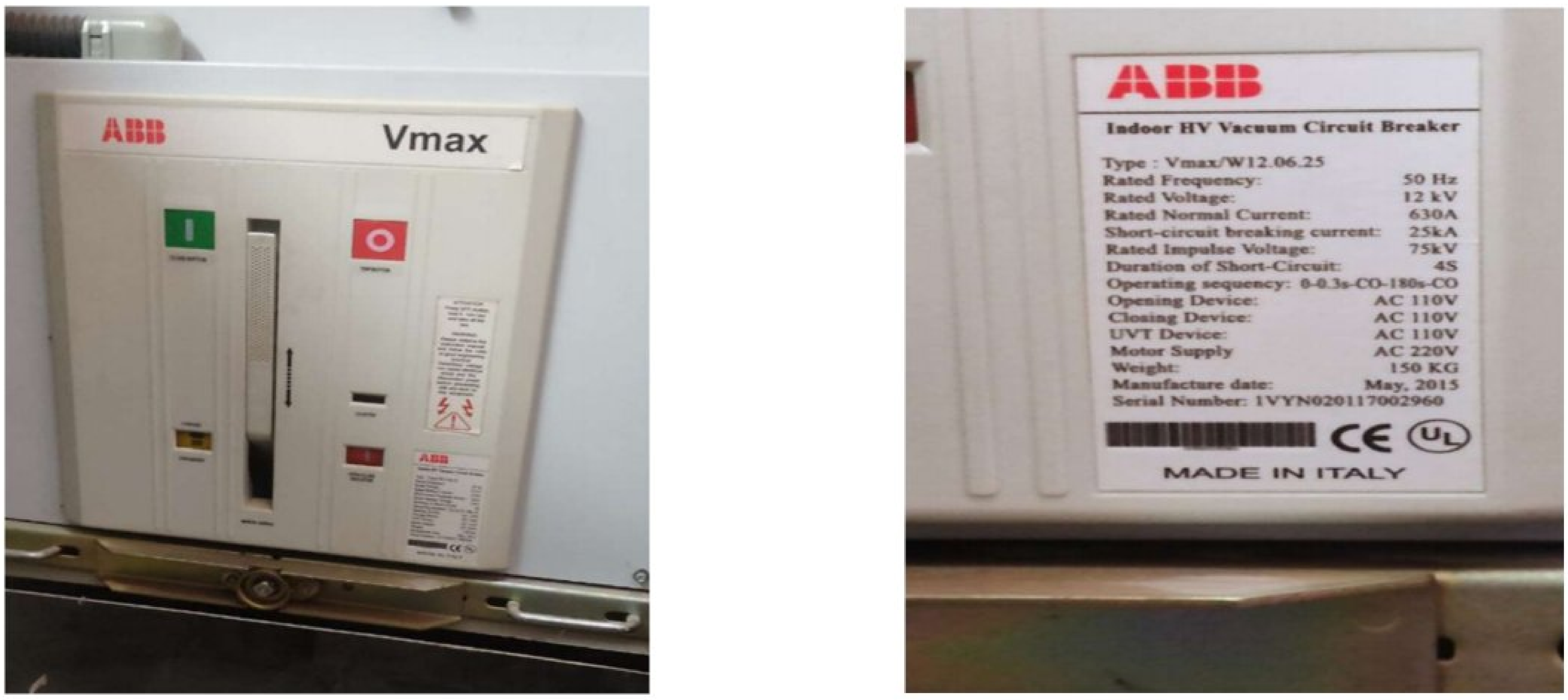


Figure 4.4: Vacuum Circuit Breaker used at the HT side with nameplate

4.2.1.3 Transformer on the HT-LT side

From the observation of the transformer that is situated inside the LT panel room , we found out the following information:

- The transformer is a star delta transformer.
- The transformer has a maximum capacity of 2000 kVA.
- The manufacturer company of the transformer Trafo-Union.
- The primary input voltage is 11 kV while the secondary side is 415 V.
- On the transformer there has been used silica gel , which is used to absorb the water from air and also to protect the transformer oil $\Delta - Y$ transformer
- Regular oil test is done on the transformer.
- By tapping the LT side voltage is made as/up to 415 volt that is again supplied on the bus.
- Transformer cooling system that has been used in the substation is ONAN (Oil Natural Air Natural)
- For the ONAN cooling system, oil spread as drop that cool the system.
- A manual changeover takes place beside the transformer that does the interconnection of more sources to distribution lines or buses.

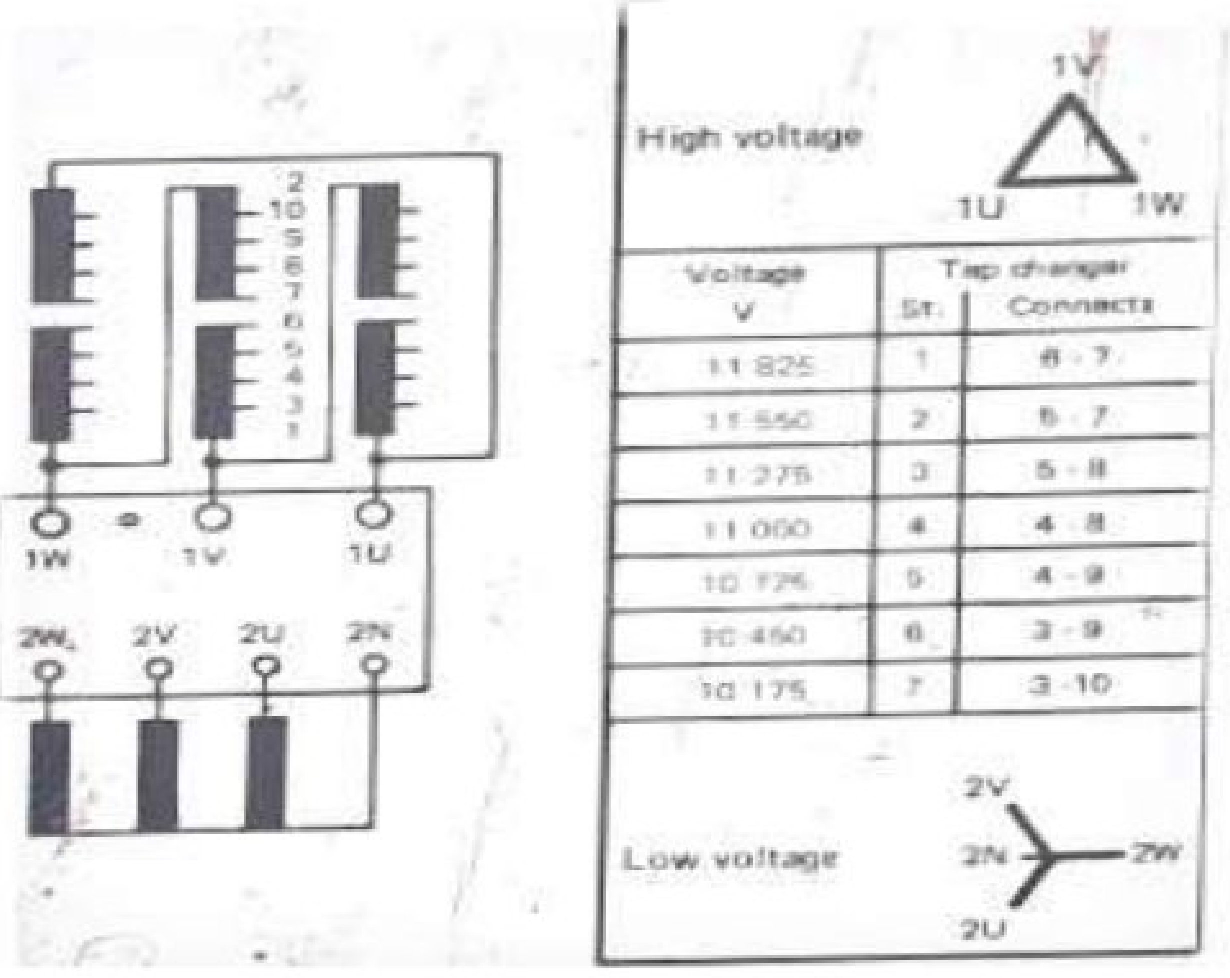


Figure 4.5: Nameplate of the transformer in the IUT substation

4.2.1.4 The LT side/ LT panel

From the observation of the LT side, we found out the following information:

- The LT side contains 0.44 KV or 440 V which is found from the secondary side of the transformer through the process of tap changing.
- Using tap changing, the output voltage is made to 215 V.
- From LT panel there are seen many distribution cables that goes to different loads of IUT like the 1st ,2nd and 3rd academic building, administrative building, north and south hall, female hall, utility building, bungalow, central and north cafeteria, library, reading room, Mosque etc.
- No voltage is seen at two extreme most sides of busbar of the LT panel.
- From LT panel many busbars can be seen and from there we are taking out many distribution lines.
- At LT side fire protection systems are taken which can be used in case of any types of faults specially of short circuit.
- For making PF (power factor) equal or improvement of the PF there is power factor improvement plant, which is mainly a capacitive bank.
- With the LT panel busbar, for alternative power sources there is connected two generators. Between connecting many sources to busbar connected there interconnection, so that of one is on, other is off MCO manual CHANGEOVER isolator ATS (AUTOMATIC TRANSFER SUSTEM MANUAL) TO ATS(Decides when source will be generator and when from lt side The interconnection mainly done with another panel connected to ats mainly no interconnection but to be se 1 meter gap
- At LT panel there is a common busbar a common earthing that is neutral and instead of copper earthing there is brought out a cable.

4.2.1.5 Generators

From the observation of the nameplate and working function and placement of the generators used in IUT substation, we can come to the following observations:

- There are two generators present currently in the IUT substation.
- The ratings of the two generators are obtained as follows:

Table-4.1: Table showing the two generator ratings

Generator-1	Generator-2
Maximum capacity- 635 kW	Maximum Capacity- 615 kW
Maximum kWh energy expedited: 3300 kWh (as of May 2019)	Maximum kWh energy expedited: 2239 kWh (as of May 2019)
Highest % loading: 83.67% (As of September 2019)	Highest % loading: 82.73% (As of September 2019)
Total Fuel Consumption: 28627.4 Litre (As of September, 2019)	Total Fuel Consumption: 12623.3 Litre (As of September, 2019)
Manufacturer Company Name- CAT (Caterpillar)	Manufacturer Company Name- Perkins

- Two generators are not running at a time, one generator runs one time according to the load demand at the IUT.
- There is presence of ATS (Automated Transfer Switch) which is mainly a switch that switches a load between the two sources, and in this case that decides what will be the source that is whether it will be the main grid will be generator and when from LT side.
- The interconnection is mainly done with another panel connected to another ATS.
- As there are many loads and various buildings at the distribution side so a common busbar is not used, rather many busbars are used to connect to different load of the whole IUT.
- At the ending point of ATS there is connected two points, one point is of one of the generators out of two generators and the other point connects the LT side).
- One ATS is made up of magnetic contact and another ATS is made up of MCB of current rating 1250A.
- 2 generators are connected to the load same time though both are not supplying power to the loads at the same time.

Figure 4.6: The 635 kVA generator of caterpillar along with the nameplate

Figure 4.7: The 615 kVA generator of Perkins

4.2.1.6 From LT panel busbar up to the distribution side

From the observation of the LT panel, busbars connected to the LT panel and the cables as well used in IUT substation, we can come to the following observations:

- As many sources are connected to busbar, for smooth operation of the power flow there is interconnection. The interconnection works in such a way that when one is on, other is off and this operation is mainly ensured by the MCO i.e, manual changeover isolator.
- A manual changeover beside the transformer that does the interconnection of more sources that goes again to distribution lines or buses. From the circuit breakers that are placed there are seen many individual line that comes and goes to hall, academic building etc.
- Using rounding method (like fan regulator) we are doing tapping, there can be seen 14 stages for 14 distributions (the more the stages the more will be convenience for small loads if introduced later),
- From a distribution line goes to a distribution panel that contains a busbar which contains a CB (circuit breaker) from there, there are some sub panels from where there are some more busbars and l Substation related BNBC rule /electrical In future 33/11 kv will be installed by IUT NOW RUNS AS 11/0.44 KV If there is busbar within the sub panel we should include in SLD
- Two ACB of 1250A are present Manual isolator and VCB (630 A) is present LT panel busbar was mainly separated from transformer using MCCB (but now it is shorted).
- The interconnection between two LT panels are ensured by a interlocking system which is mainly a MCCB BETWEEN the two LT panel sides and is mainly an electrical type interlocking.

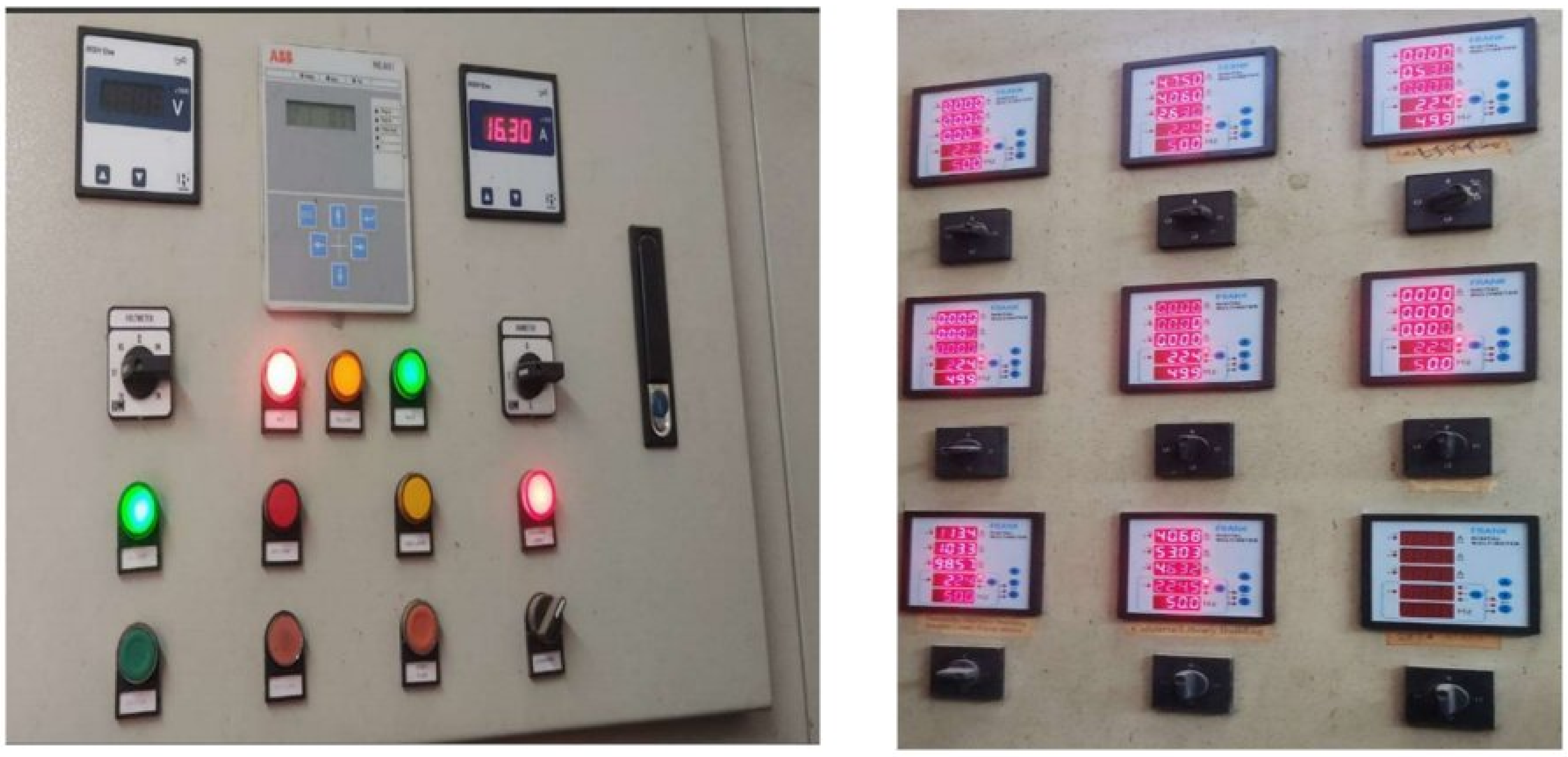


Figure 4.8: LT side panel (combined)

4.2.1.7 At the distribution side

Mainly at the distribution side, we have made the survey for only the 1st,2nd and 3rd academic building. The observations, data along with pictures of the distribution board, busbars and other busbar components that we have seen in these three academic buildings are given elaborately as follows:

1) **On LT panel of the main busbar:**

- Here we can see three MCCB circuit breakers (marked as 6,7 and 8) of current rating 250 A of manufacturer company Siemens which goes to the 1stacademic building.

Figure 4.9: Circuit Breakers from main busbar of LT panel that goes to 1st academic building

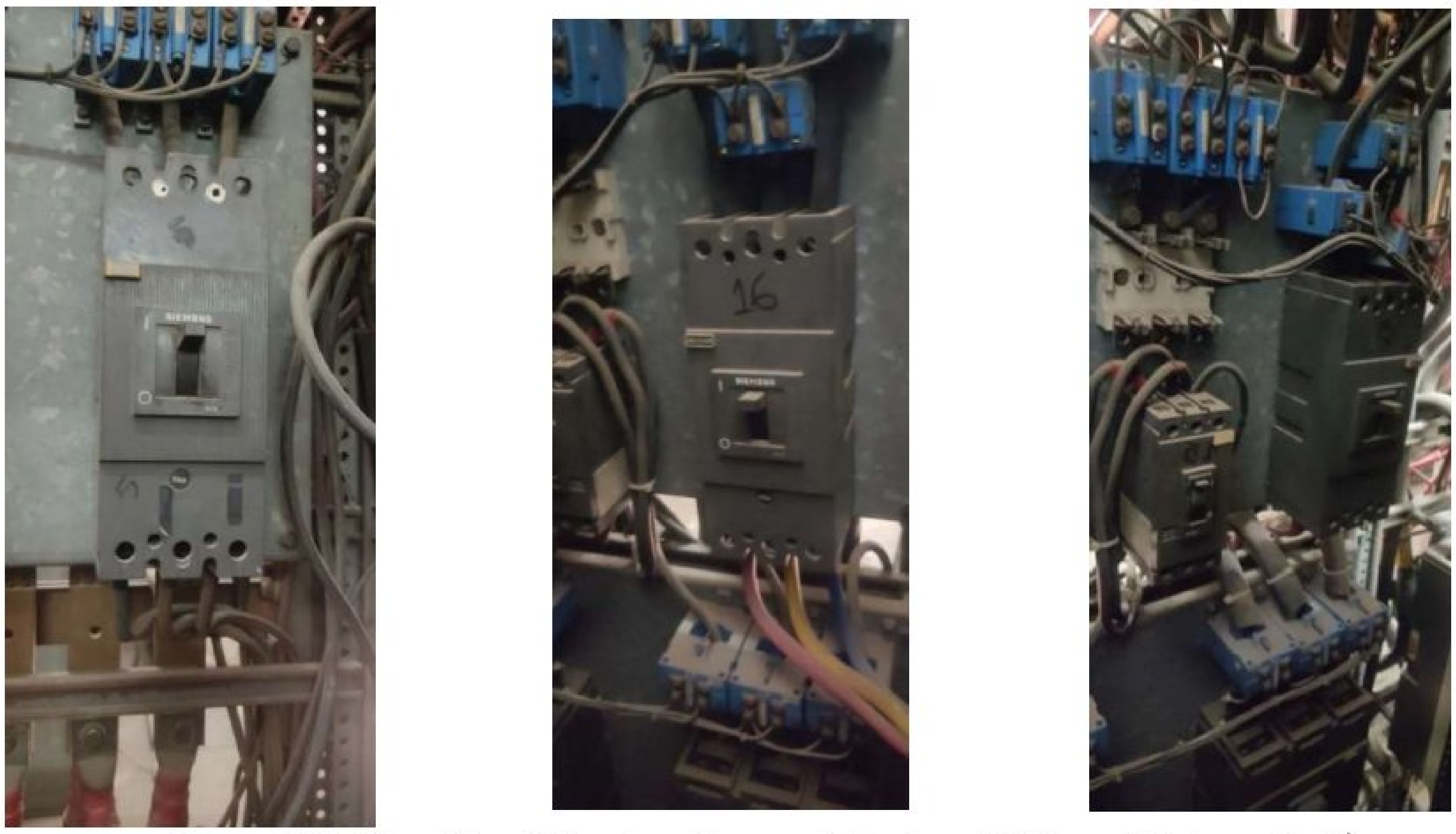


Figure 4.10: More Circuit Breakers from main busbar of LT panel that goes to 1st academic building

- Here we can see three MCCB circuit breakers (marked as 1,2 and 3) of current rating 250 A of manufacturer company Siemens which goes to the 3rd academic building.

2) **On the first academic building:**
- There can be seen a direct line coming from the LT panel to a MCCB circuit breaker of 160 A of TP type (three phase) that goes directly the lift of the 1st academic building.

Figure 4.11: Circuit Breakers from main busbar of LT panel that goes to 1st academic building

Figure 4.12: 160 A (TP) MCCB circuit breaker that comes directly from LT panel that goes to the lift of first academic building

- There can be seen main distribution board that contains one main MCCB circuit breaker of current rating of 500 A and of TP type and is situated on the ground floor of the first academic building.
- From the main distribution board, total 6 MCCB, each of 160 A (TP) goes to the 1st, 2nd, 3rd, 4th and 5th floor of as well as on the dean room of the first academic building.
- For the AC load, on the 1st floor of the 1st academic building, total 16 MCB each of 20 A current rating are connected. Here, total 8 CBs are used and 8 are unused. Each AC load here is taken as an average of 1.5 kW.

- For the AC load, on the 2^{nd} floor of the 1^{st} academic building, total 10 MCB each of 16 A current rating are connected. Here, all CB's are used.
- For the AC load, on the 3^{rd} floor of the 1^{st} academic building, total 11 MCB each of 20 A current rating are connected. Here, all CB's are used.
- For the AC load, on the 4^{th} floor of the 1^{st} academic building, total 16 MCB each of 20 A current rating are connected. Here, total 8 CB's are used and 8 are unused.
- Another line from the LT panel comes directly to the main distribution panel of the 1^{st} academic building where circuit breakers of 500 A and 200 A are connected. From the busbar connected to these circuit breakers, there comes 6 line with having circuit breakers, each of 63 A current rating and total connected load of 5 kW each to each of the line.

Figure 4.13: Main distribution board from LT panel situated at the ground floor of first academic building

Figure 4.14: Main MCCB (TP) breaker coming from the LT panel to 1st academic building

Figure 4.15: Main MCCB (TP) breakers going to 1st,2nd,3rd,4th,5th and dean room of first academic building

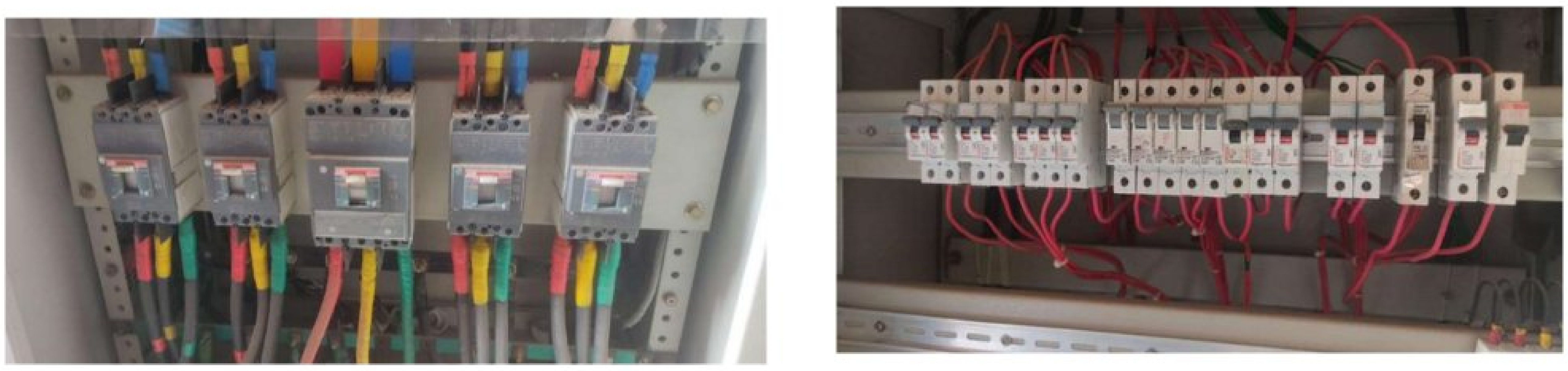


Figure 4.16: Other MCCB (TP) and MCB (SP) circuit breakers coming from the LT panel to the first academic building

Figure 4.17: Main distribution board (AC load) of 1st floor of 1st academic building

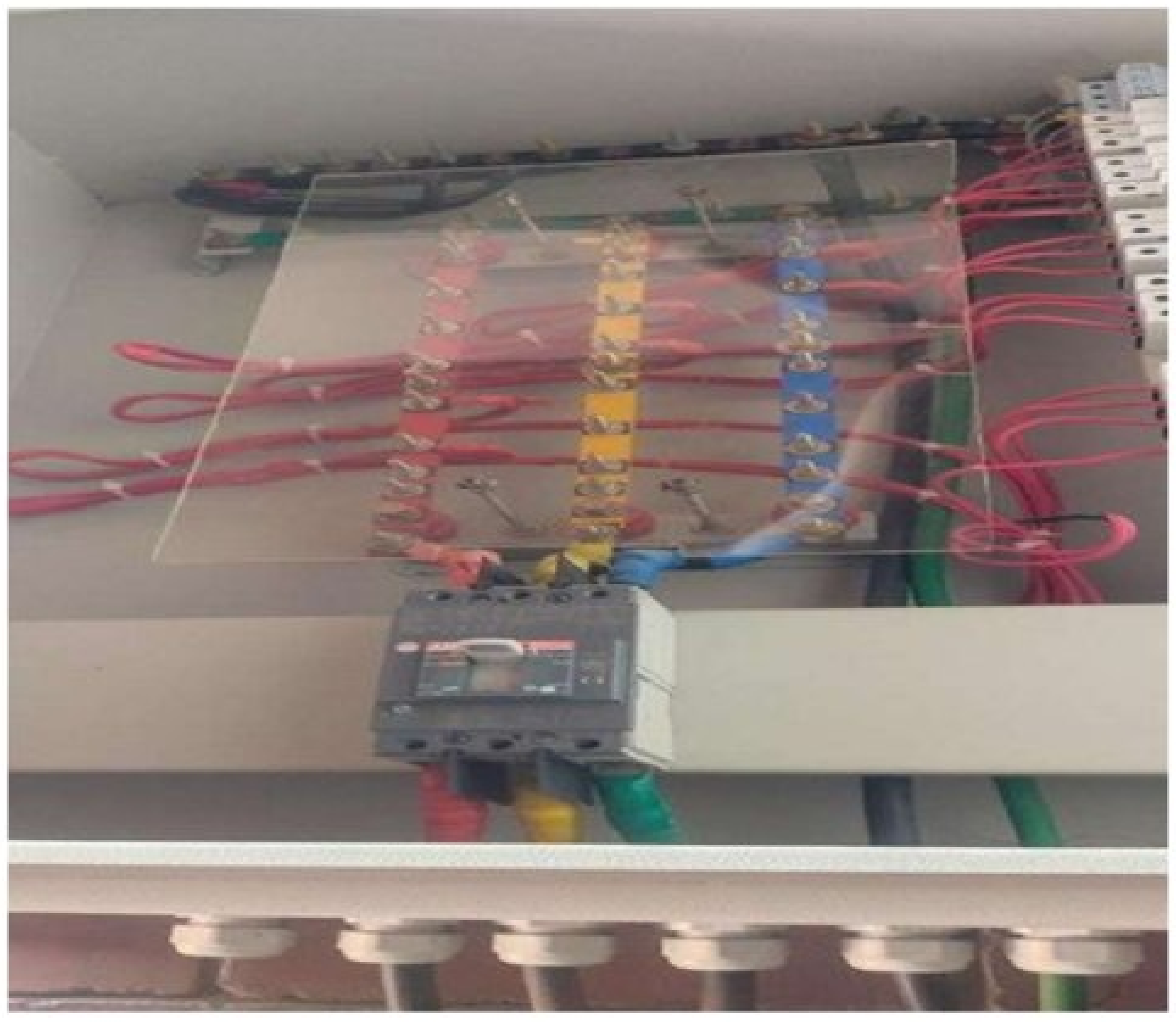


Figure 4.18: Main distribution board (AC load) of 2nd floor of 1st academic building

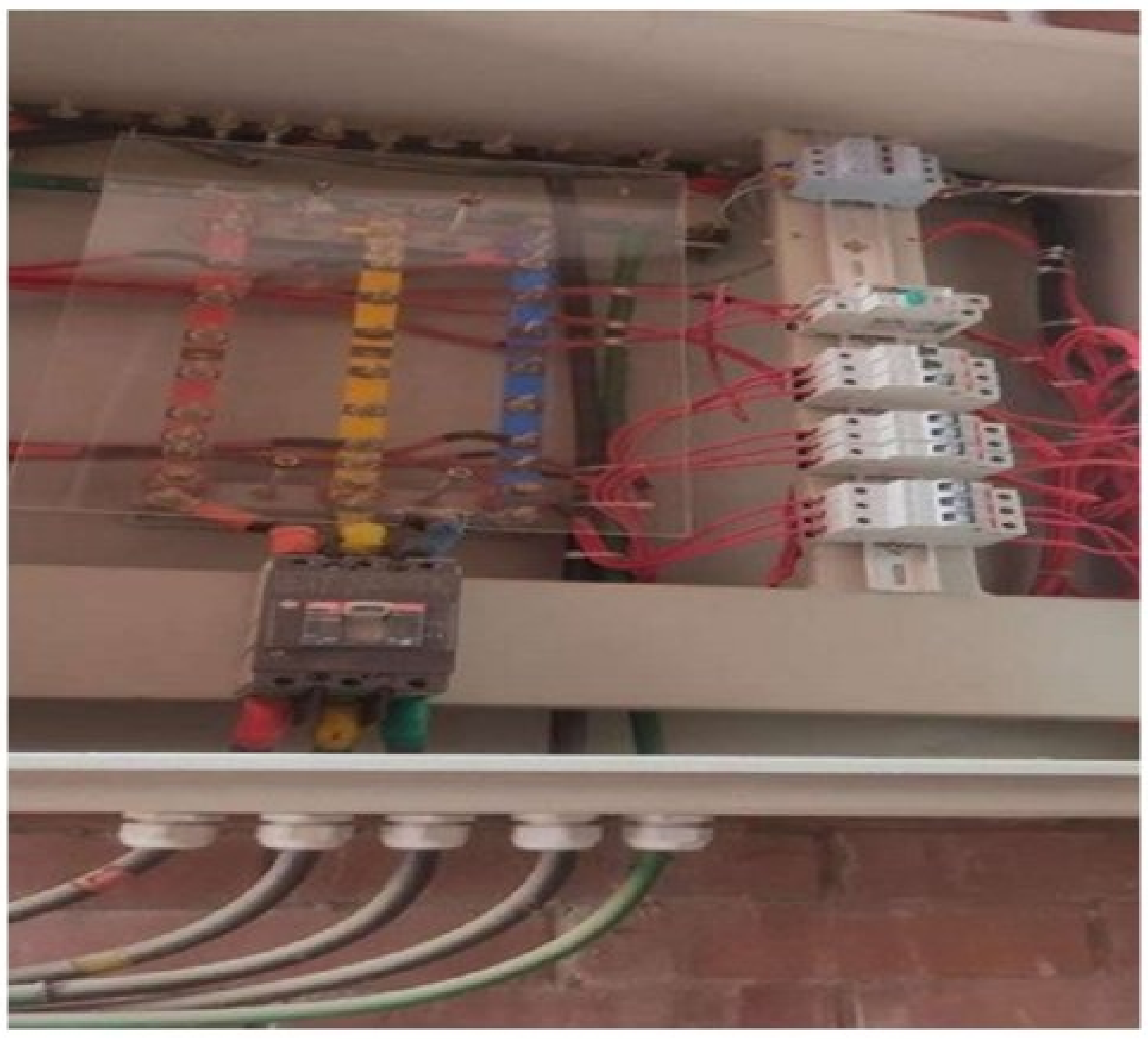


Figure 4.19: Main distribution board (AC load) of 3rd floor of 1st academic building

Figure 4.20: Main distribution board (AC load) of 4th floor of 1st academic building

The final single line diagram of the first academic building that is drawn on the CAD software based on our surveying is:

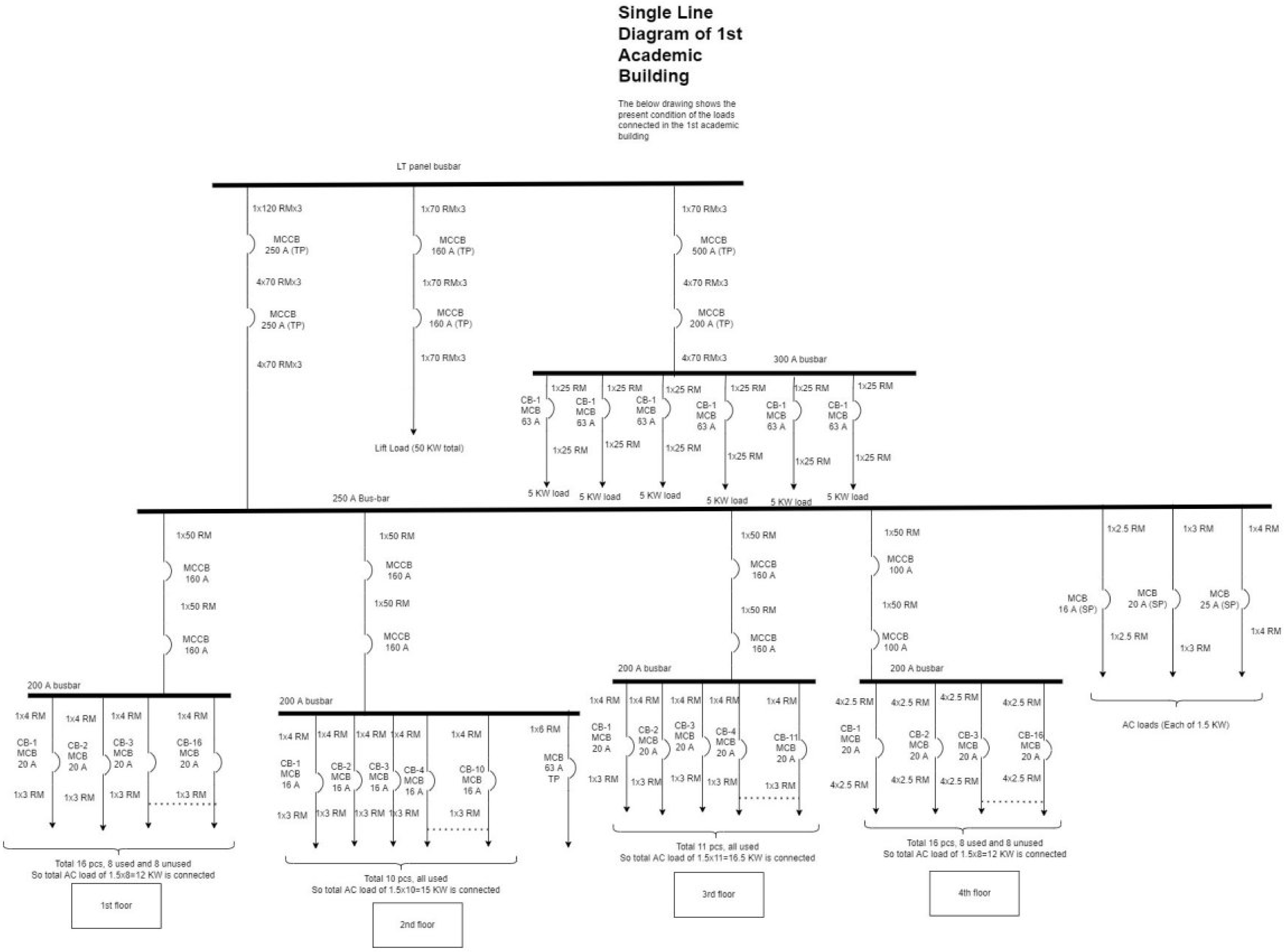


Figure 4.21: SLD (estimated based on survey) of first academic building

3) On the second academic building:

Here the survey of load flow is done only based on the AC load. The salient points we have found from the survey are as follows:

- Here we can see that the main breaker that is coming from the LT panel is a modified or tunable breaker that is tuned to 500 A as the cable and busbar rating can withstand up to this much of the current though this circuit breaker has a current rating of 1000 A.
- On the ground floor of the first academic building, there is seen a line with a circuit breaker of 160 A MCCB (TP) circuit breaker coming where there is

attached a total of 25 MCB circuit breakers of 16 A (SP) where 3 of them are used and the remaining 22 are unused.

- On the 1st floor of the first academic building, there is seen a line with a circuit breaker of 160 A MCCB (TP) circuit breaker coming where there is attached a total of 24 MCB circuit breakers of 16 A (TP) where 7 of them are used and the remaining 17 are unused. There is also a presence of two 10A MCB (SP) and a 16 A MCB (SP) circuit breakers which is also unused.
- On the 2nd floor of the first academic building, there is seen a line with a circuit breaker of 160 A MCCB (TP) circuit breaker coming where there is attached a total of 24 MCB circuit breakers of 16 A (TP) where 4 of them are used and the remaining 20 are unused. Here there is also presence of a 32 A MCB (SP) circuit breaker which is also unused.
- On the 3rd floor of the first academic building, there is seen a line with a circuit breaker of 160 A MCCB (TP) circuit breaker coming where there is attached a total of 24 MCB circuit breakers of 16 A (TP) where 4 of them are used and the remaining 20 are unused. There is also a presence of two 10A MCB (SP) circuit breakers which is also unused.
- On the 4th floor of the first academic building, there is seen a line with a circuit breaker of 160 A MCCB (TP) circuit breaker coming where there is attached a total of 24 MCB circuit breakers of 16 A (TP) where 4 of them are used and the remaining 20 are unused. There is also a presence of two 10A MCB (SP) circuit breakers which is also unused.
- On the 5th floor of the first academic building, there is seen a line with a circuit breaker of 160 A MCCB (TP) circuit breaker coming where there is attached a total of 24 MCB circuit breakers of 16 A (SP) where 5 of them are used and the remaining 19 are unused. There is also a presence of two 32A MCB (SP) and a 16 A MCB (SP) circuit breakers which is also unused. There is also a presence of three 40 A MCB (TP) circuit breakers which is also unused.
- A special busbar that we also have observed is the BBT (Bus-Bar Trunking system) in where instead of cable wiring, the electrical devices like circuit breaker and others are connected onto an adapter like plug and all these networks are directly fitted to a current carrying busbar.

Figure 4.22: Main breaker that is coming from the LT panel to the second academic building that is a modified breaker tuned to 500 A for convenience of rating required

Figure 4.23: Main distribution board of first floor of 2nd academic building (only for AC load)

Figure 4.24: Busbar Trunking System (BBT) of second floor of second academic building (BBT also present on other floors as well) with circuit breaker mounted on this special busbar

Figure 4.25: Main distribution board of second floor (and third floor) also of 2nd academic building (only for AC load)

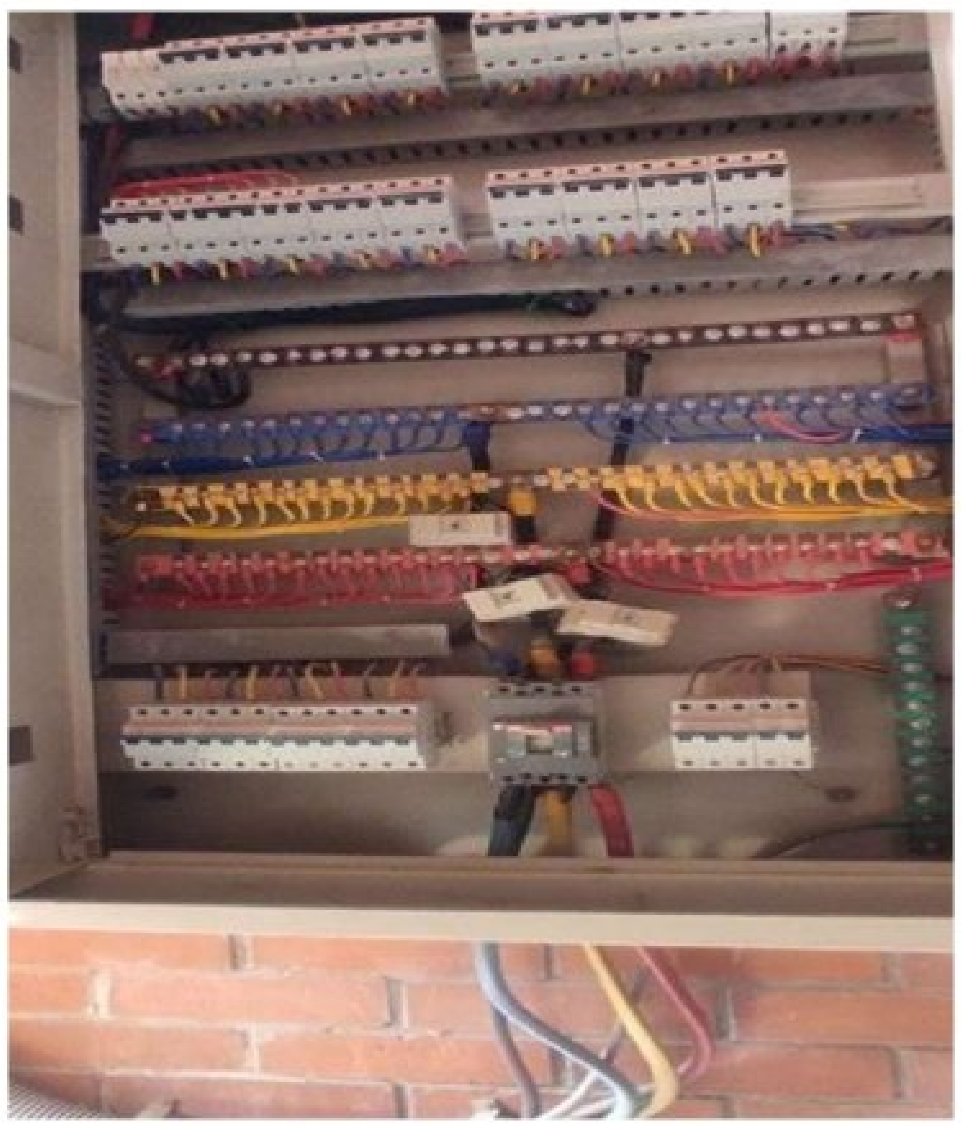


Figure 4.26: Main distribution board of fourth floor of 2nd academic building (only for AC load)

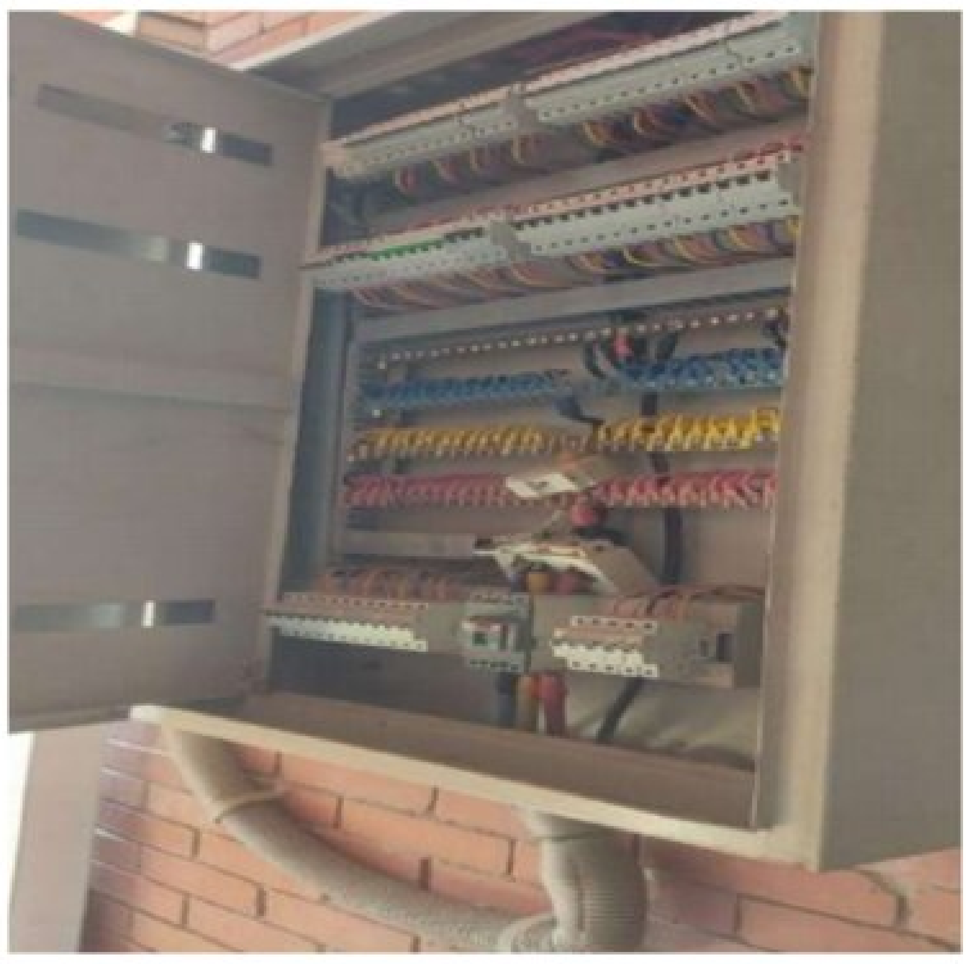


Figure 4.27: Main distribution board of fifth floor of 2nd academic building (only for AC load)

The single line diagram drawn from these obtained survey results are as follows:

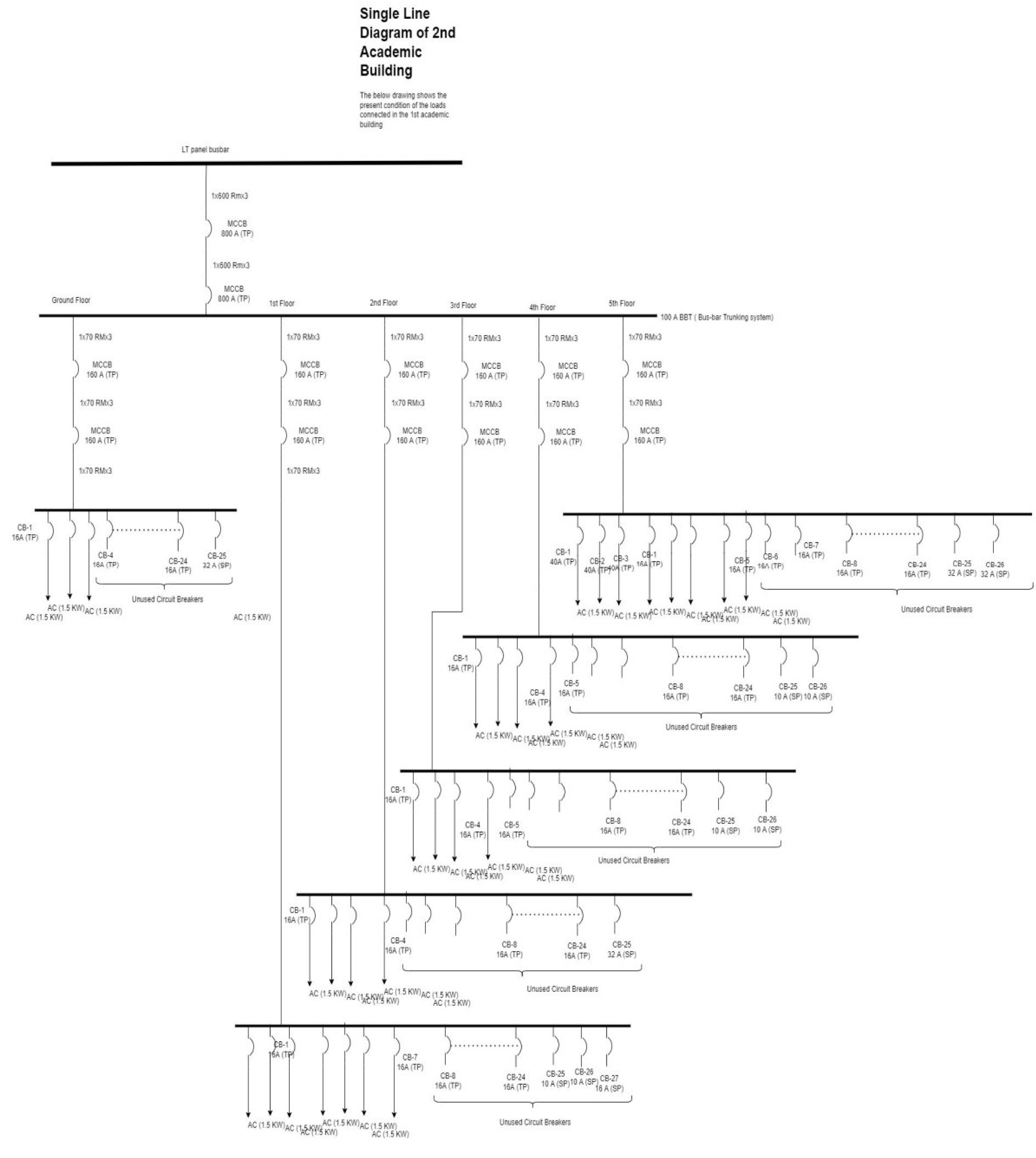


Figure 4.28: SLD (estimated based on survey) of second academic building (only for AC loads)

4) On the third academic building:

- From the LT panel busbar, two lines of cable size 1x95 RMx3 comes out. One line has two 250 A MCCB (TP) circuit breaker connected to it and another line has one 250 A MCCB (TP) circuit breaker and one 160 A MCCB (TP) circuit breaker connected to it.
- The first line of size 1x95 RMx3 goes to a main distribution board of same cable rating in the 3rd academic building in where there are a total 30 MCB (SP) of current rating 20 A each connected to the busbar of the main distribution board from where there again goes several lines to distribution board of different rooms that contain the heavy load like air conditioner, each having rating of 1.5 kW.
- The second 1x95 RMx3 line goes to another busbar that is situated in the 3rd academic building of current rating 250 A (approx.). From this busbar again two lines, one having size of 1x6 RM and another having size of 1x95 RM comes out. One of the line is again connected to MCCB (TP) of current rating 63 A and another connected to MCCB (TP) of current rating 250 A.
- The line having size of 1x95 RM splits into another line of size 1x50 RM to which another MCCB circuit breaker (TP) of current rating 160 A is connected.
- Both of the cables having sizes of 1x6 RM and 1x95 RM goes into a busbar where 10 A (SP) MCB circuit breaker is connected. A total of 9 of such circuit breakers are connected to the busbar of current rating 100 A and only one (TP) is connected to the busbar of the same rating where one pole of the TP circuit breaker is used to make the connection for the supply of single phase (1ϕ) load. Each of these lines connect to different rooms that contain the light loads like tube-lights, fans, projectors, PC's etc. Based on our survey, we have found that there are 6 fans of 80 W each and 4 lights of 5 W each in each room of the 3rd academic building.

Figure 4.29: Main Distribution board of the 3rd academic building that goes to light loads of each rooms like tube-light, fan etc.

Figure 4.30: Main Distribution board of the 3rd academic building that goes to heavy load of each rooms like air-conditioner

Figure 4.31: The 250 A MCCB (TP) breaker that comes from the main busbar of the LT panel to the distribution boxes for light loads like tube-light, fan etc.

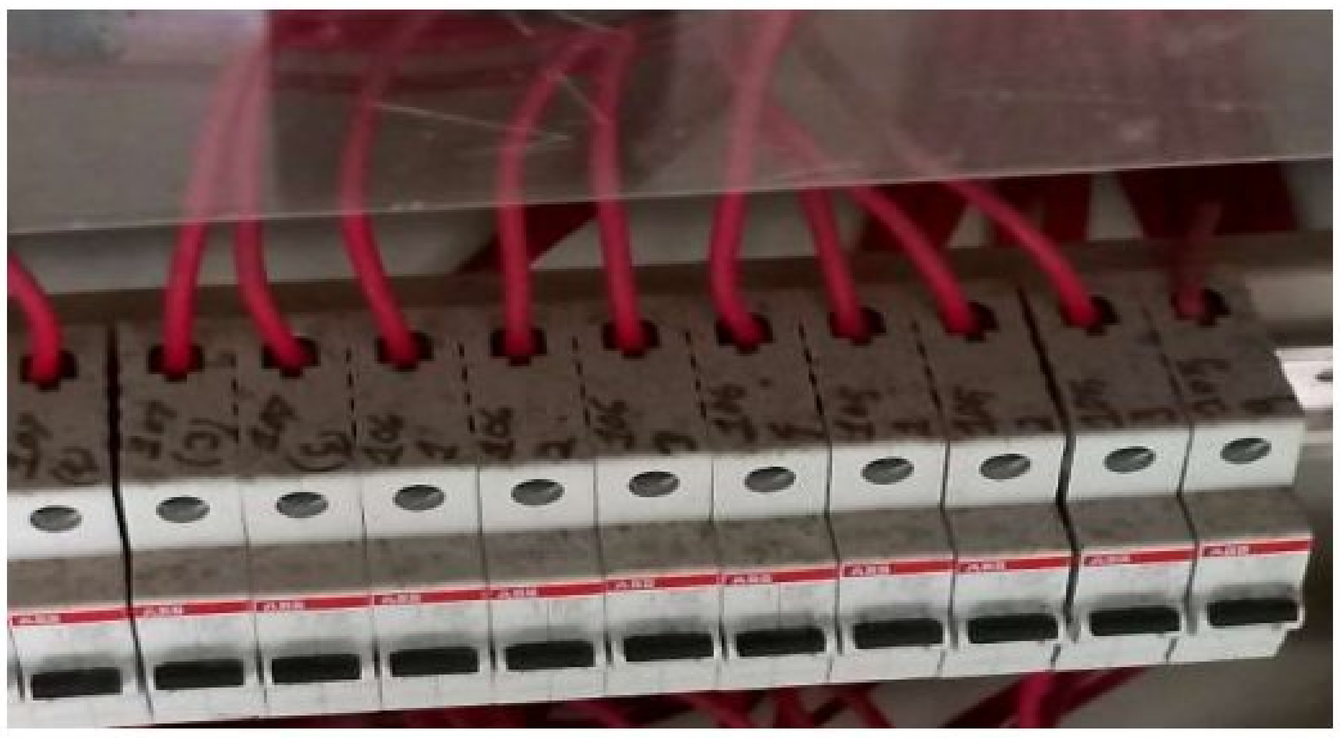


Figure 4.32: 10 A MCB (SP) circuit breakers that protects each sub distribution board of the 3rd academic building

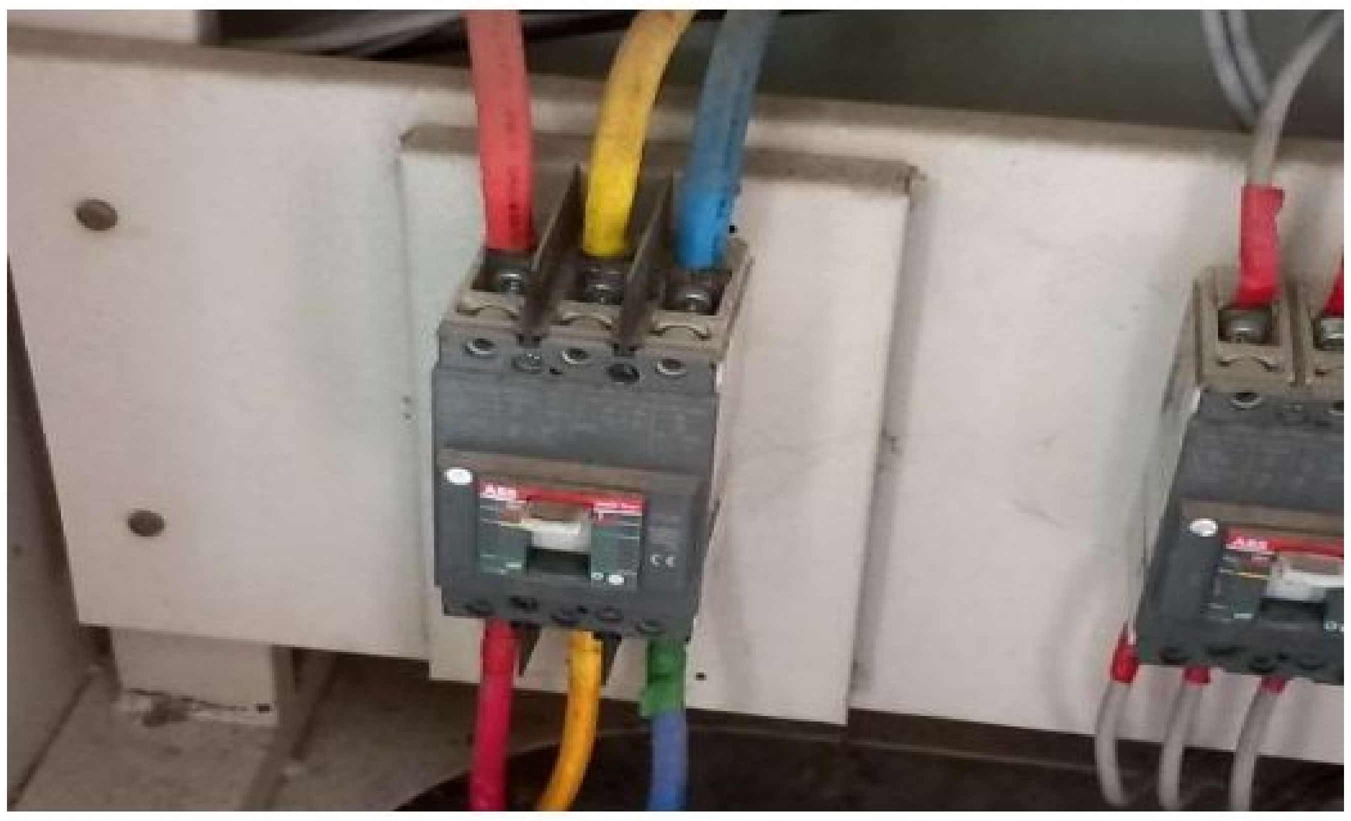


Figure 4.33: The 250 A MCCB (TP) breaker that comes from the main busbar of the LT panel to the distribution boxes for heavy loads like air conditioner.

Figure 4.34: Voltmeter assigned to the main distribution board for the loads for constant maintenance of the upcoming voltage from the LT panel

Figure 4.35: Sub distribution box (that goes to each room of 3rd academic building)

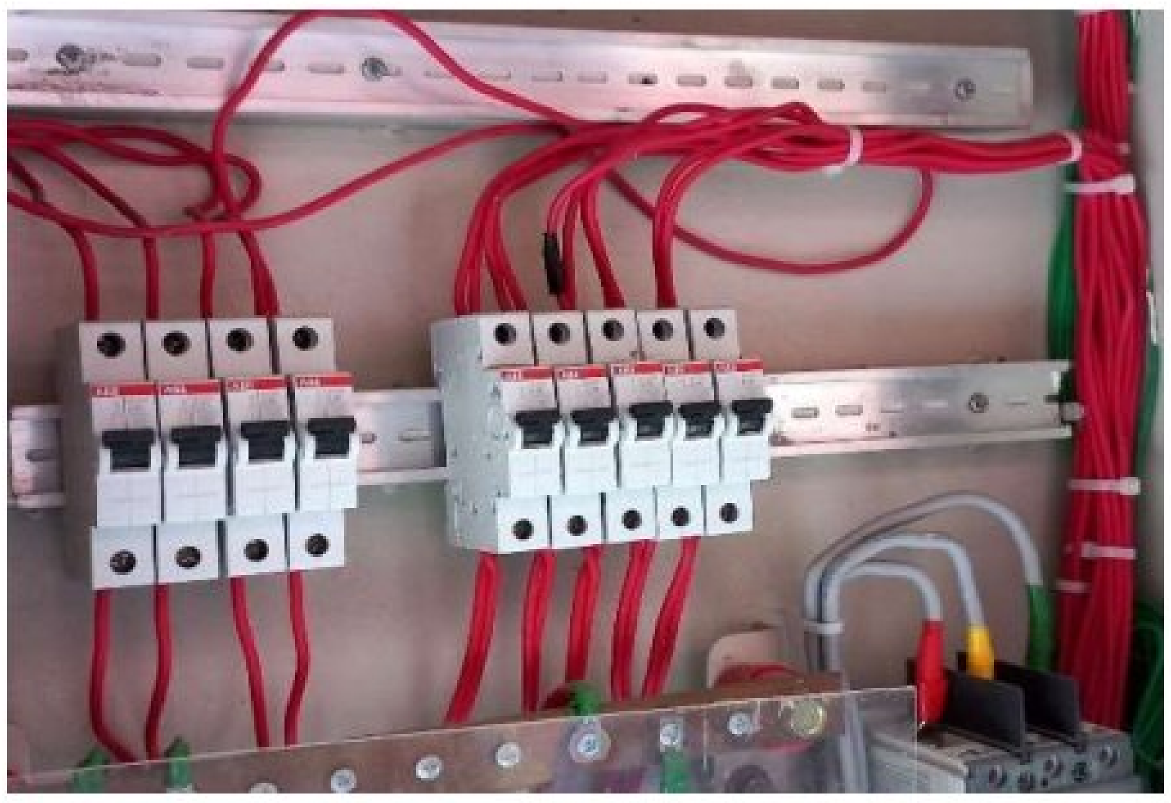


Figure 4.36: 10 A MCB (SP) circuit breakers that protects each room of the 3rd academic building

Figure 4.37: The 160 A MCCB (TP) breaker that is used on the sub distribution board of the 3rd academic building

The final single line diagram that we have drawn based on our survey of the 3rd academic building is as follows:

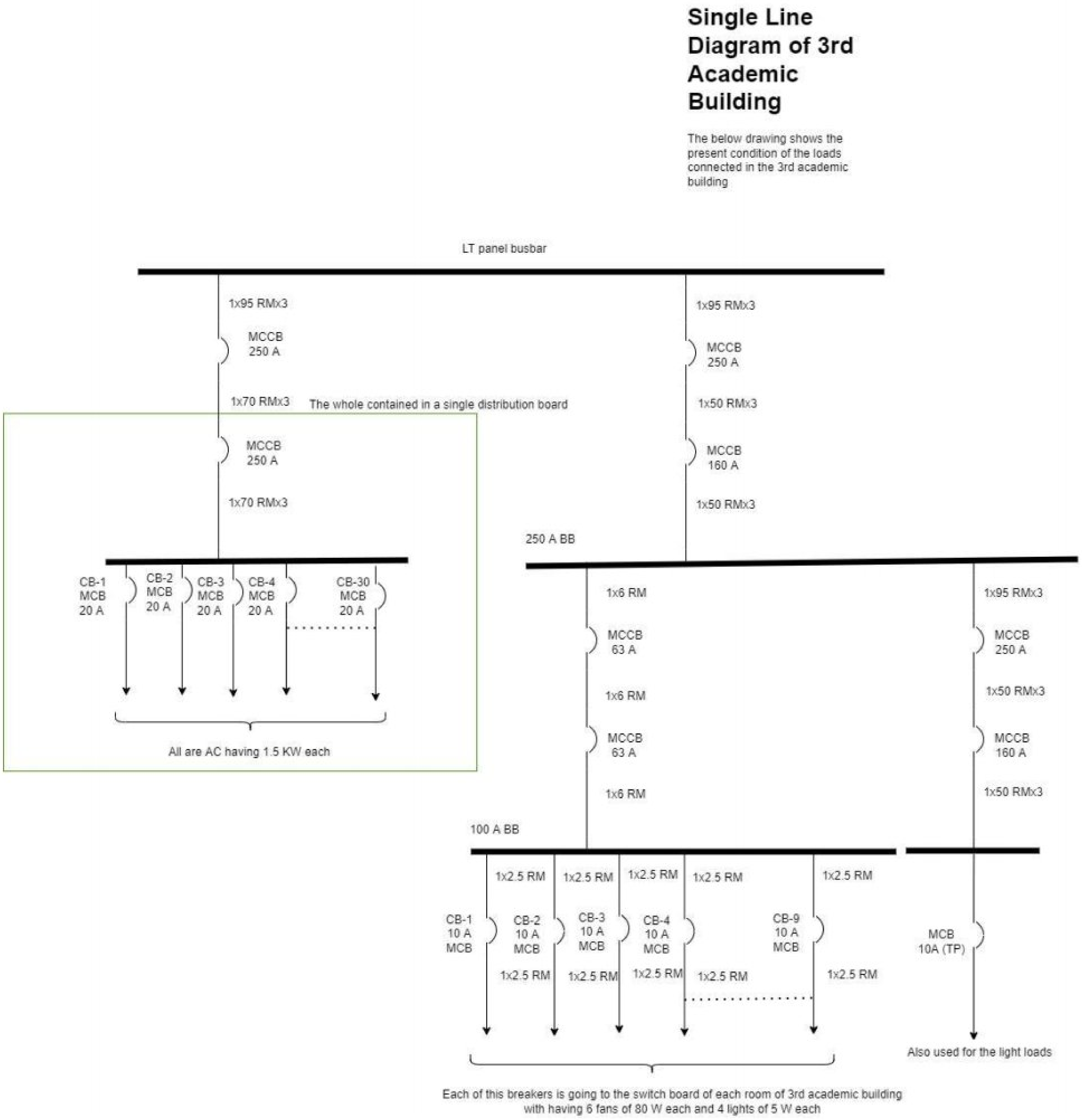


Figure 4.38: SLD for the 3rd academic building (based on survey and estimation of some of the ratings)

4.2.1.8 Surveying at the other areas within the IUT campus

We have also made survey with some other areas within the IUT campus which is outside of the three academic buildings. Below there is shown a distribution board which is outside of the 1st academic building that contains the main circuit breakers for the pump, South Hall Region-1,2 and 3 and finally the CDS canteen:

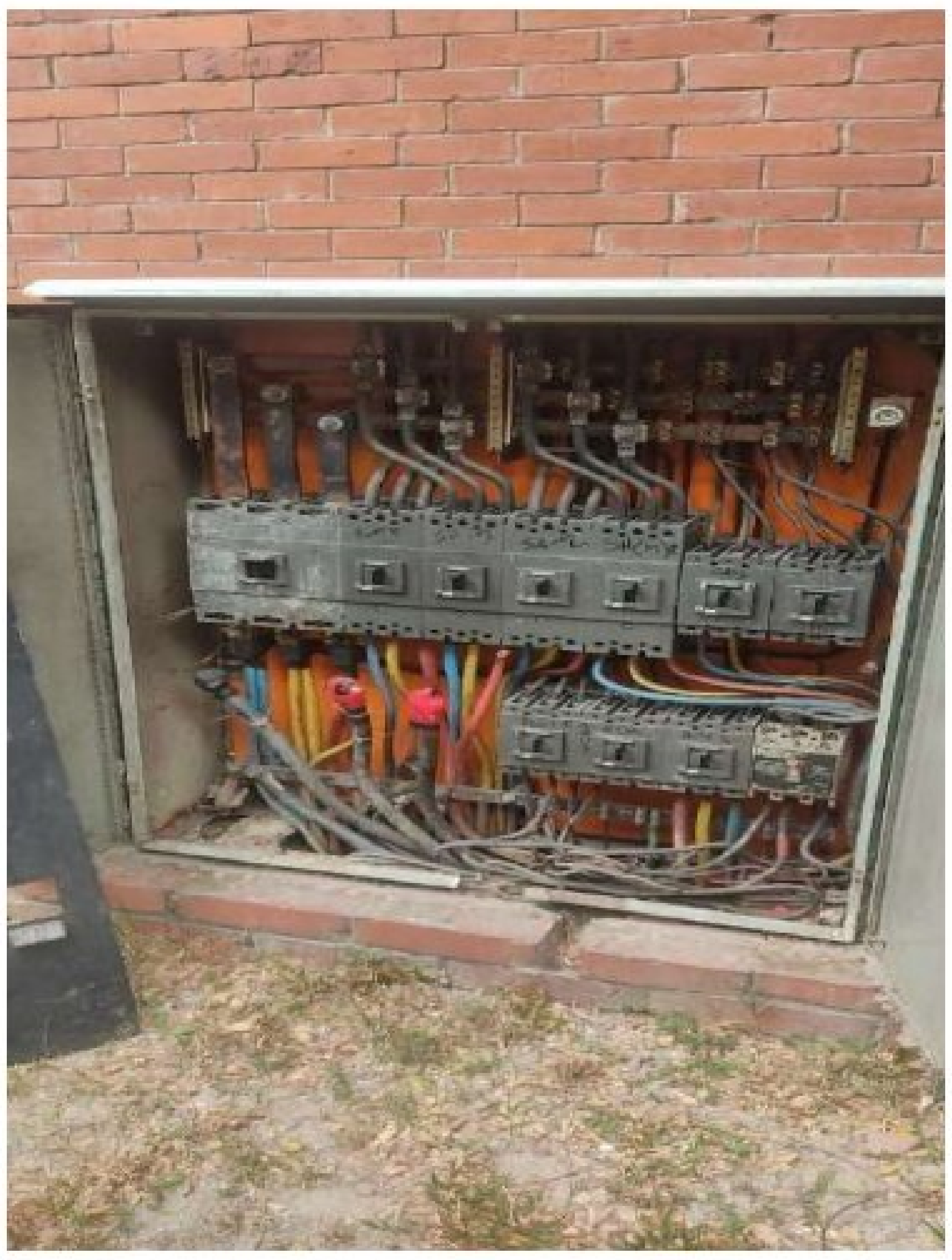


Figure 4.39: Main circuit breakers for the line coming from the LT panel to the pump, South Hall region-1,2 and 3, CDS canteen

4.2.1.9 Final single line diagram obtained from the surveying and estimation of loads

From the complete surveying of the transmission side i.e from the main grid up to the LT panel well as in the transmission side of the 1st,2nd and 3rd academic building at the distribution side i.e from the LT panel upto the load side, an estimated single line diagram that we have drawn in a CAD software is given in figure 4.

4.2.2 Simulations

In our whole research process, the second operation that we did is the simulation. In case of simulation part, we have mainly used the ETAP software to have a load flow analysis of the overall substation of IUT up to the 1st,2nd and 3rd academic building on the distribution side and starting from the transmission side of the main grid up to the LT panel.

We mainly know that for a long time the power engineers have been relying on single line diagrams and assumptions of load flow in each of the networks or buses. But as the technology is changing, there is need of performing simulations to experience real live events like knowing the reading all the real and reactive power values within each component of the network without visiting each and every components in the transmission and distribution side. This simulation software have also made the

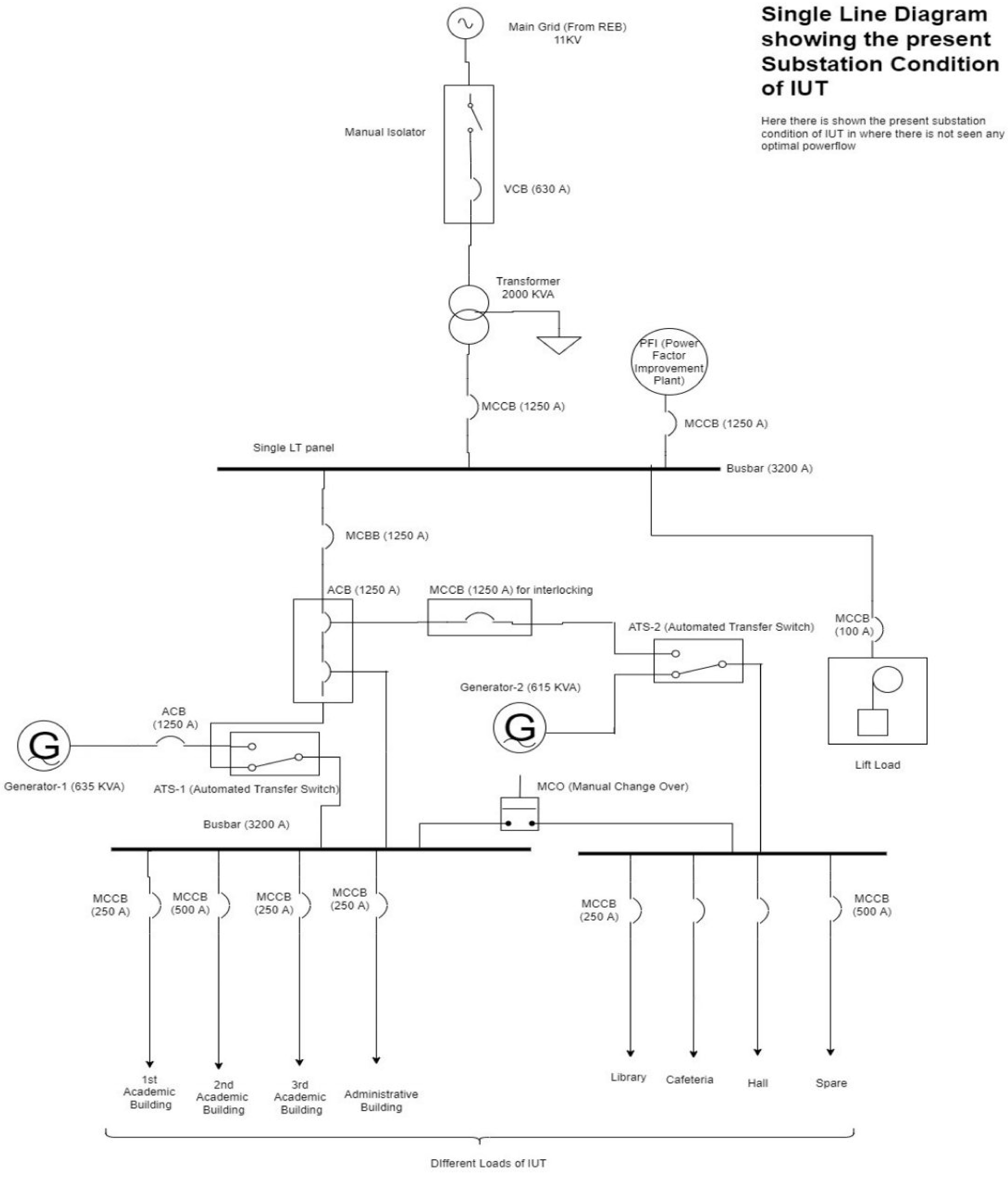


Figure 4.40: SLD of the IUT substation (based on survey and estimation of load)

engineers to detect different types of faults within a power station or substation for which this process has become easier for them than before. ETAP mainly stands for Electrical Transient Analyzer Program. ETAP software mainly is an electrical engineering analytical and cloud-based software in where the information that is being read on the power station can be simulated easily using real data through server computers that synchronize the data collected from the field with the simulation output data. ETAP software has also made easy for the engineers to collect some data on the power station manually through its mobile app.

Based on the different tutorials, we have learnt to use the ETAP software and we have both designed and simulated the present IUT substation from the main grid from BREB up to the 1^{st},2^{nd} and 3^{rd} academic building as distribution side.

The design of the substation that we have mainly done through the ETAP software is given clearly in the figure 4 and 4. respectively.

The part of the simulation results will be discussed thoroughly in the results and discussions chapter later.

4.2.3 Analysis and proposing a plan

This analysis part has been also discussed elaborately and clearly in the chapter entitled "Simulation Results, Observations and Discussions" chapter in where we have shown all the simulation results, statistical data created based on the simulation result, table output got from the simulation result and finally the conclusions that we have finalized based on the simulation result through the whole substation network of IUT.

Finally, the proposition of a plan for the improvement of the IUT substation has been discussed elaborately in the chapter entitled "Proposing a better substation structure based on field surveying, observations and simulation results."

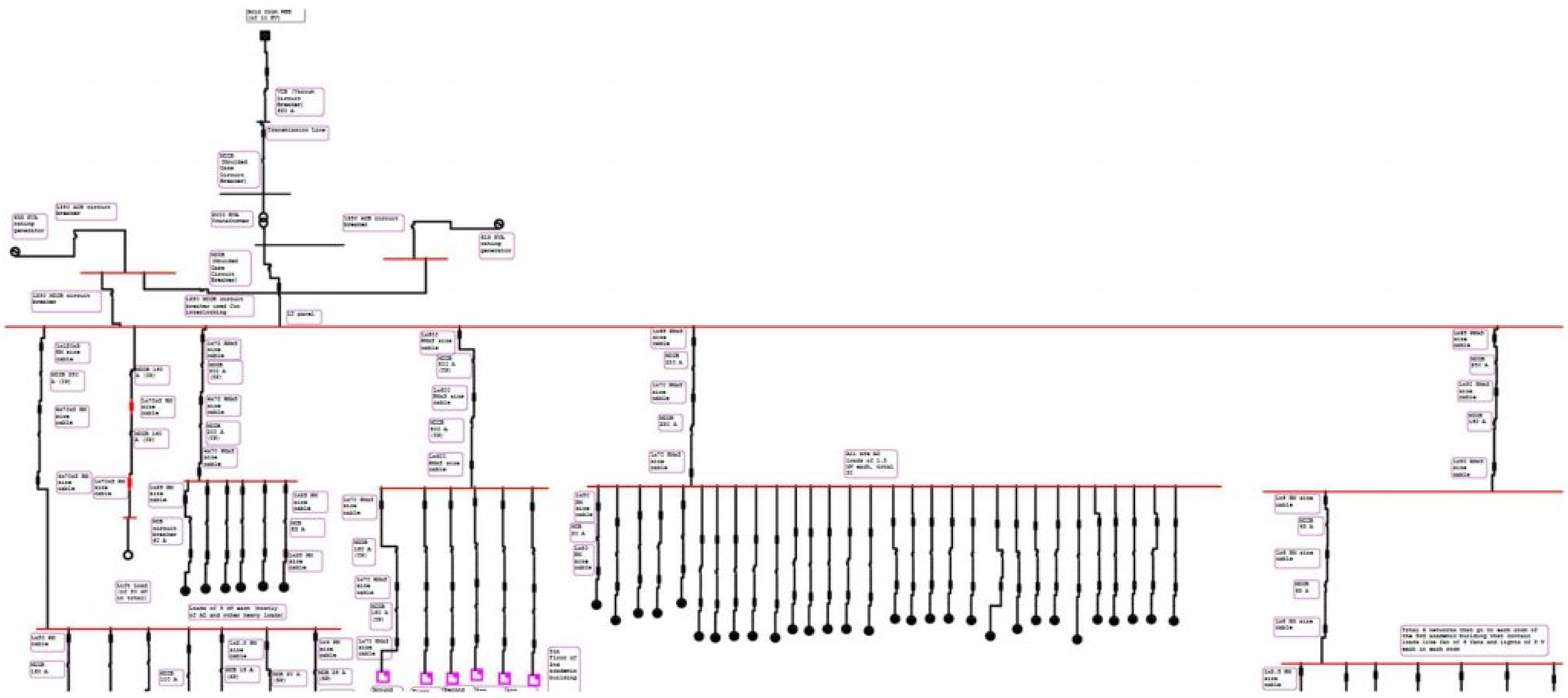


Figure 4.41: Design of the IUT substation using ETAP

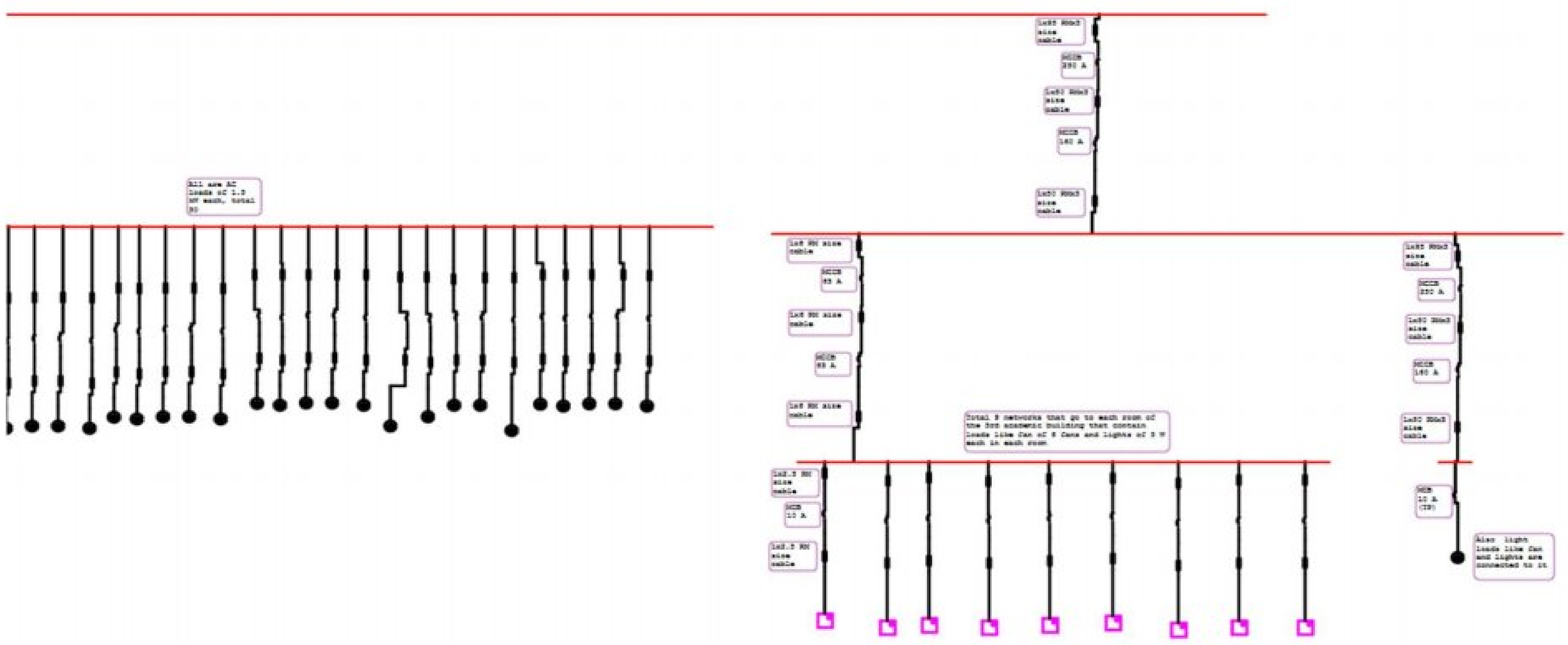


Figure 4.42: Design of the IUT substation using ETAP

Chapter 5

Simulation Results, Observations and Discussions

5.1 Introduction

This chapter mainly focuses on the simulation result that we have obtained after we have designed the IUT substation from the main grid that is coming form BREB , LT panel and finally to the distribution side (only for the 1^{st}, 2^{nd} and 3^{rd} academic buildings).

5.2 Simulation Results

The following pictures show the results of the simulation that we have obtained after designing a portion of the IUT substation in the ETAP software. It is to be mentioned before that, we have interchanged some data and values in order to get an optimal result. We have also used the trial and error methods in those portion of the transmission and distribution networks where we have found some abnormal value that is values that may come much greater or smaller than the desired value, specially on the buses and on the load sides. One thing is needed to be clear that we have used here the average loads for typical loads that we have obtained after field surveying through the IUT substation, like for AC load, we have taken 1.5 kW as average load, for ceiling fans we have taken 80 W as average load and for tube-light we have taken 5 W as average load. And in each cases, for busbar current ratings we have taken the ratings according to the width and height of the bus on which mainly the current ratings are dependent upon. Besides, for cable we have taken the current rating based on the RMA size of the cable in each of the cases. Finally, it is to be mentioned that we have taken 11 kV as primary side voltage and 0.44 kV in ETAP software for each of the bus voltages right after the second to make the ETAP simulation error free. Here a MCCB circuit breaker of current rating 1250 A is used as electrical interlocking instead of ATS interlocking system as the ETAP software lags such an option of inserting ATS into the network.

5.2.1 Simulation up to LT panel

We have divided the simulation into two types:

i) Simulation upto LT panel when no generators are running i.e, normal power flow

ii) Simulation upto LT panel when no generators are running i.e when there is load shedding or due to maintenance if one of the line is cut.

5.2.1.1 Simulation upto LT panel when no generators are running

In this case the simulation upto LT panel is given below:

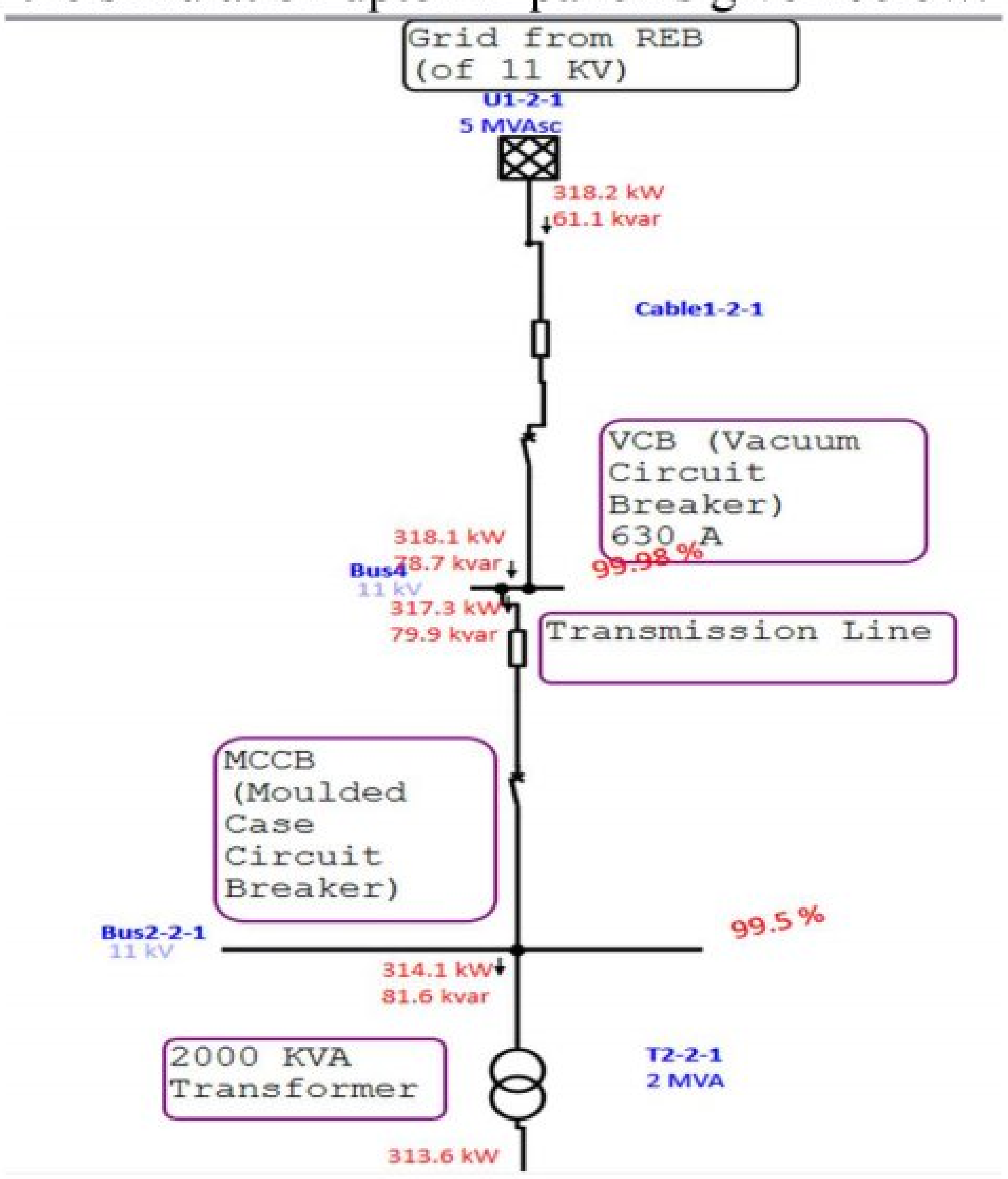


Figure 5.1: Real and Reactive power flow with voltage drop as percentage in each bus from main grid to the transformer

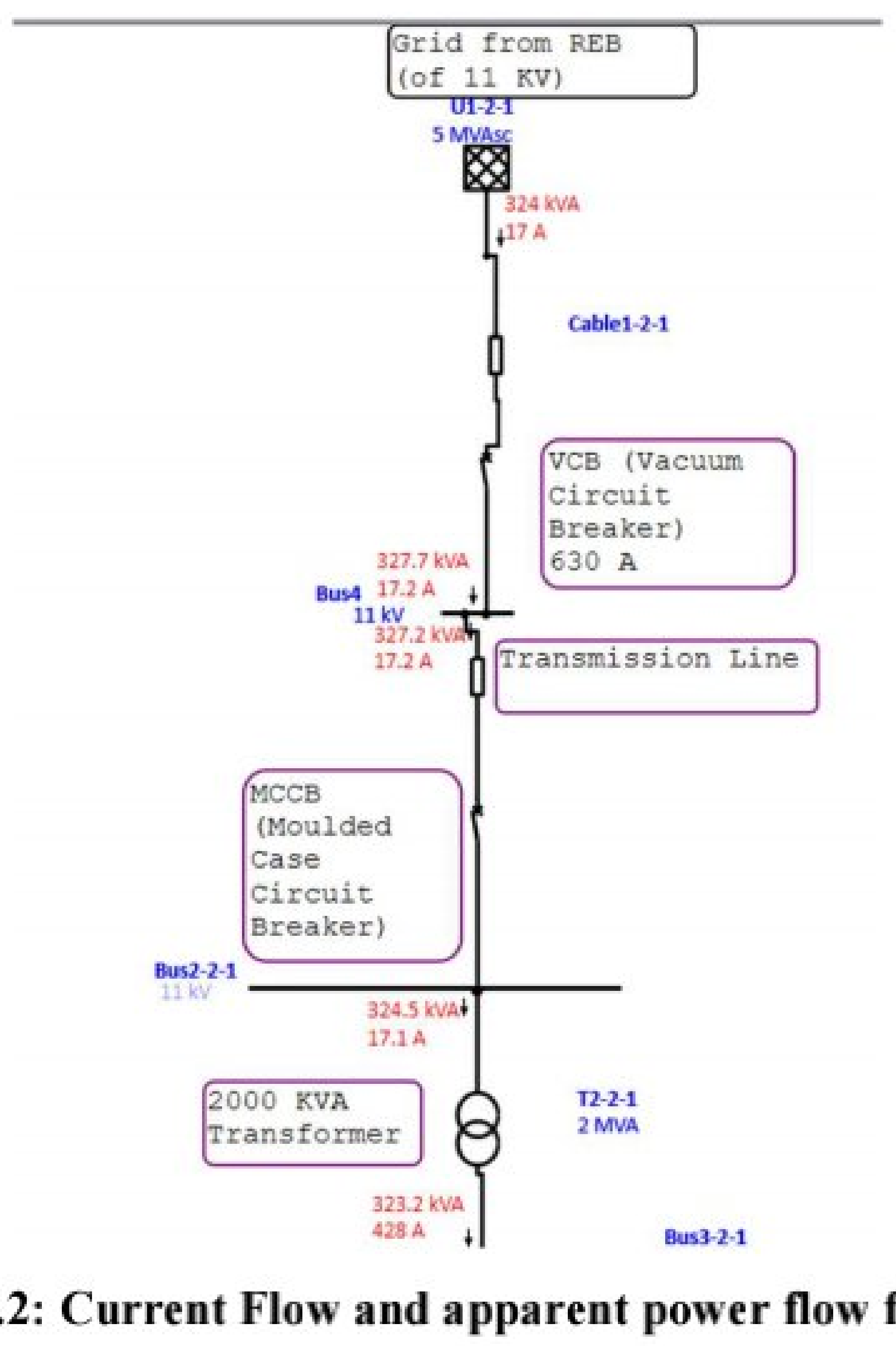


Figure 5.2: Current Flow and apparent power flow from main grid to the transformer

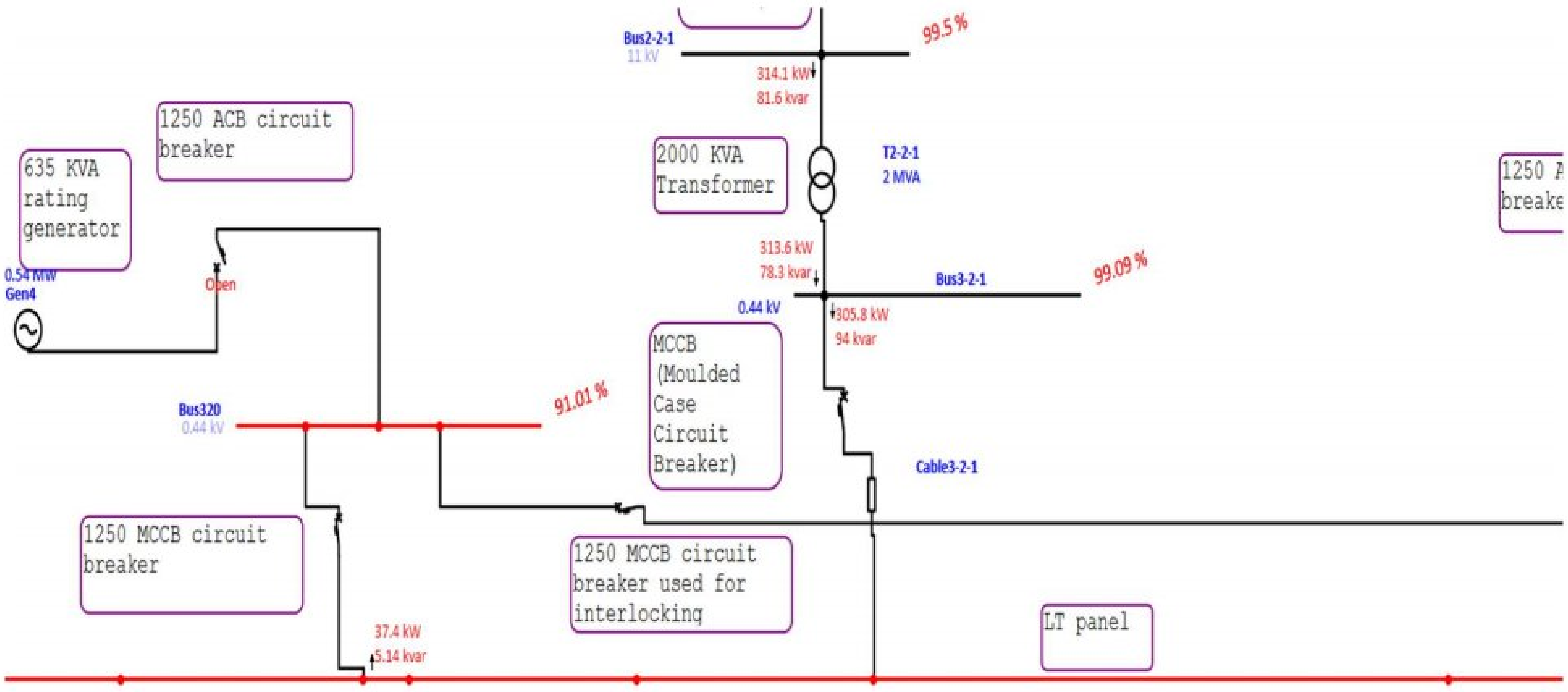


Figure 5.3: Real and Reactive power flow voltage drop as percentage in each bus from transformer to the LT panel

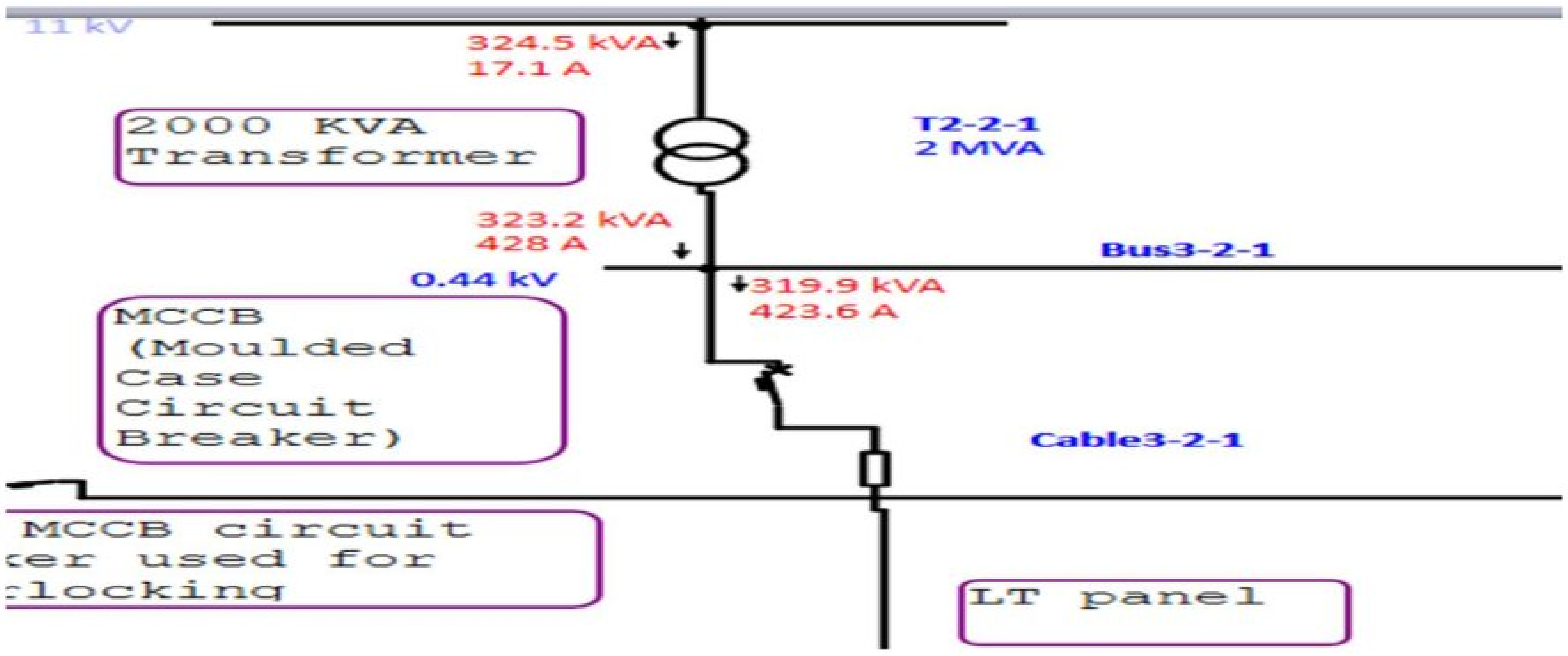


Figure 5.4: Current Flow and apparent power flow from transformer to the LT panel

5.2.1.2 Simulation upto LT panel when one of the generators is running

In this case the simulation upto LT panel is given below:

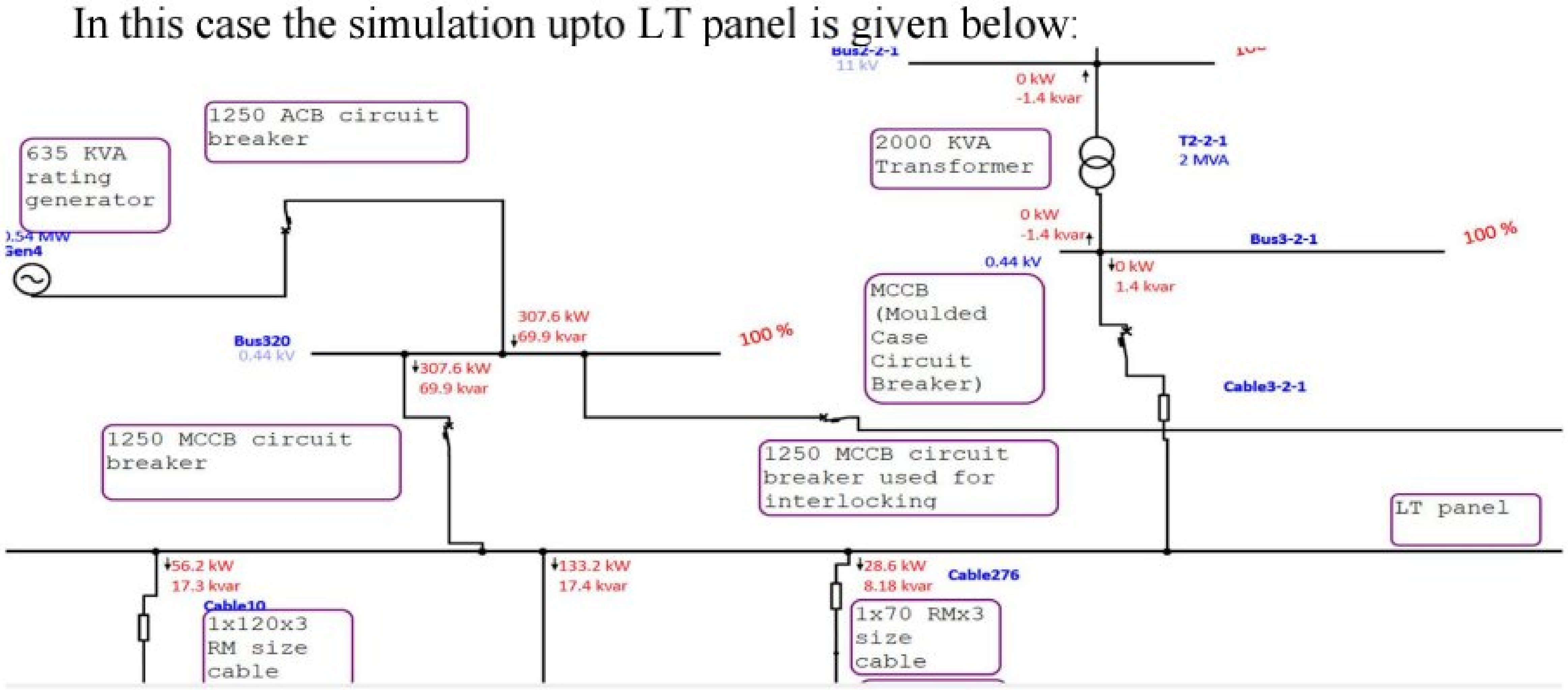


Figure 5.5: Real and reactive power from the transformer upto the LT side with voltage percentage at each bus when 635 kVA rating generator is running

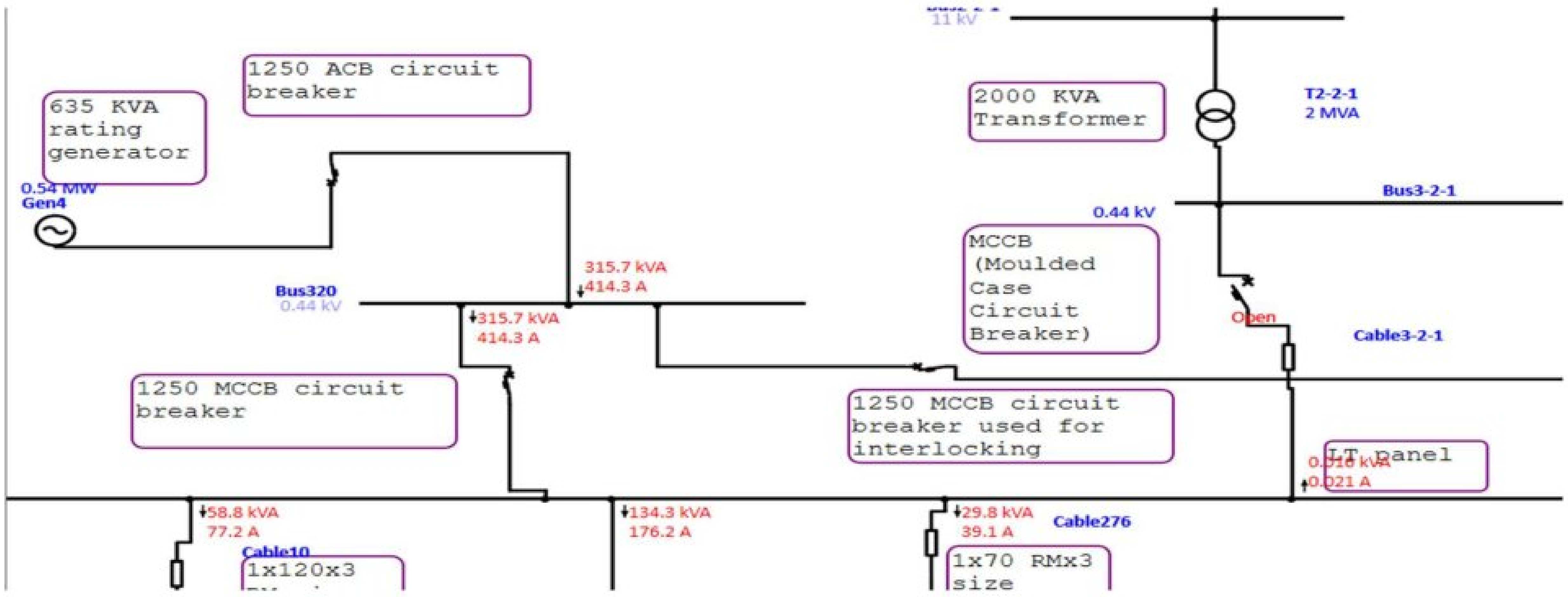


Figure 5.6: Current Flow and Apparent power flow from the transformer to the LT panel when the 635 kVA generator is running

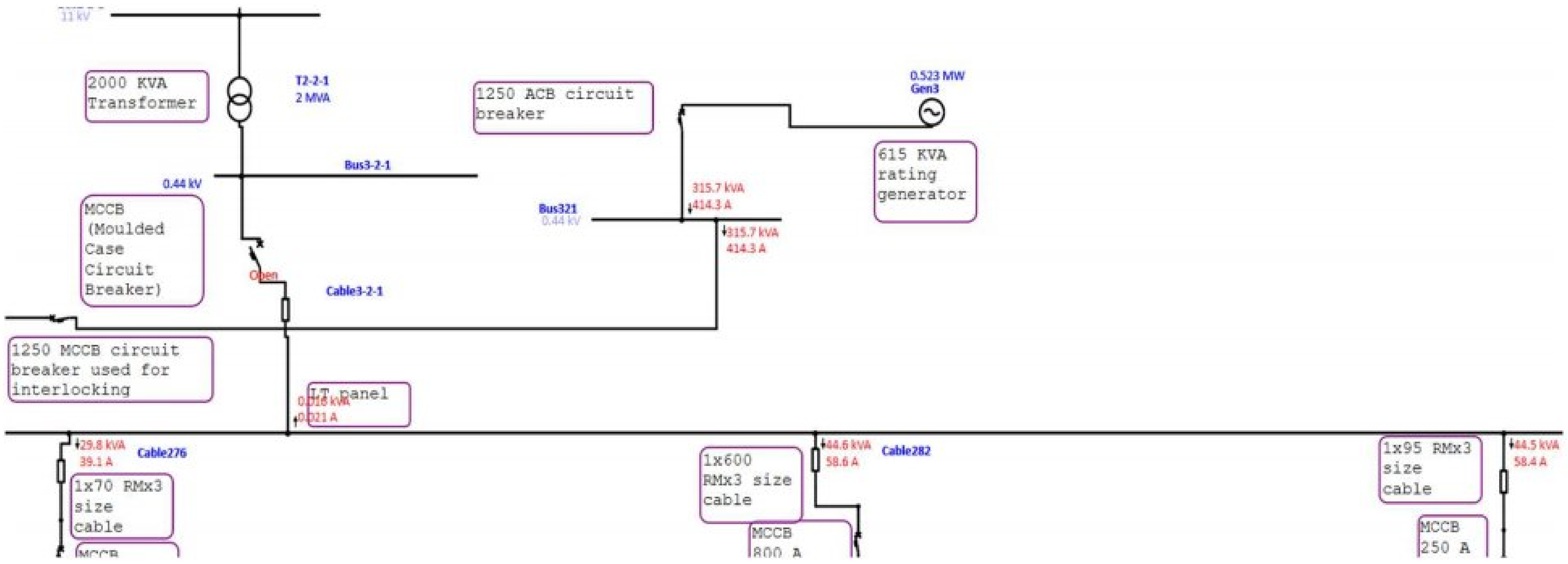


Figure 5.7: Current Flow and Apparent power flow from the transformer to the LT panel when the 615 kVA generator is running

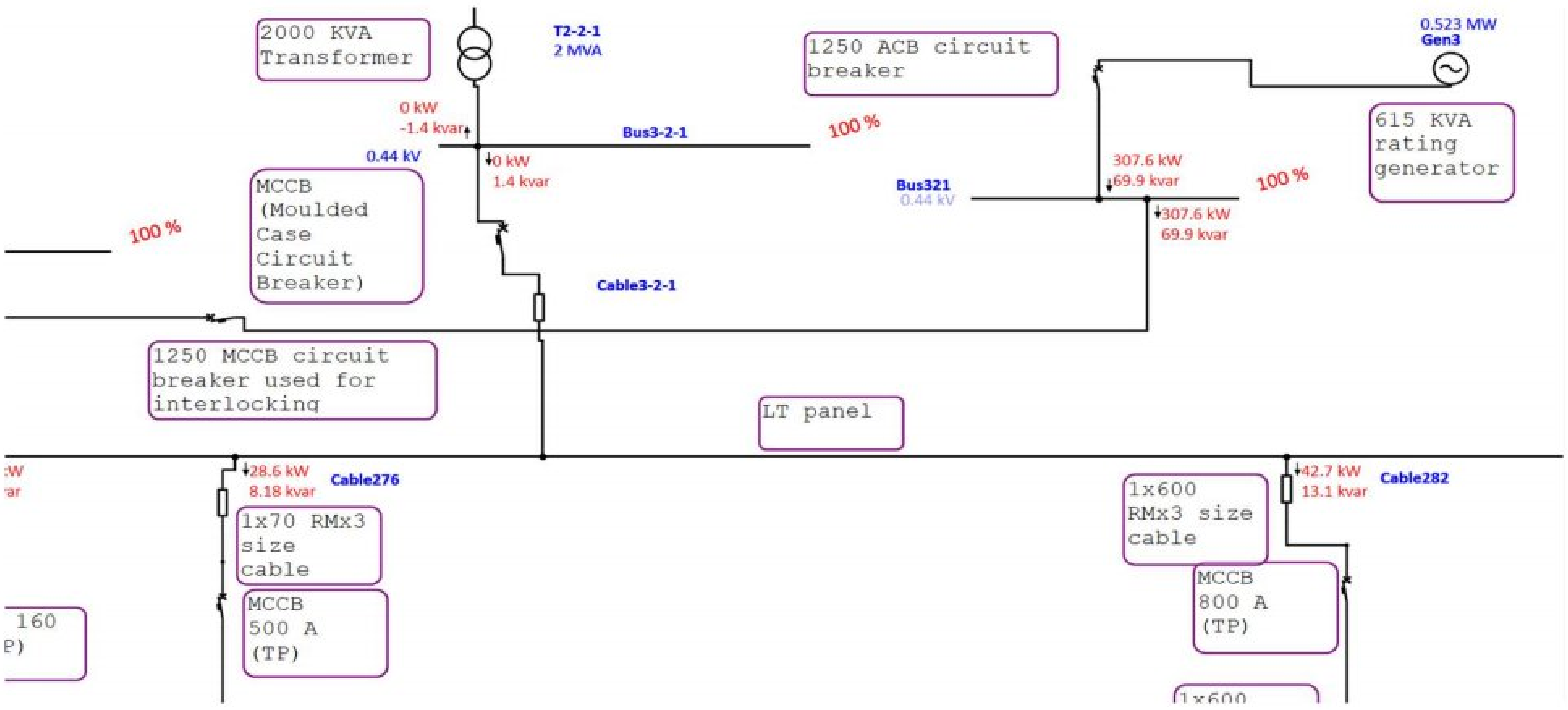


Figure 5.8: Real and reactive power from the transformer upto the LT side with voltage percentage at each bus when 615 kVA rating generator is running

5.2.2 Simulation from LT panel to the distribution side

After thorough simulations in the ETAP software, we have come up in the below results for the real and reactive power as well as the current flowing through each network:

5.2.2.1 Simulation for the 1st academic building

Below there is given our simulation results of the distribution sides of 1st academic building using ETAP software for the following parameters that is given in the section 5.2.2.

Here we need to mention one thing before that in each of the floors of the 1st academic building, as the distribution network side is huge, so we have used a new component called a composite network which is similar to the subcircuit option of other electrical simulation software like proteus or OrCAD where we express a large circuit network as a network block (mainly for a 2-port network).

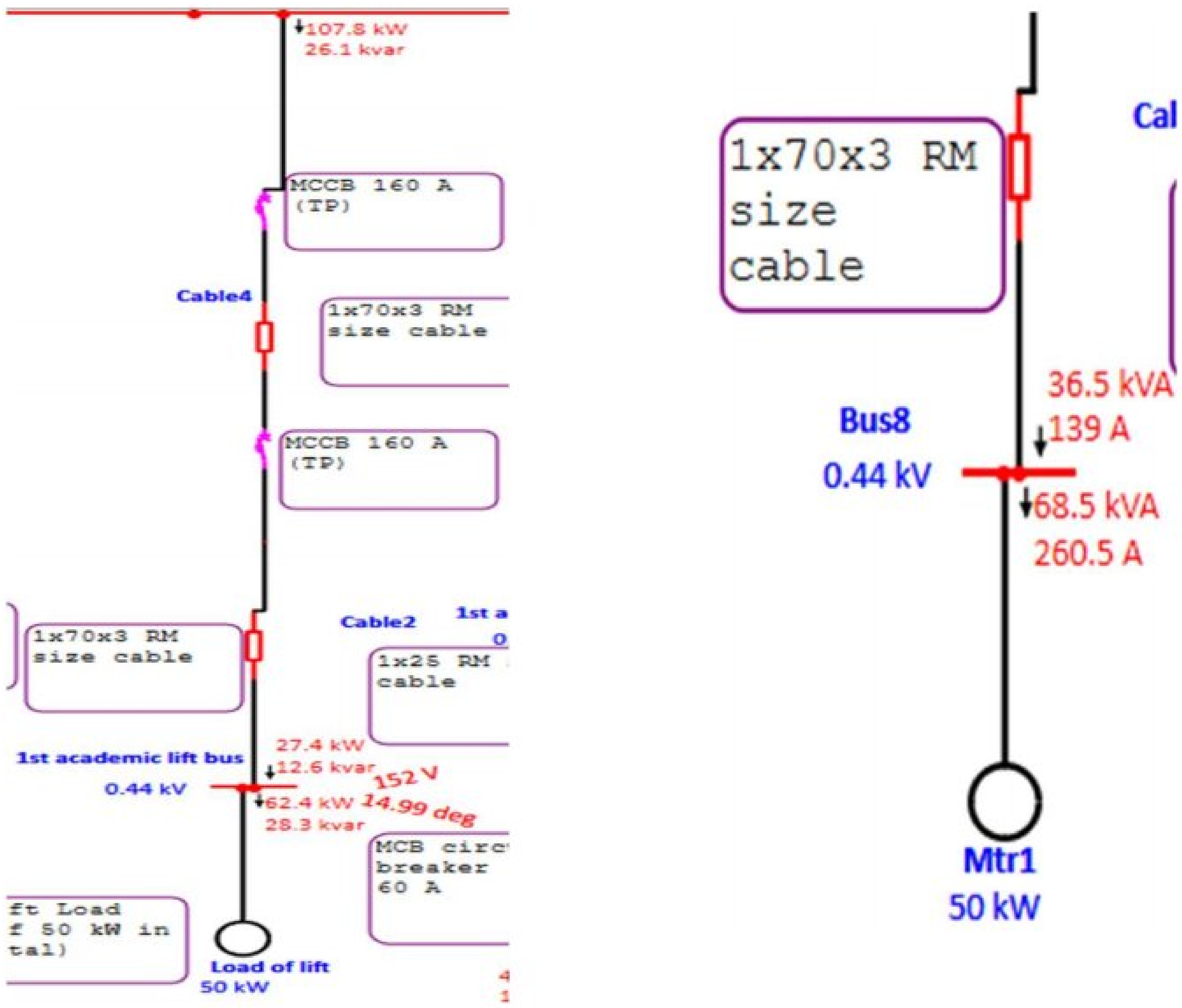


Figure 5.9: Real and reactive power, current, apparent power flow and voltage drop in each bus along with phase angle for the lift load of 1st academic building where the lift load is considered as an induction motor

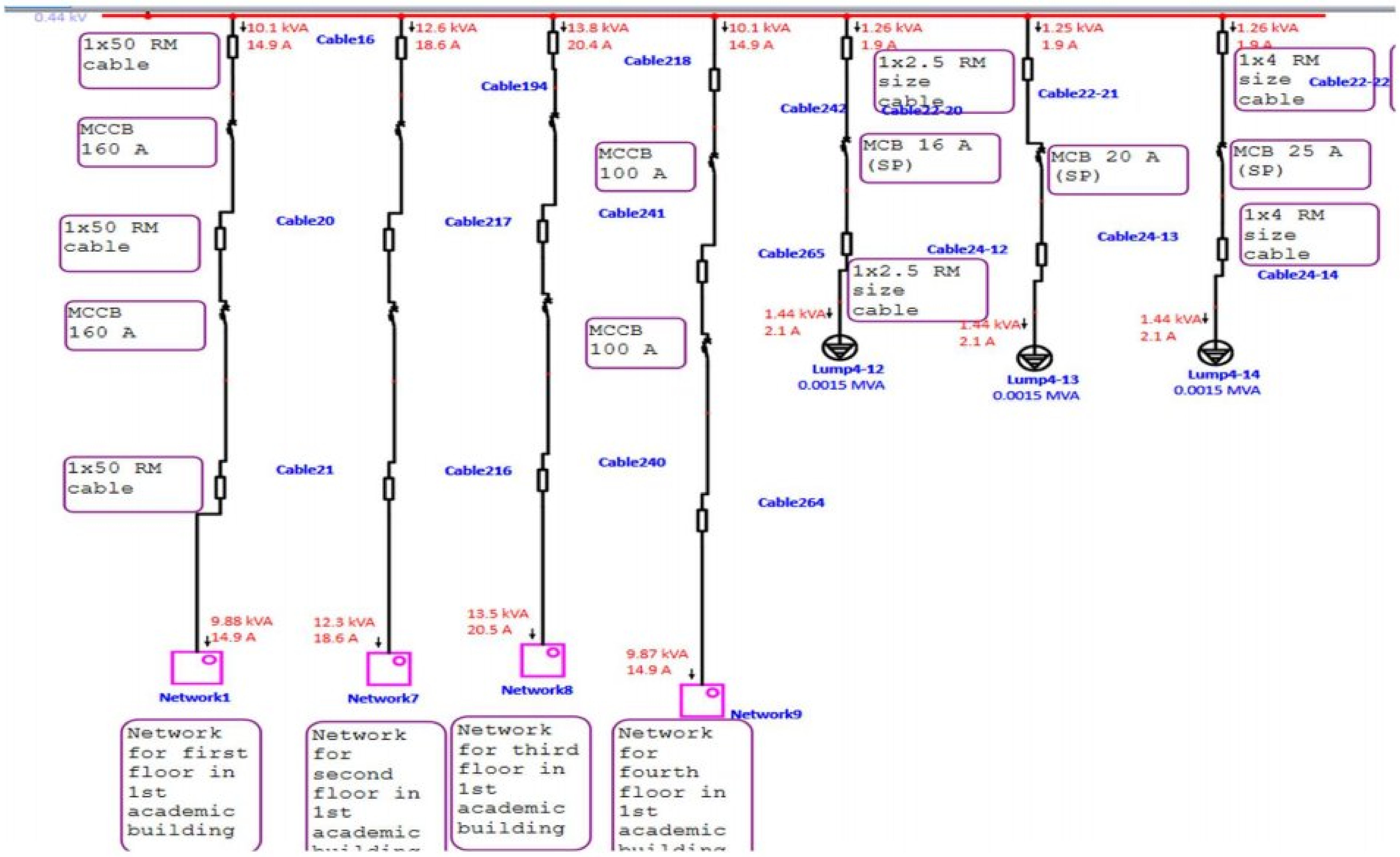


Figure 5.10: Current and apparent power flow through each floor of 1st academic building

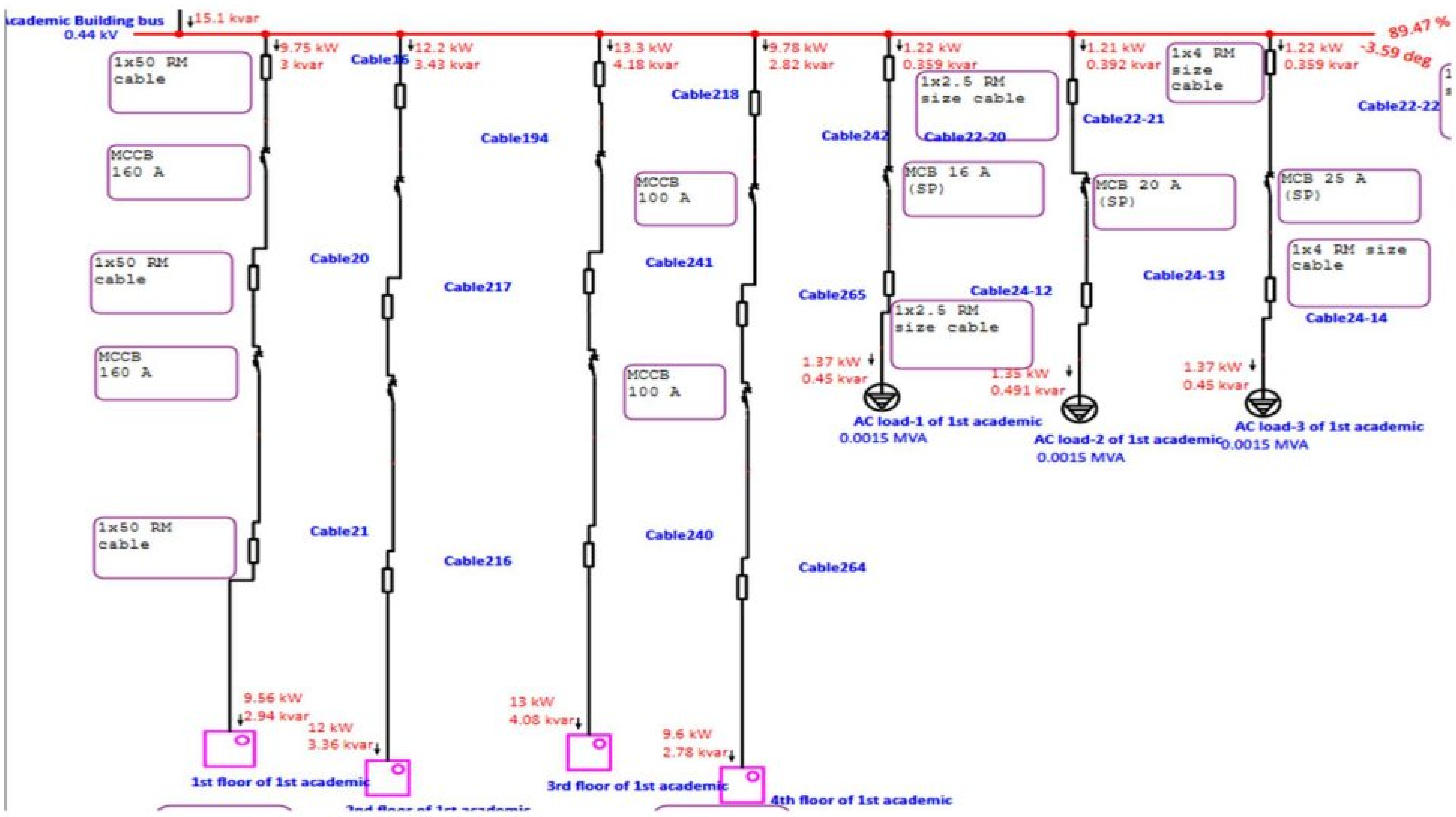


Figure 5.11: Real and reactive power for the distribution network with percentage of voltage drop in the bus out of the total voltage drop of bus of 1st academic building (only for AC load)

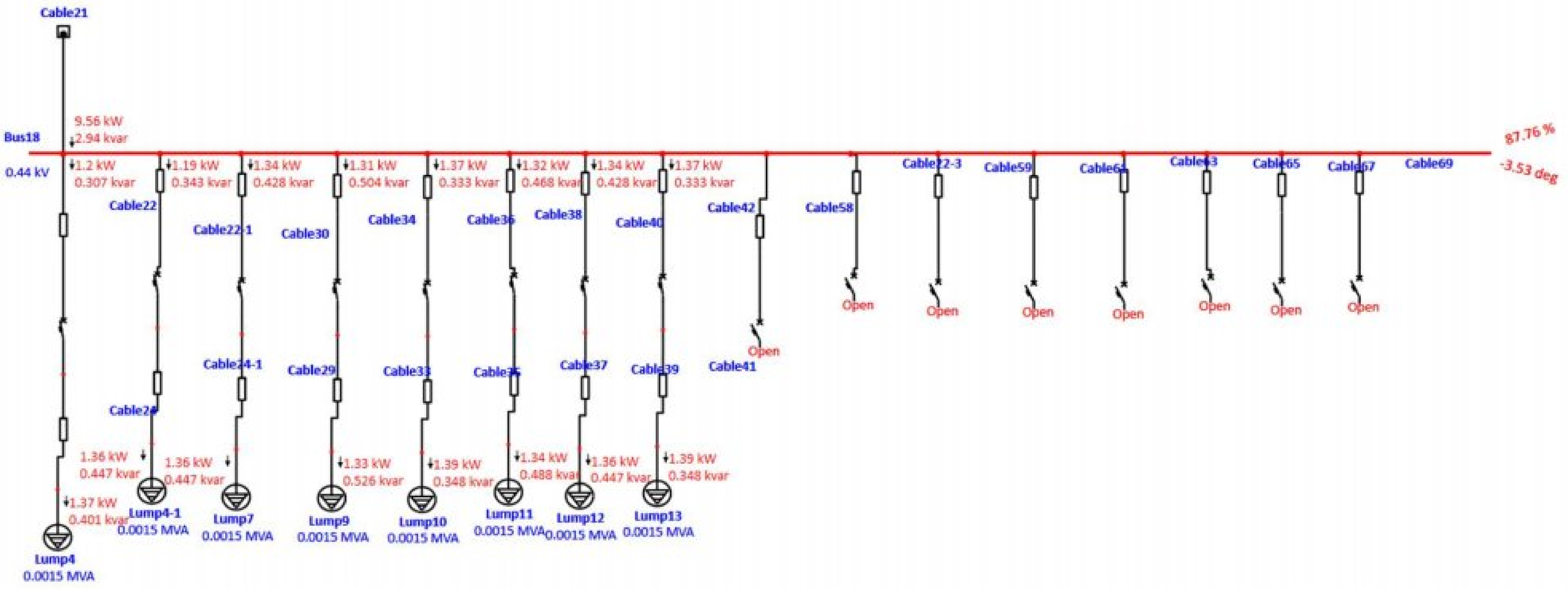


Figure 5.12: Real and Reactive power with percentage of voltage drop in the bus out of the total voltage drop of bus for the composite network of 1st floor of 1st academic building

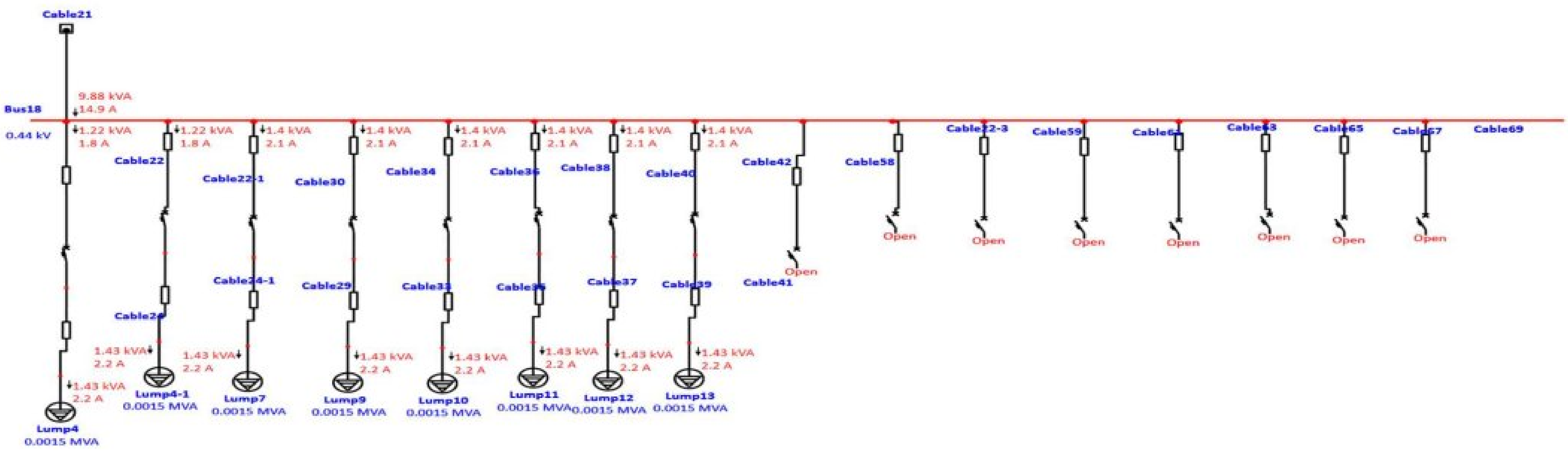


Figure 5.13: Current and apparent power flow for the composite network of 1st floor of 1st academic building

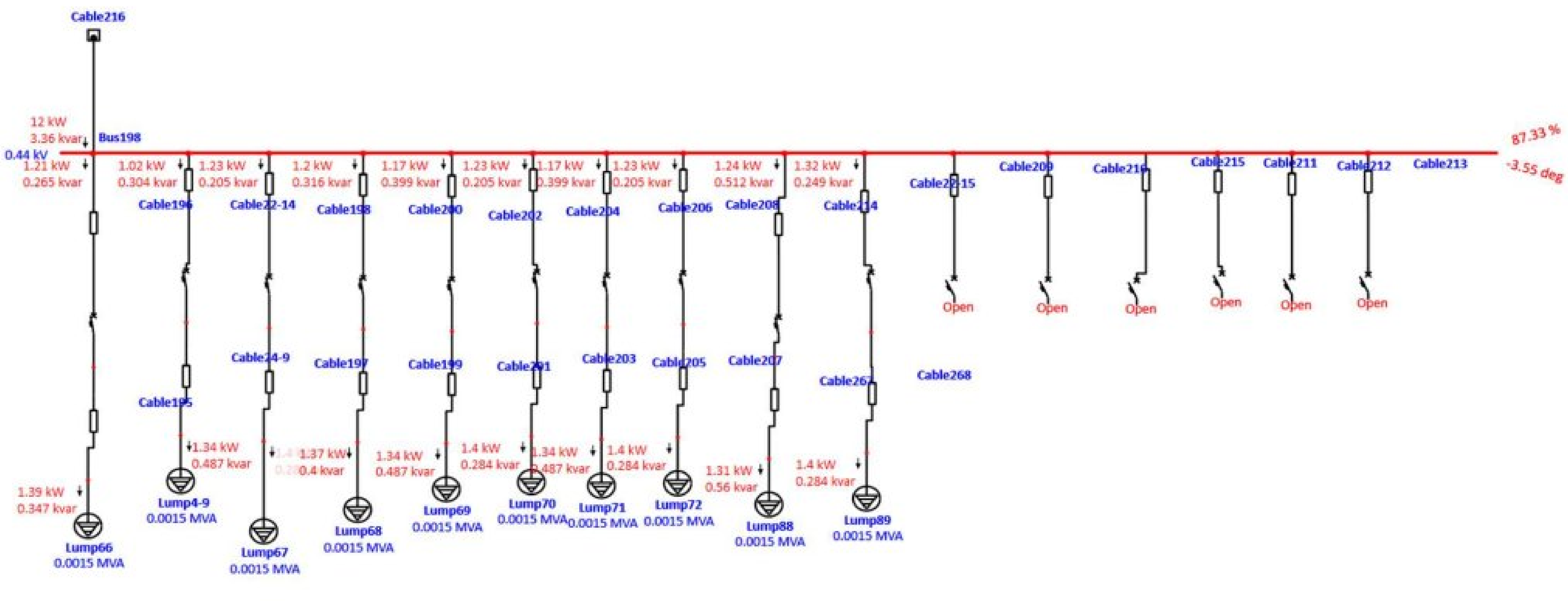


Figure 5.14: Real and Reactive power with percentage of voltage drop in the bus out of the total voltage drop of bus for the composite network of 2nd floor of 1st academic building

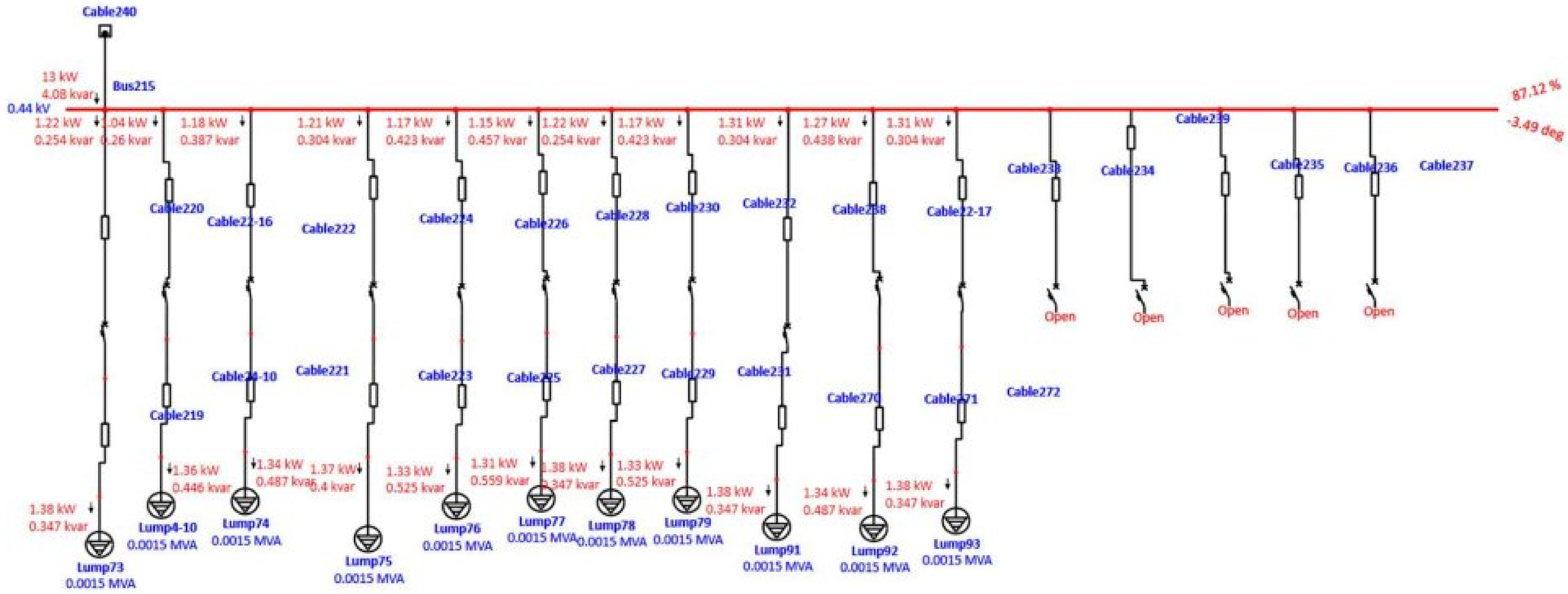


Figure 5.15: Real and Reactive power with percentage of voltage drop in the bus out of the total voltage drop of bus for the composite network of 3rd floor of 1st academic building

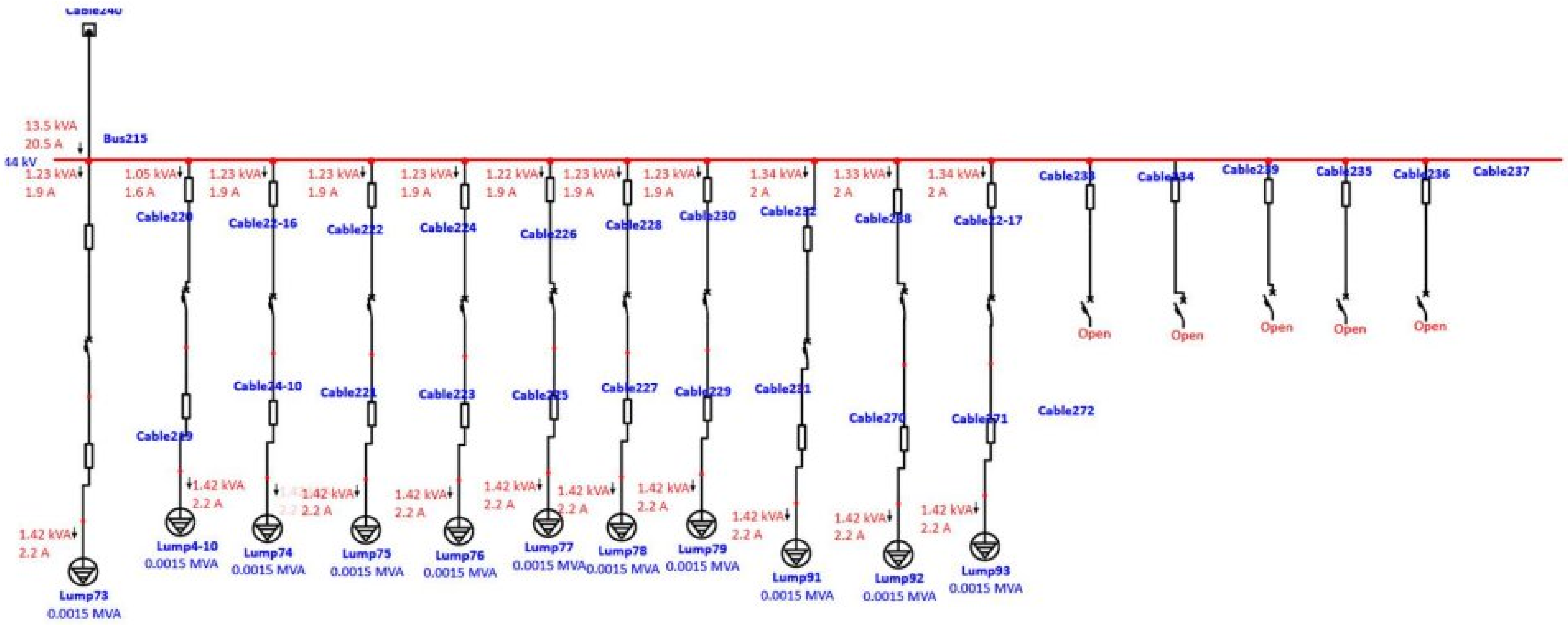


Figure 5.16: Current and apparent power flow of 3rd floor of 1st academic building

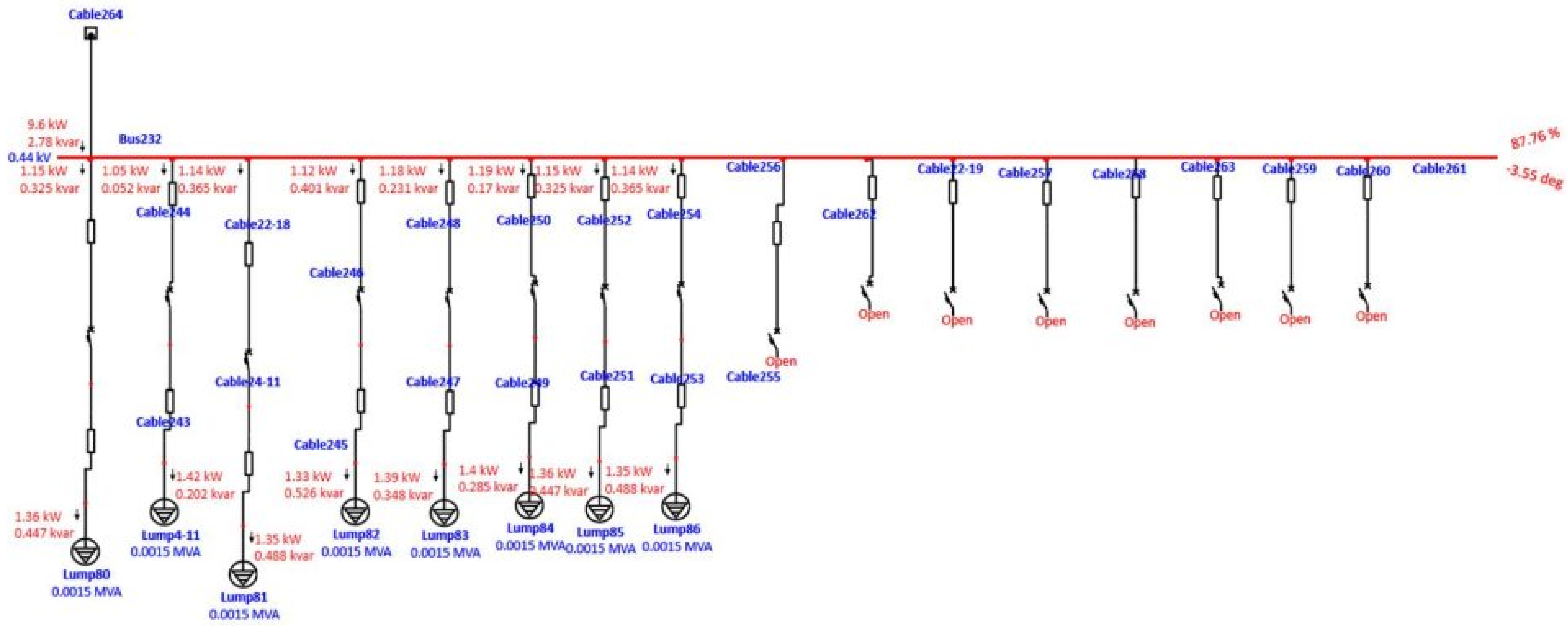


Figure 5.17: Real and Reactive power with percentage of voltage drop in the bus out of the total voltage drop of bus for the composite network of 4th floor of 1st academic building

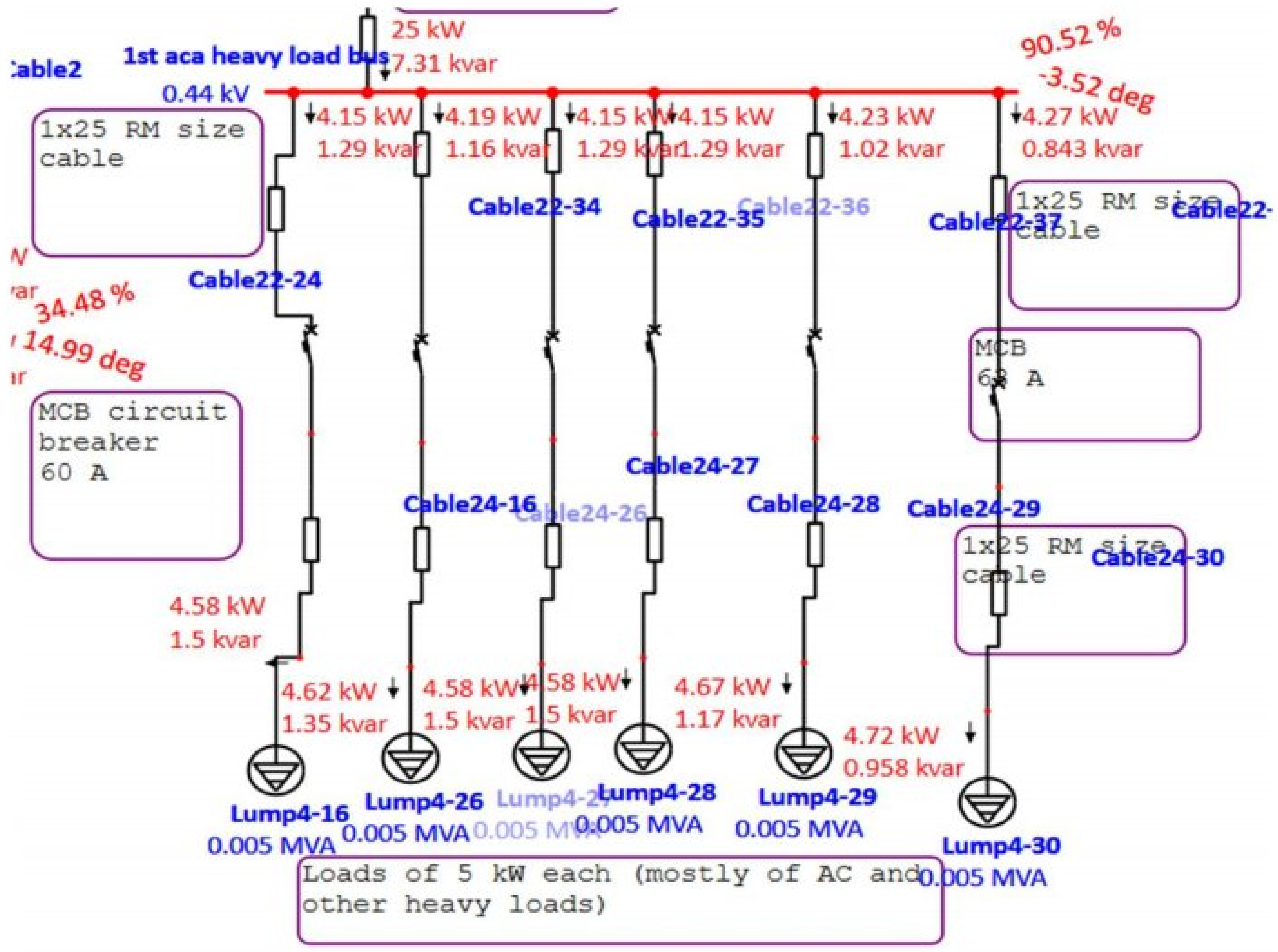


Figure 5.18: Real and Reactive power for 5 kW heavy loads other than AC load in the 1st academic building

5.2.2.2 Simulation for the 2nd academic building

In this section we shall discuss about the simulation of real power, reactive power and current flow through each bus and each portion of the distribution network of the second academic building. Here we require to be clear that the simulation here is done also for the AC loads only as we could not get enough time in measuring other loads while doing survey in the second academic building and we have also taken the average of AC load as 1.5 kW here also.

Here, likewise as we did for the 1st academic building, we have used the composite network for representing the networks for the different floors of the 2nd academic building.

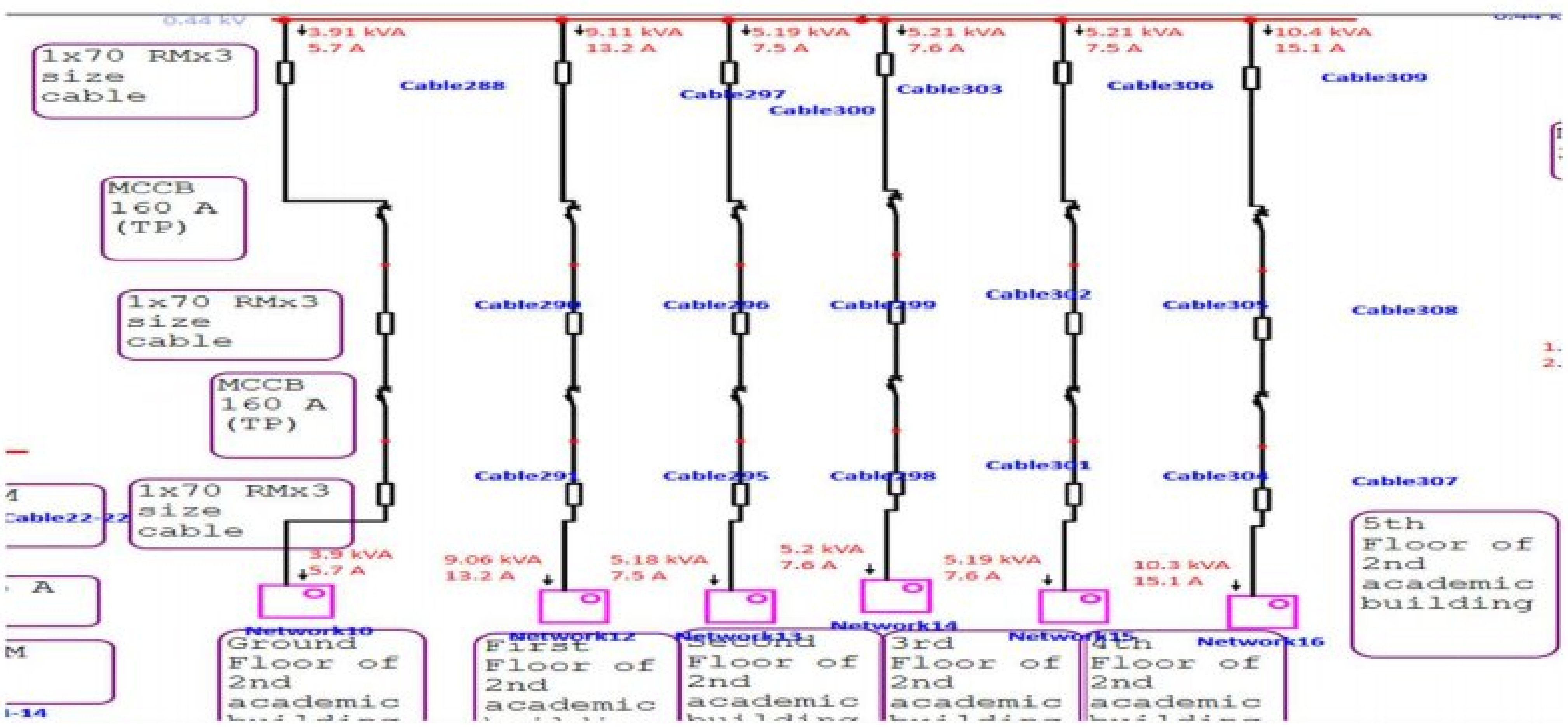


Figure 5.19: Current flow and apparent power for the distribution network of 2nd academic building (only for AC load)

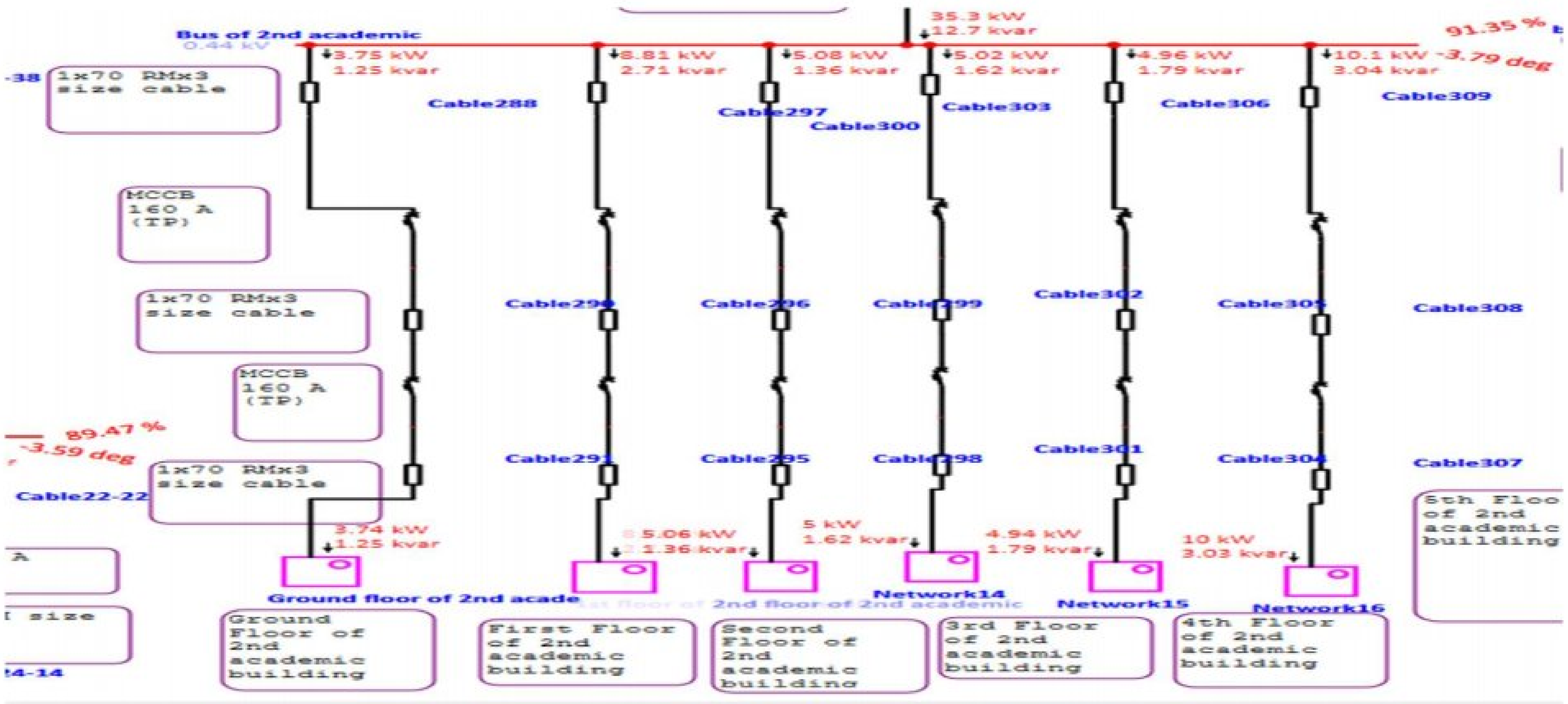


Figure 5.20: Real and reactive power for the distribution network with percentage of voltage drop in the bus out of the total voltage drop of bus of 2nd academic building (only for AC load)

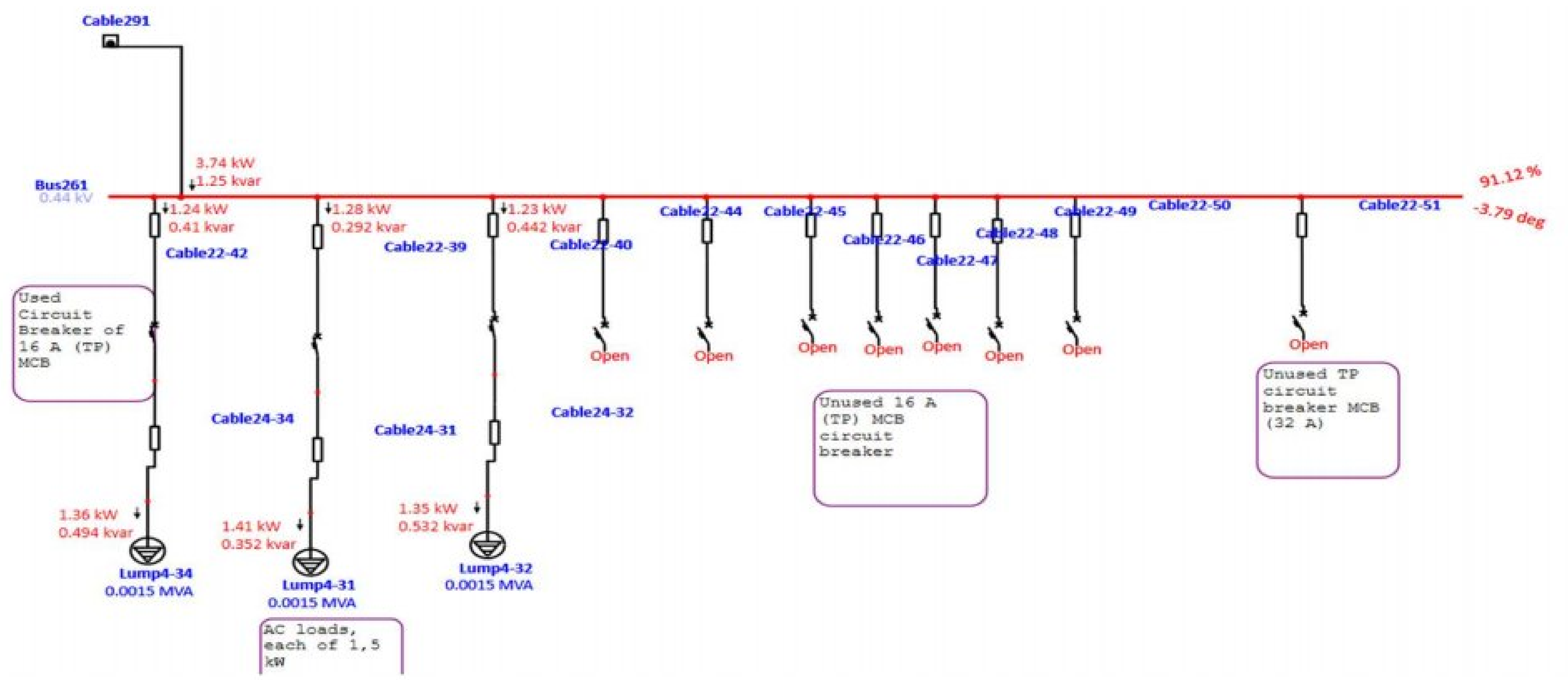


Figure 5.21: Real and Reactive power with percentage of voltage drop in the bus out of the total voltage drop of bus for the composite network of ground floor of 2nd academic building

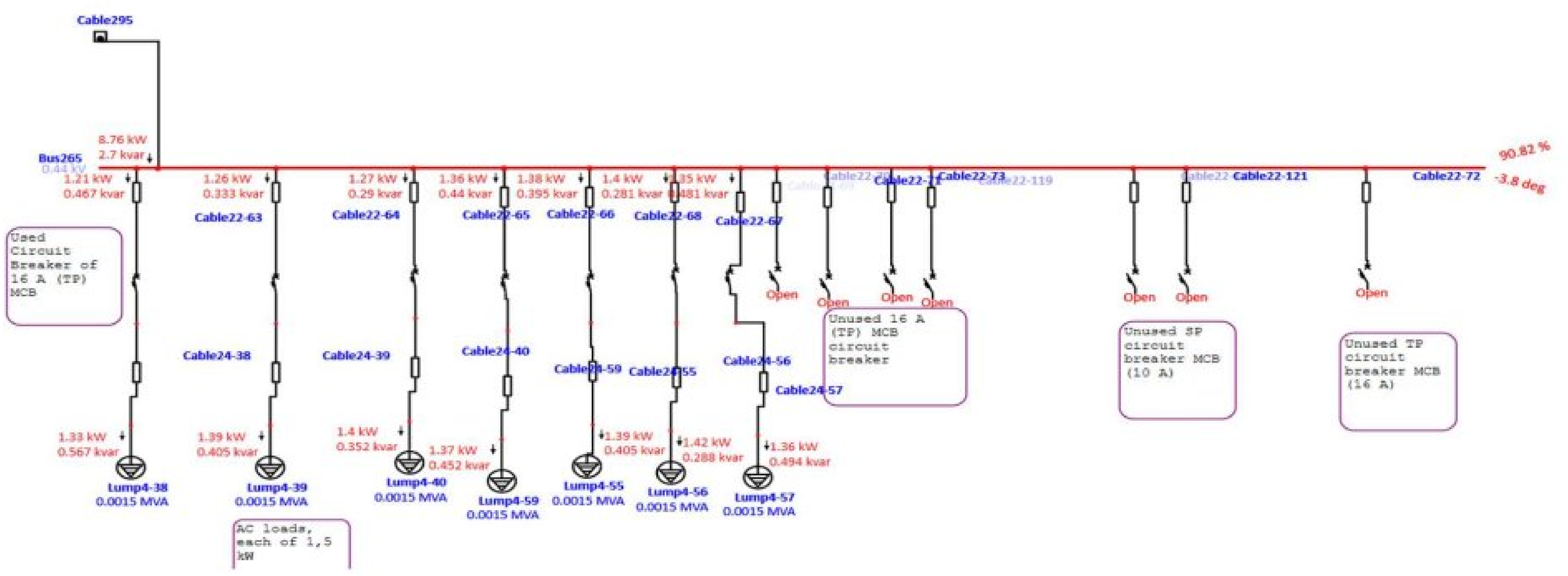


Figure 5.22: Real and Reactive power with percentage of voltage drop in the bus out of the total voltage drop of bus for the composite network of 1st floor of 2nd academic building

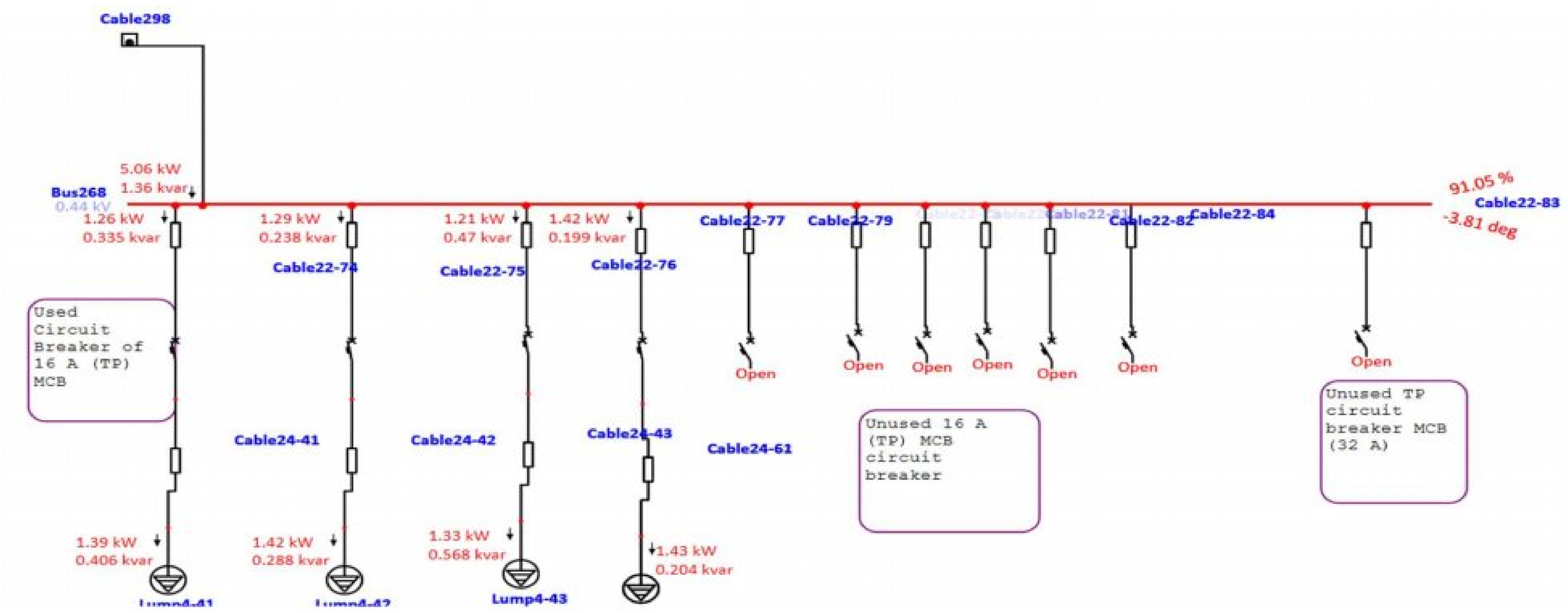


Figure 5.23: Real and Reactive power with percentage of voltage drop in the bus out of the total voltage drop of bus for the composite network of 2nd floor of 2nd academic building

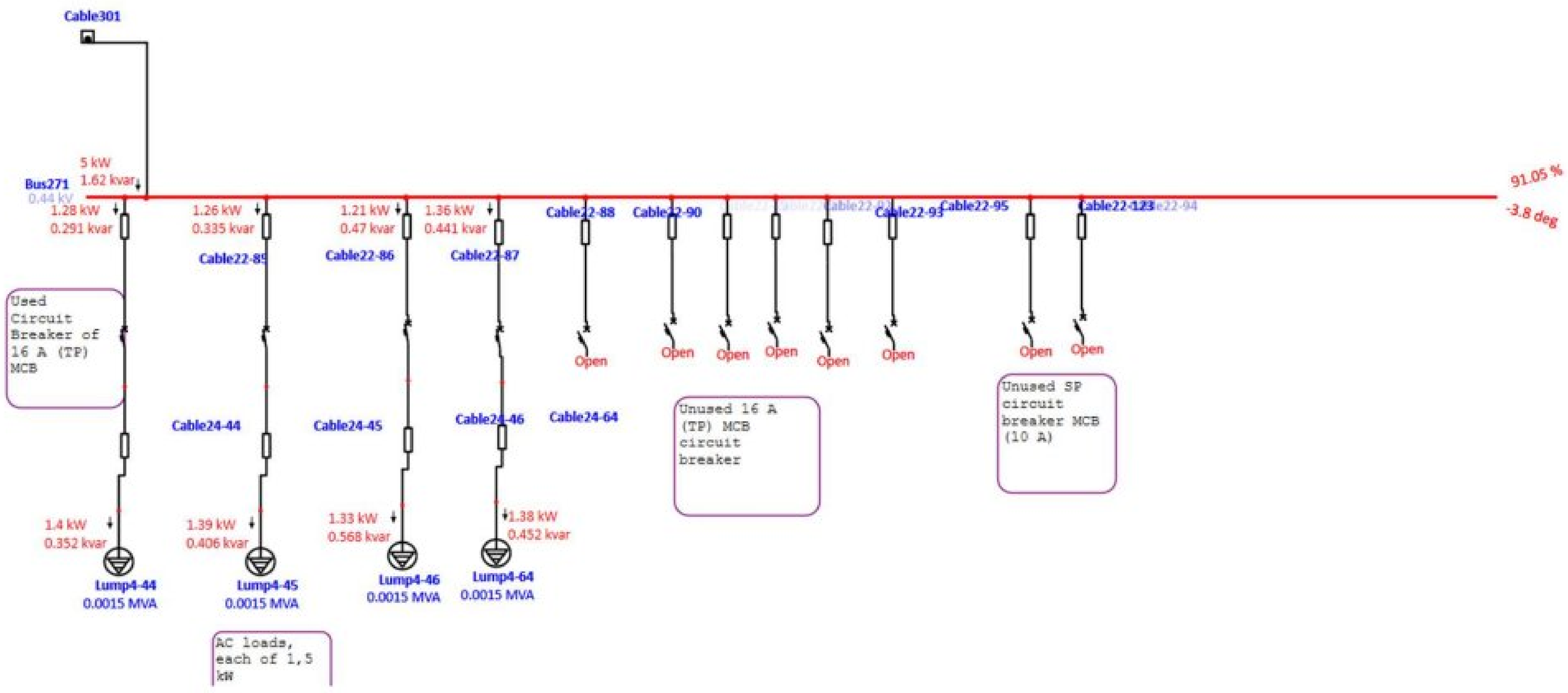


Figure 5.24: Real and Reactive power with percentage of voltage drop in the bus out of the total voltage drop of bus for the composite network of 3rd floor of 2nd academic building

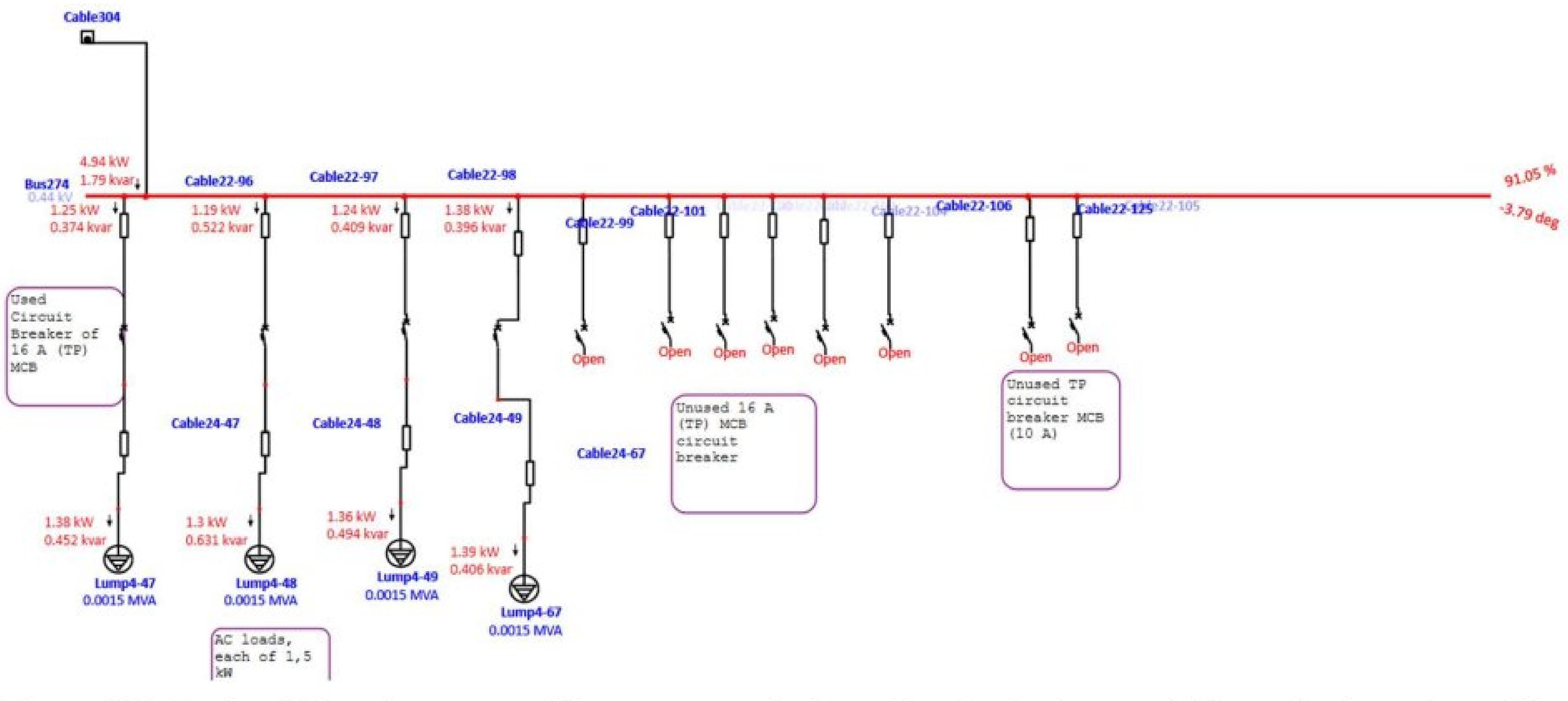


Figure 5.25: Real and Reactive power with percentage of voltage drop in the bus out of the total voltage drop of bus for the composite network of 4th floor of 2nd academic building

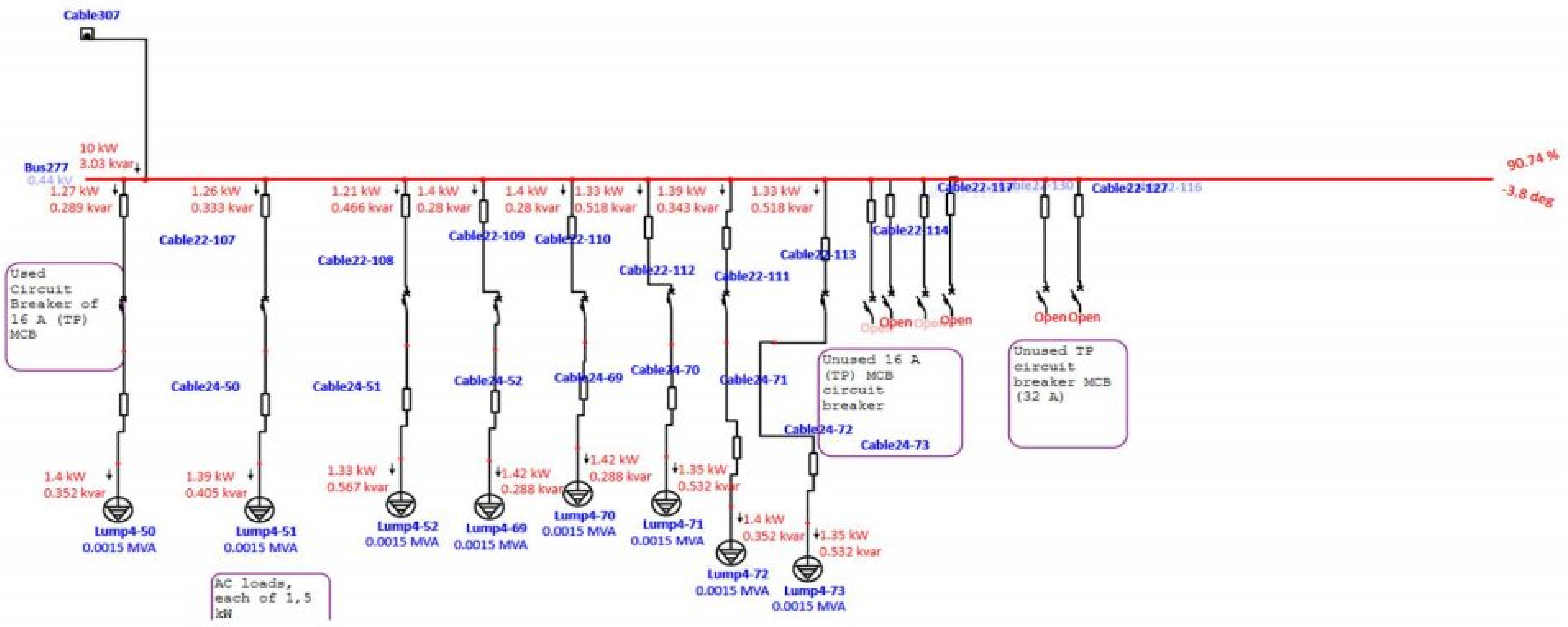


Figure 5.26: Real and Reactive power with percentage of voltage drop in the bus out of the total voltage drop of bus for the composite network of 5th floor of 2nd academic building

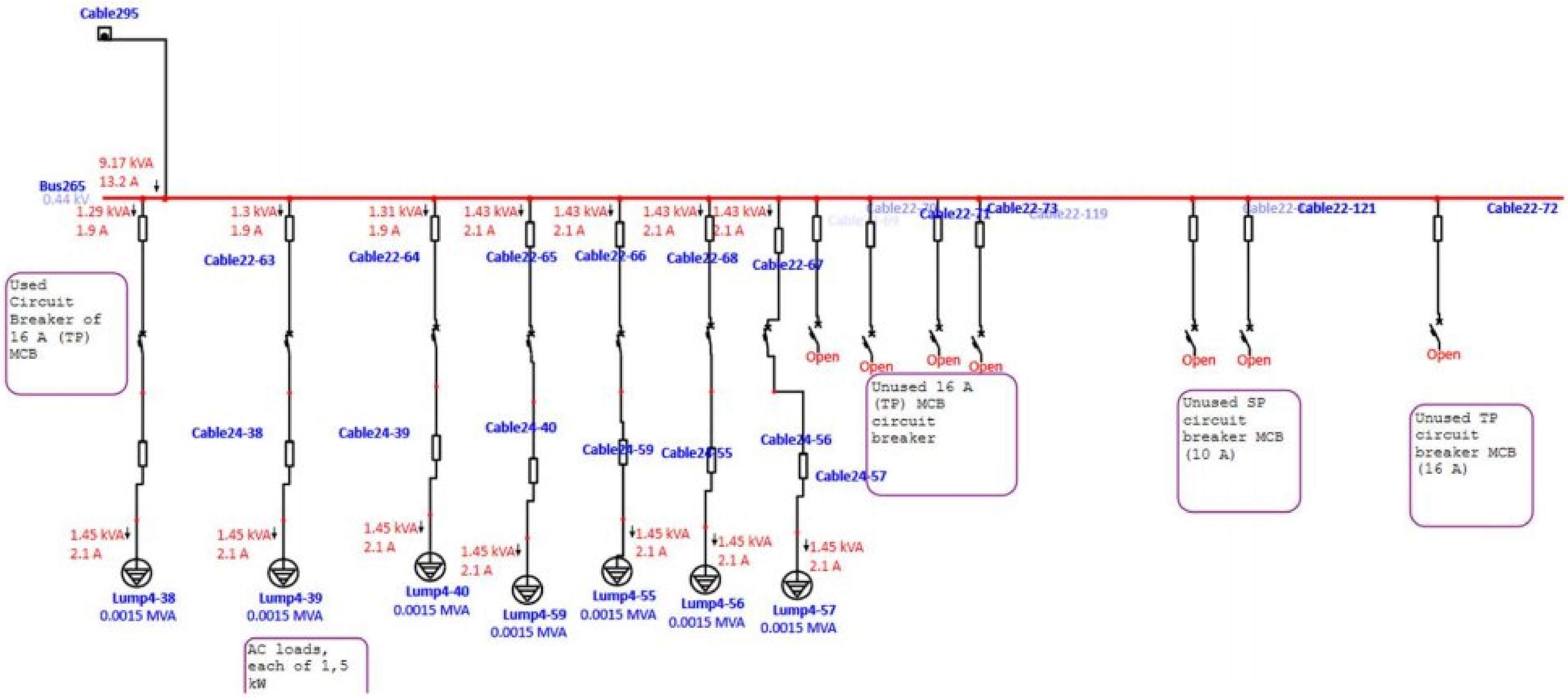


Figure 5.27: Current and apparent power flow through the 1st floor of 1st academic building

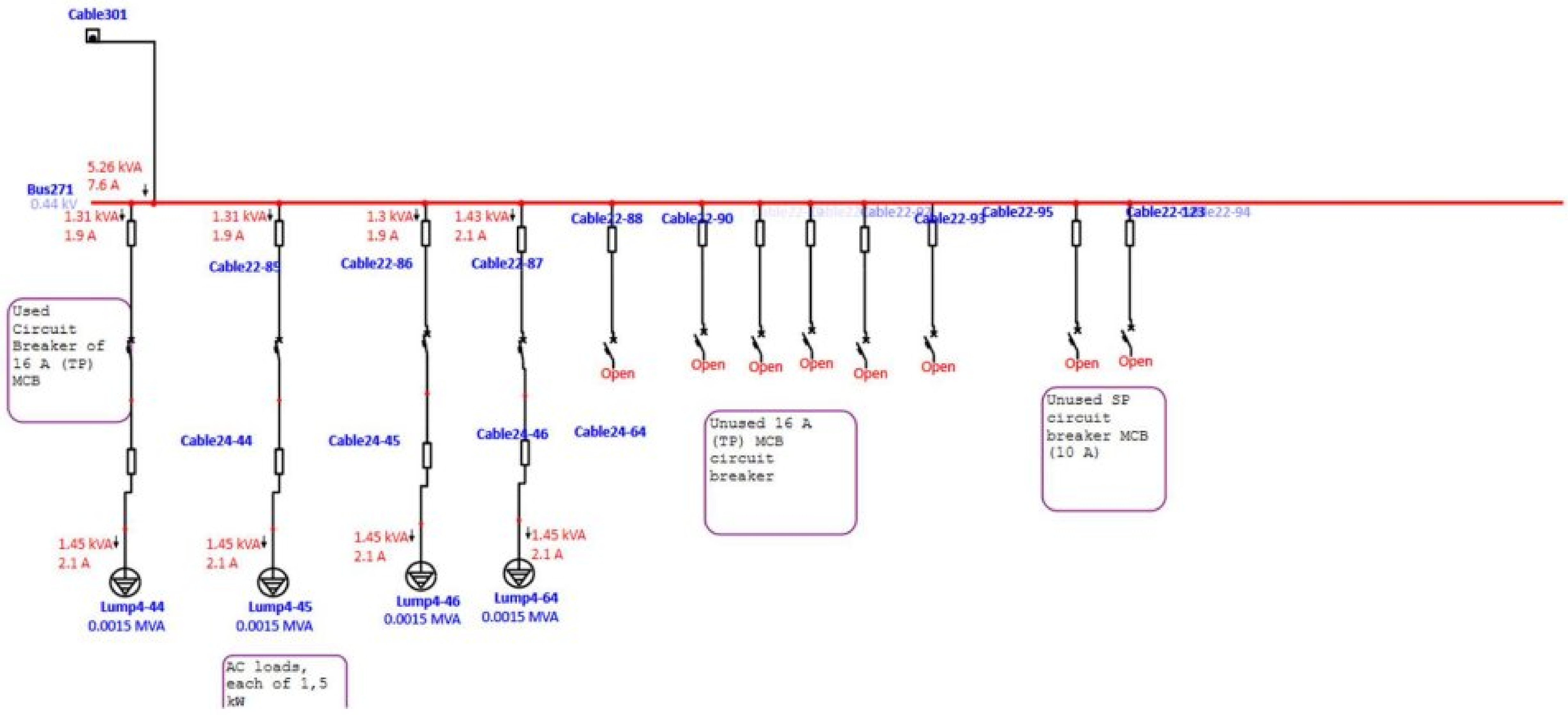


Figure 5.28: Current and apparent power flow through the 3rd floor of 1st academic building

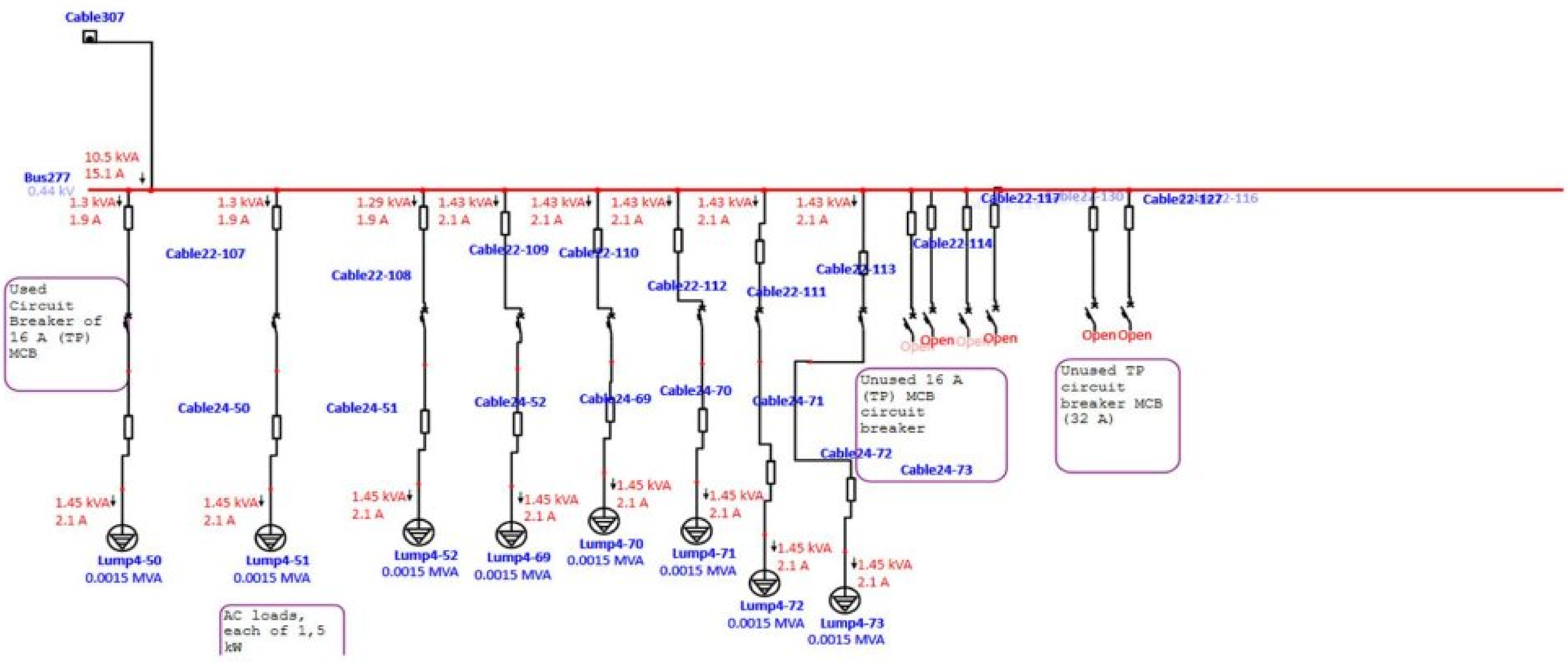


Figure 5.29: Current and apparent power flow through the 5th floor of 1st academic building

5.2.2.3 Simulations for the third academic building

Below are the results of the simulation of real power, reactive power, percentage of bus voltage drop, current flow and apparent power flow that is flowing through the third academic building:

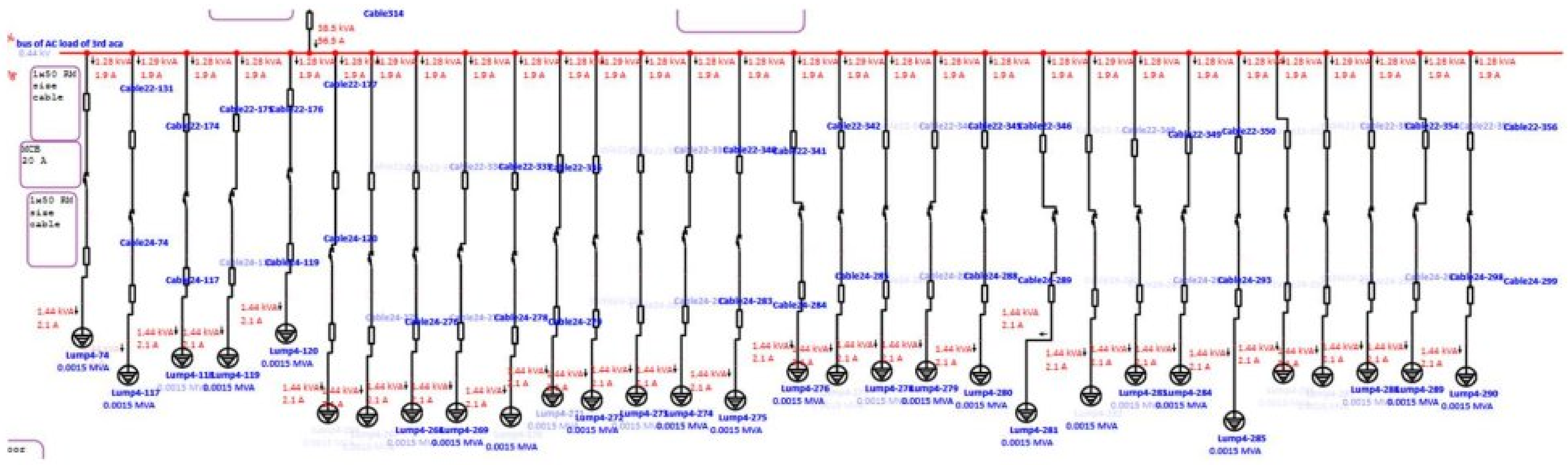


Figure 5.30:Current and apparent power flow, Real and reactive power flow through 25 AC loads with percentage of voltage drop in the bus out of the total voltage drop of bus for all the rooms situated in the 3rd academic building

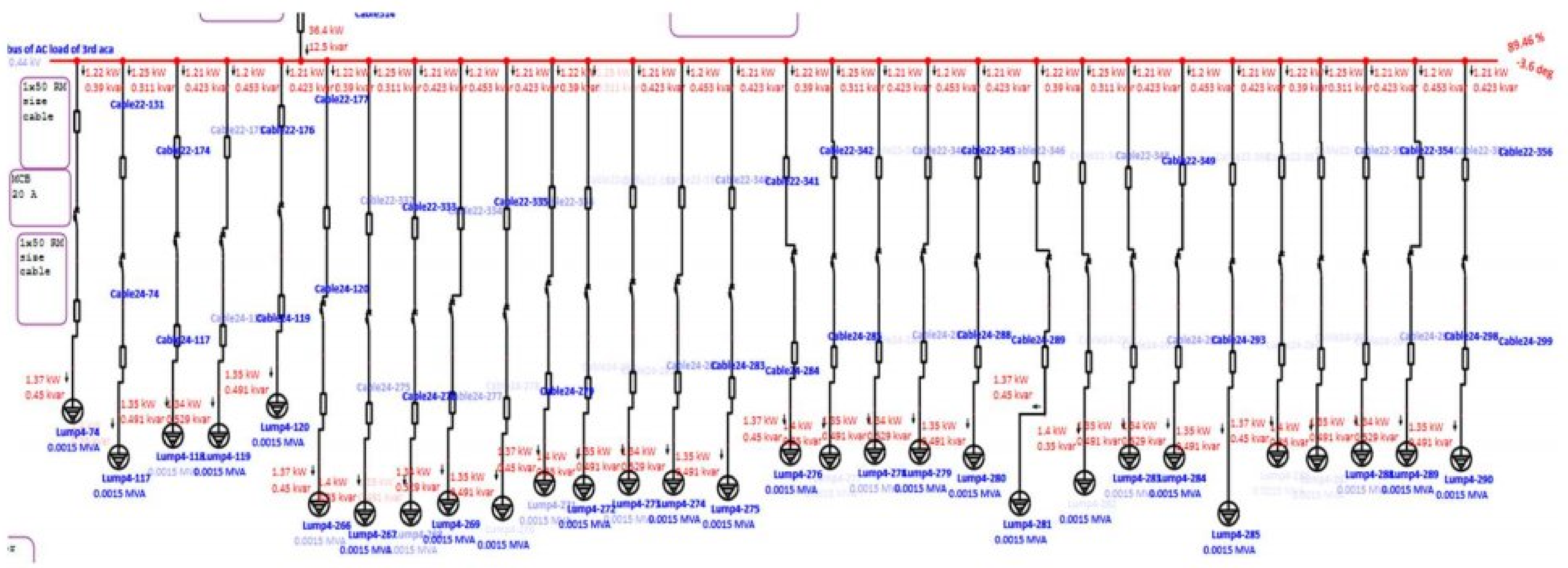


Figure 5.31: Real and reactive power flow through 25 AC loads with percentage of voltage drop in the bus out of the total voltage drop of bus for all the rooms situated in the 3rd academic building

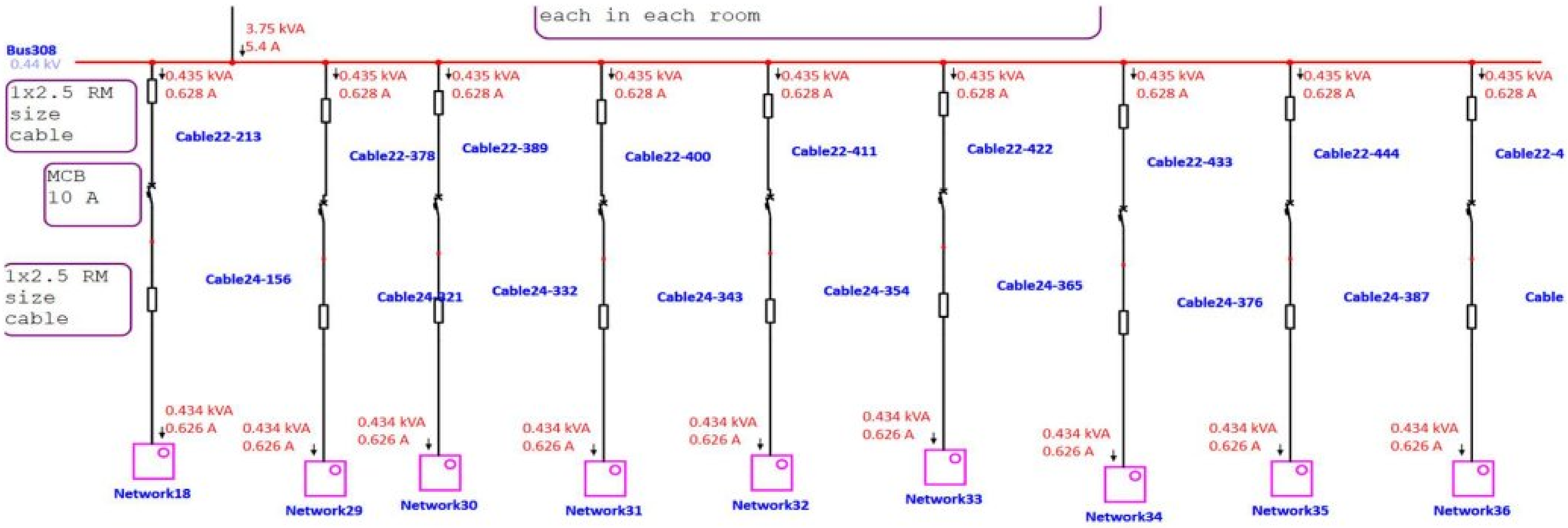


Figure 5.32: Current and apparent power flow of the 9 networks which is used for light and fan load of third academic building

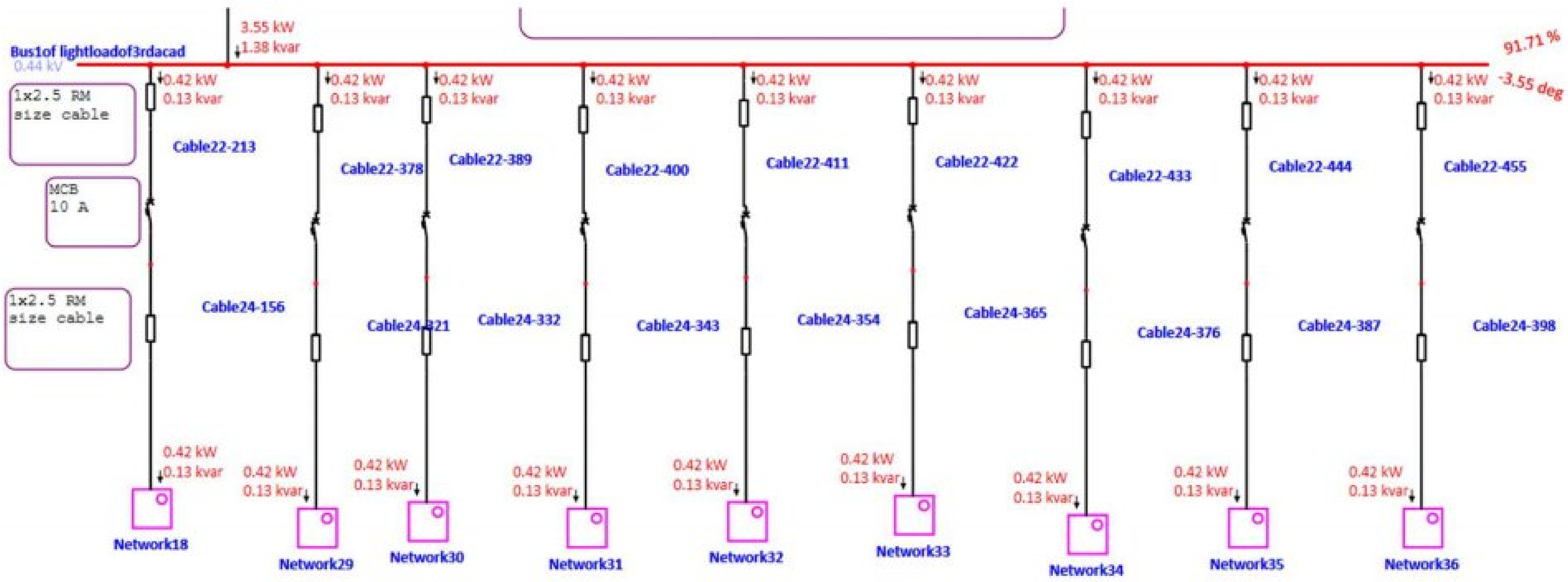


Figure 5.33: Real and reactive power flow through 9 of the distribution box where each distribution box connects light loads with each room with percentage of voltage drop in the bus out of the total voltage drop of bus of the 3rd academic building

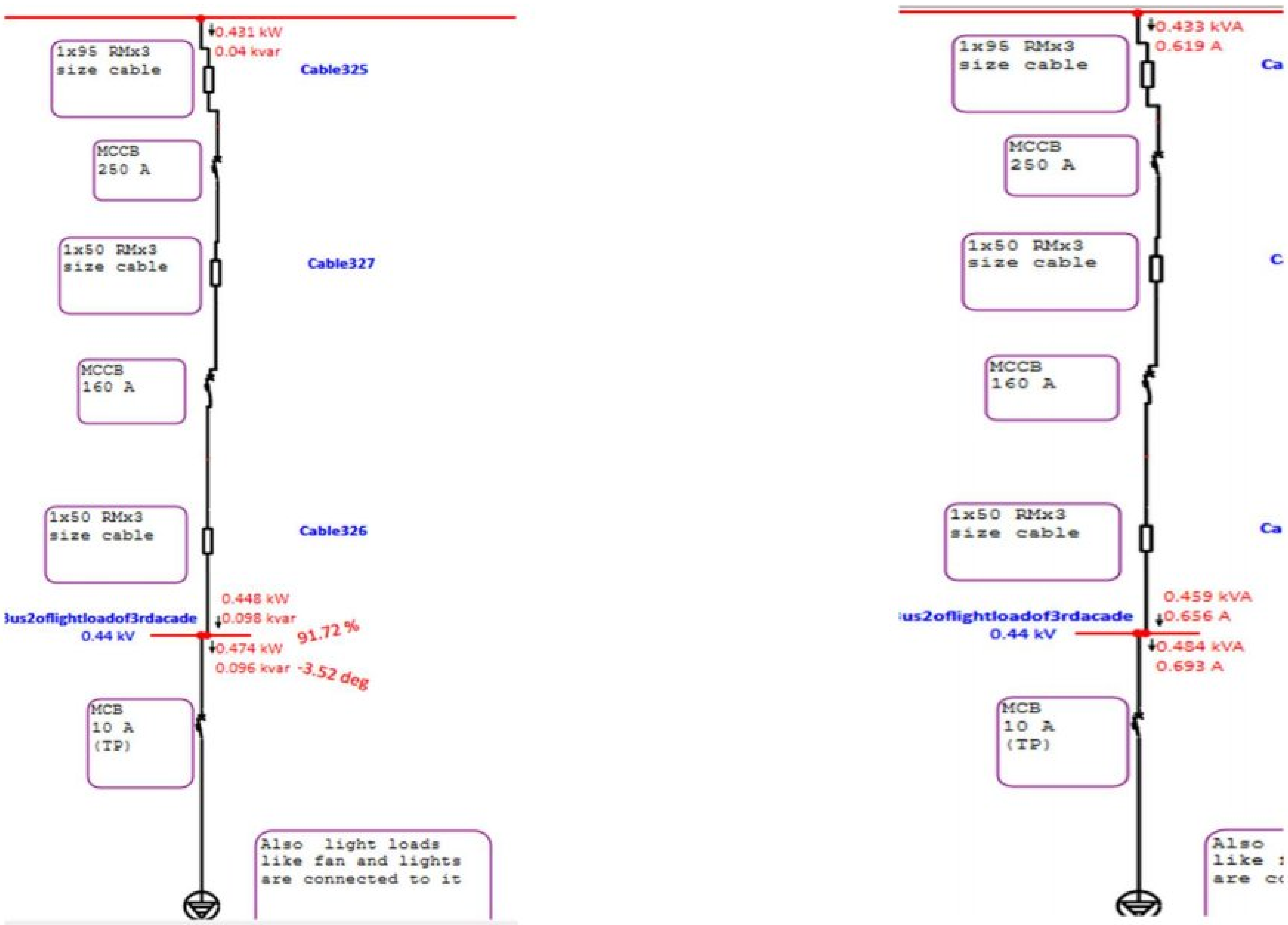


Figure 5.34: Real ,reactive power flow as well as current and apparent power flow to a single 10 A TP circuit breaker that is present within the sub distribution panel of the 3rd academic building

5.3 Statistical and tabular simulation results

In this section we have tried to show the overall simulation results of the IUT substation in both as a tabular data and statistical data. The data mainly includes the bus voltage drop, load flow in each networks, current and power flow through each networks etc.

5.3.1 Tabular simulation results

This section mainly mentions about the tabular results for the load flow analysis that we have got from the substation of IUT. Some of the tabular results are given below as follows:

Table 5.1: Input Data of some of the buses of present IUT substation

Bus Input Data

Bus			Initial Voltage		Constant kVA	
ID	kV	Sub-sys	% Mag.	Ang.	MW	Mvar
1st aca heavy load bus	0.440	1	100.0	0.0		
1st Academic Building bus	0.440	1	100.0	0.0		
Bus for the lift of 1st academic	0.440	1	100.0	0.0	0.062	0.028
Bus of 2nd academic	0.440	1	100.0	0.0		
bus of AC load of 3rd academic	0.440	1	100.0	0.0		
Bus of LT panel	0.440	1	100.0	0.0		
Bus1-2-1	11.000	1	100.0	0.0		
Bus-1 of light loads of 3rd academic	0.440	1	100.0	0.0		
Bus2-2-1	11.000	1	100.0	0.0		
Bus-2 of light loads of 3rd academic	0.440	1	100.0	0.0		
Bus3-2-1	0.440	1	100.0	0.0		
Bus4	11.000	1	100.0	0.0		

Table 5.2: Total Data of the buses of present IUT substation (according to the data got from survey and for only 1st,2nd and 3rd academic building)

Total Number of Buses	Constant Apparent Power (in KVA unit)		Constant Impedance (Z)	
	Real Power (MW)	Reactive Power (MVar)	Real Power (MW)	Reactive Power (MVar)
470	0.203	0.072	0.035	0.011

Table 5.3: Line/Cable/busway input data of present IUT substation (according to the data got from survey and for only 1st,2nd and 3rd academic building)

Line/Cable/Busway Input Data

Line/Cable/Busway	ohms or siemens/1000 m per Conductor (Cable) or per Phase (Line/Busway)		Length						
ID	Library	Size	Adj. (m)	% Tol.	#/Phase	T (°C)	R	X	Y
Cable1 from LTt oAC1acade	11MCUS3	120	400.0	0.0	3	75	0.186940	0.098800	0.0001147
cable1 from main bus 3rd	11MCUS1	630	400.0	0.0	4	75	0.040059	0.096500	0.0002193
cable1 LT light of 3rdaca	11MCUS1	630	400.0	0.0	4	75	0.040059	0.096500	0.0002193
Cable1 of 1f of 1st acade	11MCUS3	50	200.0	0.0	1	75	0.471165	0.115000	0.0000817
Cable1 of 1f of 2nd acade	11MCUS3	70	100.0	0.0	1	75	0.327145	0.108000	0.0000936
Cable1 of 2f of 1st acade	11MCUS3	50	200.0	0.0	1	75	0.471165	0.115000	0.0000817
Cable1 of 2f of 2nd acade	11MCUS3	70	100.0	0.0	1	75	0.327145	0.108000	0.0000936
Cable1 of 3f of 1st acade	11MCUS3	50	200.0	0.0	1	75	0.471165	0.115000	0.0000817
Cable1 of 3f of 2nd acade	11MCUS3	70	100.0	0.0	1	75	0.327145	0.108000	0.0000936
Cable1 of 4f of 1st acade	11MCUS3	50	200.0	0.0	1	75	0.471165	0.115000	0.0000817
Cable1 of 4f of 2nd acade	11MCUS3	70	100.0	0.0	1	75	0.327145	0.108000	0.0000936
Cable1 of 5f of 2nd acade	11MCUS3	70	100.0	0.0	1	75	0.327145	0.108000	0.0000936
cable1 of 5kW of 1st acad	11MCUS3	70	400.0	0.0	4	75	0.327145	0.108000	0.0000936

Table 5.4: Information table of the only two winding 2000 kVA transformer used in the substation

2-Winding Transformer Input Data

Transformer		Rating					Z Variation			% Tap Setting		Adjusted	Phase Shift	
ID	Phase	MVA	Prim. kV	Sec. kV	% Z1	X1/R1	+ 5%	- 5%	% Tol.	Prim.	Sec.	% Z	Type	Angle
Transformer of 2000 KVA rating With a centre tap to convert 215 V using trapping	3-Phase	2.000	11.000	0.440	6.25	6.00	0	0	0	0	0	6.2500	Dyn	0.000

Table 5.5: Information table showing the cable data used in the substation (up to the survey taken)

ohms or siemens/1000 m per Conductor (Cable) or per Phase (Line/Busway)						
Line/Cable/Busway	**Length**					
ID	**Size**	**Adj. (m)**	**#/Phase**	**R**	**X**	**Y**
Cable1 from LT panel to AC load of 1st academic building	120	400	3	0.18694	0.0988	0.000115
cable1 from main bus to 3rd academic building	630	400	4	0.040059	0.0965	0.000219
cable1 from LT panel to light of 3rd academic building	630	400	4	0.040059	0.0965	0.000219
Cable1 of 1st floor of 1st academic building	50	200	1	0.471165	0.115	8.17E-05
Cable1 of 1st floor of 2nd academic building	70	100	1	0.327145	0.108	9.36E-05
Cable1 of 2nd floor of 1st academic building	50	200	1	0.471165	0.115	8.17E-05
Cable1 of 2nd floor of 2nd academic building	70	100	1	0.327145	0.108	9.36E-05
Cable1 of 3rd floor of 1st academic building	50	200	1	0.471165	0.115	8.17E-05
Cable1 of 3rd floor of 2nd academic building	70	100	1	0.327145	0.108	9.36E-05
Cable1 of 4th floor of 1st academic building	50	200	1	0.471165	0.115	8.17E-05
Cable1 of 4th floor of 2nd academic building	70	100	1	0.327145	0.108	9.36E-05
Cable1 of 5th floor of 2nd academic building	70	100	1	0.327145	0.108	9.36E-05
cable1 of 5kW load of 1st academic building	70	400	4	0.327145	0.108	9.36E-05
cable1 of ac of 1st academic building	630	400	4	0.040059	0.0965	0.000219
cable1 of ac of 3rd academic building	95	400	3	0.236536	0.123	0.000102
Cable1 of ground floor of 2nd academic building	70	100	1	0.327145	0.108	9.36E-05
Cable1 of lift load of 1st academic building	16	400	1	1.398526		

ohms or siemens/1000 m per Conductor (Cable) or per Phase (Line/Busway)						
Line/Cable/Busway	**Length**					
ID	**Size**	**Adj. (m)**	**#/Phase**	**R**	**X**	**Y**
cable1 to TP (Triple Pole) circuit breaker of 3rd academic building	95	400	4	0.236536	0.123	0.000102
Cable2 from LT to AC of 1st academic building	70	300	4	0.327145	0.108	9.36E-05
cable2 from main bus 3rd academic	630	400	4	0.040059	0.0965	0.000219
cable2 from LT panel to light of 3rd academic building	630	400	4	0.040059	0.0965	0.000219
Cable2 of 1st floor of 1st academic building	50	200	1	0.471165	0.115	8.17E-05
Cable2 of 1st floor of 2nd academic building	70	100	1	0.327145	0.108	9.36E-05
Cable2 of 2nd floor of 1st academic building	50	200	1	0.471165	0.115	8.17E-05
Cable2 of 2nd floor of 2nd academic building	70	100	1	0.327145	0.108	9.36E-05
Cable2 of 3rd floor of 1st academic building	50	200	1	0.471165	0.115	8.17E-05
Cable2 of 3rd floor of 2nd academic building	70	100	1	0.327145	0.108	9.36E-05
Cable2 of 4th floor of 1st academic building	50	200	1	0.471165	0.115	8.17E-05
Cable2 of 4th floor of 2nd academic building	70	100	1	0.327145	0.108	9.36E-05
Cable2 of 5th floor of 2nd academic building	70	100	1	0.327145	0.108	9.36E-05
cable2 of 5kW load of 1st academic building	70	300	4	0.327145	0.108	9.36E-05
cable2 of ac of 1st academic building	630	400	4	0.040059	0.0965	0.000219
cable2 of ac of 3rd academic building	70	400	4	0.327145	0.13	9.05E-05
Cable2 of ground floor of 2nd academic building	70	100	1	0.327145	0.108	9.36E-05
Cable2 of lift load of 1st academic building	16	400	1	1.398526		
cable2 of light of 3rd academic building	2.5	5	1	9.011375		
cable2 to TP (Triple Pole) circuit breaker of 3rd academic building	50	400	4	0.471165	0.138	7.92E-05
Cable3 from LT to AC of 1st academic building	70	300	4	0.327145	0.108	9.36E-05

ohms or siemens/1000 m per Conductor (Cable) or per Phase (Line/Busway)						
Line/Cable/Busway	**Length**					
ID	**Size**	**Adj. (m)**	**#/Phase**	**R**	**X**	**Y**
cable3 from main bus 3rd academic building	630	400	4	0.040059	0.0965	0.000219
cable3 LT light of 3rd academic building	630	400	4	0.040059	0.0965	0.000219
Cable3 of 1st floor of 1st academic building	50	200	1	0.471165	0.115	8.17E-05
Cable3 of 1st floor of 2nd academic building	70	100	1	0.327145	0.108	9.36E-05
Cable3 of 2nd floor of 1st academic building	50	200	1	0.471165	0.115	8.17E-05
Cable3 of 2nd floor of 2nd academic building	70	100	1	0.327145	0.108	9.36E-05
Cable3 of 3rd floor of 1st academic building	50	200	1	0.471165	0.115	8.17E-05
Cable3 of 3rd floor of 2nd academic building	70	100	1	0.327145	0.108	9.36E-05
Cable3 of 4th floor of 1st academic building	50	200	1	0.471165	0.115	8.17E-05
Cable3 of 4th floor of 2nd academic building	70	100	1	0.327145	0.108	9.36E-05
Cable3 of 5th floor of 2nd academic building	70	100	1	0.327145	0.108	9.36E-05
cable3 of 5kW load of 1st academic building	70	300	4	0.327145	0.108	9.36E-05
cable3 of ac of 1st academic building	630	400	4	0.040059	0.0965	0.000219
cable3 of ac of 3rd academic building	70	400	4	0.327145	0.13	9.05E-05
Cable3 of gf of 2nd academic building	70	100	1	0.327145	0.108	9.36E-05
cable3 of light of 3rd academic building	2.5	10	1	9.011375		
cable3 to TP CB of 3rd academic building	50	400	4	0.471165	0.138	7.92E-05
cable4 of light of 3rd academic building	2.5	5	1	9.011375		
cable5 of light of 3rd academic building	2.5	10	1	9.011375		
cable6 of light of 3rd academic building	2.5	5	1	9.011375		
cable7 of light of 3rd academic building	2.5	10	1	9.011375		
cable8 of light of 3rd academic building	2.5	5	1	9.011375		

ohms or siemens/1000 m per Conductor (Cable) or per Phase (Line/Busway)						
Line/Cable/Busway	**Length**					
ID	**Size**	**Adj. (m)**	**#/Phase**	**R**	**X**	**Y**
cable9 of light of 3rd academic building	2.5	10	1	9.011375		
cable10 of light of 3rd academic building	2.5	5	1	9.011375		
cable11 of light of 3rd academic building	2.5	10	1	9.011375		
cable12 of light of 3rd academic building	2.5	5	1	9.011375		
cable13 of light of 3rd academic building	2.5	10	1	9.011375		
cable14 of light of 3rd academic building	2.5	5	1	9.011375		
cable15 of light of 3rd academic building	2.5	10	1	9.011375		
cable16 of light of 3rd academic building	2.5	5	1	9.011375		
cable17 of light of 3rd academic building	2.5	10	1	9.011375		

Table 5.6: Table showing the branch connections of all of the buses that are connected to the IUT substation

Connected Bus ID		**% Impedance, Pos. Seq., 100 MVA Base**			
From Bus	**To Bus**	**R**	**X**	**Z**	**Y**
Bus2-2-1	Bus3-2-1	51.37468	308.2481	312.5	
Bus of LT panel	Bus11	1287.465	680.4408	1456.216	2.66E-05
Main bus of light load of 3rd academic building	Bus304	206.914	498.4504	539.6909	6.79E-05
Bus of LT panel	Bus298	206.914	498.4504	539.6909	6.79E-05
1st Academic Building bus	Bus15	4867.406	1188.017	5010.292	3.16E-06
Bus of 2nd academic	Bus267	1689.798	557.8513	1779.498	1.81E-06
1st Academic Building bus	Bus183	4867.406	1188.017	5010.292	3.16E-06
Bus of 2nd academic	Bus270	1689.798	557.8513	1779.498	1.81E-06
1st Academic Building bus	Bus200	4867.406	1188.017	5010.292	3.16E-06
Bus of 2nd academic	Bus273	1689.798	557.8513	1779.498	1.81E-06
1st Academic Building bus	Bus217	4867.406	1188.017	5010.292	3.16E-06
Bus of 2nd academic	Bus276	1689.798	557.8513	1779.498	1.81E-06
Bus of 2nd academic	Bus279	1689.798	557.8513	1779.498	1.81E-06

Connected Bus ID		% Impedance, Pos. Seq., 100 MVA Base			
From Bus	**To Bus**	**R**	**X**	**Z**	**Y**
Bus of LT panel	Bus248	1689.798	557.8513	1779.498	2.9E-05
Bus of LT panel	Bus257	206.914	498.4504	539.6909	6.79E-05
Bus of LT panel	Bus296	1629.037	847.1075	1836.125	2.36E-05
Bus of 2nd academic	Bus258	1689.798	557.8513	1779.498	1.81E-06
Bus of LT panel	Bus7	28895.17			
Bus1 of light load of 3rd academic building	Bus19-145	4654.636			
Main bus of light load of 3rd academic building	Bus306	1221.778	635.3306	1377.093	3.14E-05
Bus11	Bus12	1267.348	418.3885	1334.624	2.17E-05
Bus304	Bus305	206.914	498.4504	539.6909	6.79E-05
Bus298	Bus299	206.914	498.4504	539.6909	6.79E-05
Bus15	Bus16	4867.406	1188.017	5010.292	3.16E-06
Bus267	Bus266	1689.798	557.8513	1779.498	1.81E-06
Bus183	Bus199	4867.406	1188.017	5010.292	3.16E-06
Bus270	Bus269	1689.798	557.8513	1779.498	1.81E-06
Bus200	Bus216	4867.406	1188.017	5010.292	3.16E-06
Bus273	Bus272	1689.798	557.8513	1779.498	1.81E-06
Bus217	Bus233	4867.406	1188.017	5010.292	3.16E-06
Bus276	Bus275	1689.798	557.8513	1779.498	1.81E-06
Bus279	Bus278	1689.798	557.8513	1779.498	1.81E-06
Bus248	Bus249	1267.348	418.3885	1334.624	2.17E-05
Bus257	Bus256	206.914	498.4504	539.6909	6.79E-05
Bus296	Bus297	1689.798	671.4876	1818.327	2.8E-05
Bus258	Bus260	1689.798	557.8513	1779.498	1.81E-06
Bus7	1st academic lift bus	28895.17	28895.17		
Bus19-145	Bus310	2327.318	2327.318		
Bus306	Bus307	2433.703	712.8099	2535.943	2.45E-05
Bus12	1st Academic Building bus	1267.348	418.3885	1334.624	2.17E-05
Bus305	Bus1 of light load of 3rd academic building	206.914	498.4504	539.6909	6.79E-05
Bus299	Main bus of light load of 3rd academic building	206.914	498.4504	539.6909	6.79E-05
Bus16	Bus18	4867.406	1188.017	5010.292	3.16E-06
Bus266	Bus265	1689.798	557.8513	1779.498	1.81E-06
Bus199	Bus198	4867.406	1188.017	5010.292	3.16E-06
Bus269	Bus268	1689.798	557.8513	1779.498	1.81E-06

Connected Bus ID		% Impedance, Pos. Seq., 100 MVA Base			
From Bus	To Bus	R	X	Z	Y
Bus216	Bus215	4867.406	1188.017	5010.292	3.16E-06
Bus272	Bus271	1689.798	557.8513	1779.498	1.81E-06
Bus233	Bus232	4867.406	1188.017	5010.292	3.16E-06
Bus275	Bus274	1689.798	557.8513	1779.498	1.81E-06
Bus278	Bus277	1689.798	557.8513	1779.498	1.81E-06
Bus249	Heavy load bus of 1st academic building	1267.348	418.3885	1334.624	2.17E-05
Bus256	Bus of 2nd academic	206.914	498.4504	539.6909	6.79E-05
Bus297	bus of AC load of 3rd academic building	1689.798	671.4876	1818.327	2.8E-05
Bus260	Bus261	1689.798	557.8513	1779.498	1.81E-06
Bus1 of light load of 3rd academic building	Bus19-310	4654.636	4654.636		
Bus307	Bus2 of light load of 3rd academic building	2433.703	712.8099	2535.943	2.45E-05
Bus19-310	Bus323	2327.318	2327.318		
Bus1 of light load of 3rd academic building	Bus19-321	4654.636	4654.636		
Bus19-321	Bus324	2327.318	2327.318		
Bus1 of light load of 3rd academic building	Bus19-332	4654.636	4654.636		
Bus19-332	Bus325	2327.318	2327.318		
Bus1 of light load of 3rd academic building	Bus19-343	4654.636	4654.636		
Bus19-343	Bus326	2327.318	2327.318		
Bus1 of light load of 3rd academic building	Bus19-354	4654.636	4654.636		
Bus19-354	Bus327	2327.318	2327.318		
Bus1 of light load of 3rd academic building	Bus19-365	4654.636	4654.636		
Bus19-365	Bus328	2327.318	2327.318		
Bus1 of light load of 3rd academic building	Bus19-376	4654.636	4654.636		
Bus19-376	Bus329	2327.318	2327.318		

Connected Bus ID		% Impedance, Pos. Seq., 100 MVA Base			
From Bus	**To Bus**	**R**	**X**	**Z**	**Y**
Bus1 of light load of 3rd academic building	Bus19-387	4654.636	4654.636		
Bus19-387	Bus330	2327.318	2327.318		
Bus18	Bus19	2895.799	2895.799		
Bus18	Bus19-1	2895.799	2895.799		
Bus198	Bus19-14	2895.799	2895.799		
Bus3-2-1	Bus of LT panel	1970.61	2257.231	2996.397	1.59E-05
Bus1-2-1	Bus4	4.035809	5.613223	6.913467	0.017637
Bus4	Bus2-2-1	102.088	204.9811	228.996	0.001395

Table 5.7: Table showing the branch loading summary of the busway or cable and reactor of the IUT substation

CKT / Branch		Busway / Cable & Reactor	
ID	**Type**	**Ampacity (Amp)**	**Loading Amp**
Cable1 from LT to AC of 1st academic building	Cable	776.0662	72.8474
cable1 from main bus of 3rd academic building	Cable	2235.521	5.386554
cable1 from LT panel to light of 3rd academic building	Cable	2235.521	1.149692
Cable1 of 1st floor of 1st academic building	Cable	158.9101	14.95674
Cable1 of 1st floor of 2nd academic building	Cable	191.7865	13.24775
Cable1 of 2nd floor of 1st academic building	Cable	158.9101	18.63935
Cable1 of 2nd floor of 2nd academic building	Cable	191.7865	7.552257
Cable1 of 3rd floor of 1st academic building	Cable	158.9101	20.49887
Cable1 of 3rd floor of 2nd academic building	Cable	191.7865	7.578086
Cable1 of 4th floor of 1st academic building	Cable	158.9101	14.92723
Cable1 of 4th floor of 2nd academic building	Cable	191.7865	7.575321
Cable1 of 5th floor of 2nd academic building	Cable	191.7865	15.11913

CKT / Branch		Busway / Cable & Reactor	
ID	Type	Ampacity (Amp)	Loading Amp
cable1 of 5kW of 1st academic building	Cable	767.1459	36.6801
cable1 of ac of 1st academic building	Cable	2235.521	49.03962
cable1 of ac of 3rd academic building	Cable	816.2076	55.11742
Cable1 of ground floor of 2nd academic building	Cable	191.7865	5.685318
cable1 of light of 3rd academic building	Cable	27.936	0.6288341
cable1 to TP (Triple Pole) circuit breaker of 3rd academic building	Cable	1088.277	0.623629
Cable2 from LT panel to AC load of 1st academic building	Cable	767.1459	74.67831
cable2 from main bus of 3rd academic building	Cable	2235.521	5.416521
cable2 that comes from LT panel to light of 3rd academic building	Cable	2235.521	5.906178
Cable2 of 1st floor of 1st academic building	Cable	158.9101	14.95736
Cable2 of 1st floor of 2nd academic building	Cable	191.7865	13.24863
Cable2 of 2nd floor of 1st academic building	Cable	158.9101	18.72662
Cable2 of 2nd floor of 2nd academic building	Cable	191.7865	7.553008
Cable2 of 3rd floor of 1st academic building	Cable	158.9101	20.57872
Cable2 of 3rd floor of 2nd academic building	Cable	191.7865	7.579014
Cable2 of 4th floor of 1st academic building	Cable	158.9101	14.95547
Cable2 of 4th floor of 2nd academic building	Cable	191.7865	7.576343
Cable2 of 5th floor of 2nd academic building	Cable	191.7865	15.11998
cable2 of 5kW load of 1st academic building	Cable	767.1459	37.81739
cable2 of ac of 1st academic building	Cable	2235.521	53.94519
cable2 of ac of 3rd academic building	Cable	927.7113	56.46556
Cable2 of ground floor of 2nd academic building	Cable	191.7865	5.68592

CKT / Branch		Busway / Cable & Reactor	
ID	Type	Ampacity (Amp)	Loading Amp
Cable2 of lift load of 1st academic building	Cable	89.3952	114.9184
cable2 of light of 3rd academic building	Cable	27.936	0.6289225
cable2 to TP(Triple Pole) circuit breaker of 3rd academic building	Cable	776.8938	0.6878006
Cable3 from LT panel to the AC load of 1st academic building	Cable	767.1459	74.6865
cable3 from main bus to the 3rd academic building	Cable	2235.521	5.444765
cable3 from LT panel to light of 3rd academic building	Cable	2235.521	5.932365
Cable3 of 1st floor of 1st academic building	Cable	158.9101	14.95825
Cable3 of 1st floor of 2nd academic building	Cable	191.7865	13.24888
Cable3 of 2nd floor of 1st academic building	Cable	158.9101	18.66881
Cable3 of 2nd floor of 2nd academic building	Cable	191.7865	7.553221
Cable3 of 3rd floor of 1st academic building	Cable	158.9101	20.52485
Cable3 of 3rd floor of 2nd academic building	Cable	191.7865	7.579299
Cable3 of 4th floor of 1st academic building	Cable	158.9101	14.93798
Cable3 of 4th floor of 2nd academic building	Cable	191.7865	7.576652
Cable3 of 5th floor of 2nd academic building	Cable	191.7865	15.12021
cable3 of 5kW load of 1st academic building	Cable	767.1459	37.82507
cable3 of ac of 1st academic building	Cable	2235.521	53.92426
cable3 of ac of 3rd academic building	Cable	927.7113	56.47612
Cable3 of ground floor of 2nd academic building	Cable	191.7865	5.686708
cable3 of light of 3rd academic building	Cable	27.936	0.6288341
cable3 to TP(Triple Pole) Circuit breaker of 3rd academic building	Cable	776.8938	0.6560747

CKT / Branch		Busway / Cable & Reactor	
ID	Type	Ampacity (Amp)	Loading Amp
cable4 of light of 3rd academic building	Cable	27.936	0.6289225
cable5 of light of 3rd academic building	Cable	27.936	0.6288341
cable6 of light of 3rd academic building	Cable	27.936	0.6289225
cable7 of light of 3rd academic building	Cable	27.936	0.6288341
cable8 of light of 3rd academic building	Cable	27.936	0.6289225
cable9 of light of 3rd academic building	Cable	27.936	0.6288341
cable10 of light of 3rd academic building	Cable	27.936	0.6289225
cable11 of light of 3rd academic building	Cable	27.936	0.6288341
cable12 of light of 3rd academic building	Cable	27.936	0.6289225
cable13 of light of 3rd academic building	Cable	27.936	0.6288341
cable14 of light of 3rd academic building	Cable	27.936	0.6289225
cable15 of light of 3rd academic building	Cable	27.936	0.6288341
cable16 of light of 3rd academic building	Cable	27.936	0.6289225
cable17 of light of 3rd academic building	Cable	27.936	0.6288341
cable18 of light of 3rd academic building	Cable	27.936	0.6289225

5.3.2 Statistical simulation results

In this section we have mainly tried to show the plots of the statistical results of the bus and cable data that is shown through tables in the subsection 5.3.2.

Below there is shown the plots of the cable sizing, ampacity and loading statistical plot:

Figure 5.35: Line plot showing the variation of load (in MW unit) of each of the buses in the substation of IUT (by taking a portion of the table generated)

Figure 5.36: Line plot showing the variation of current (in A (ampere) unit) of each of the buses in the substation of IUT (by taking a portion of the table generated)

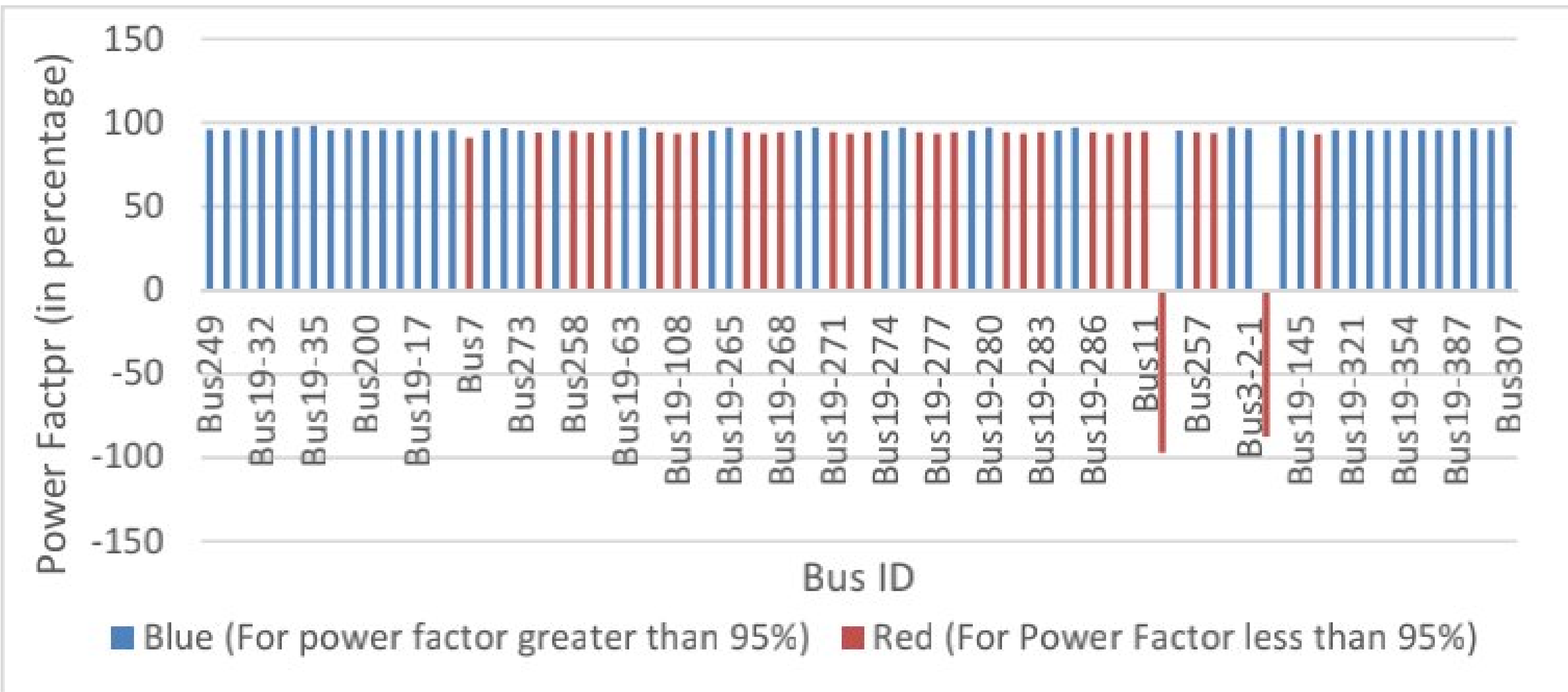


Figure 5.37: Column plot showing bus and its corresponding power factor along with ID used on the substation of IUT (by taking a portion of the table generated)

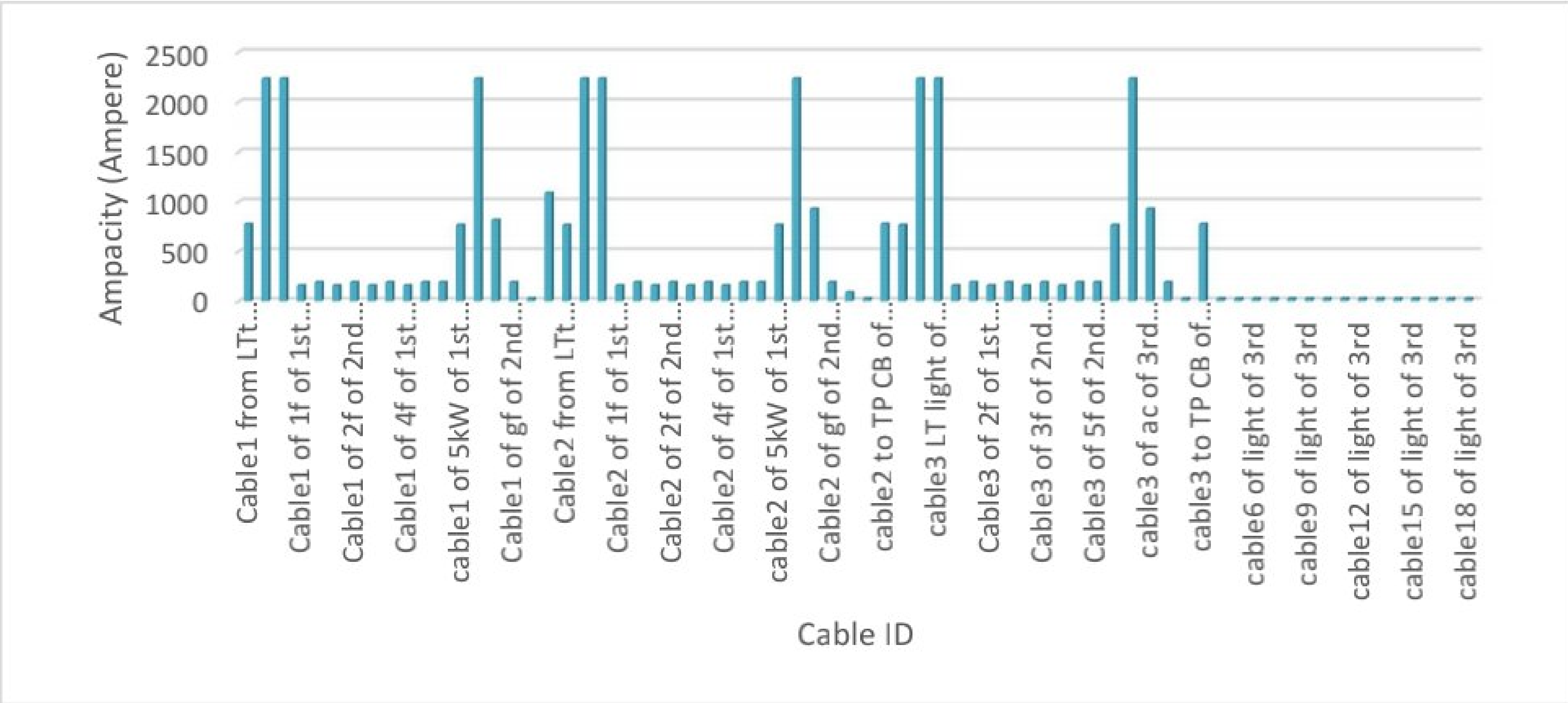


Figure 5.38: Column plot showing cable and its corresponding current carrying capacity or ampacity on the substation of IUT (by taking a portion of the table generated)

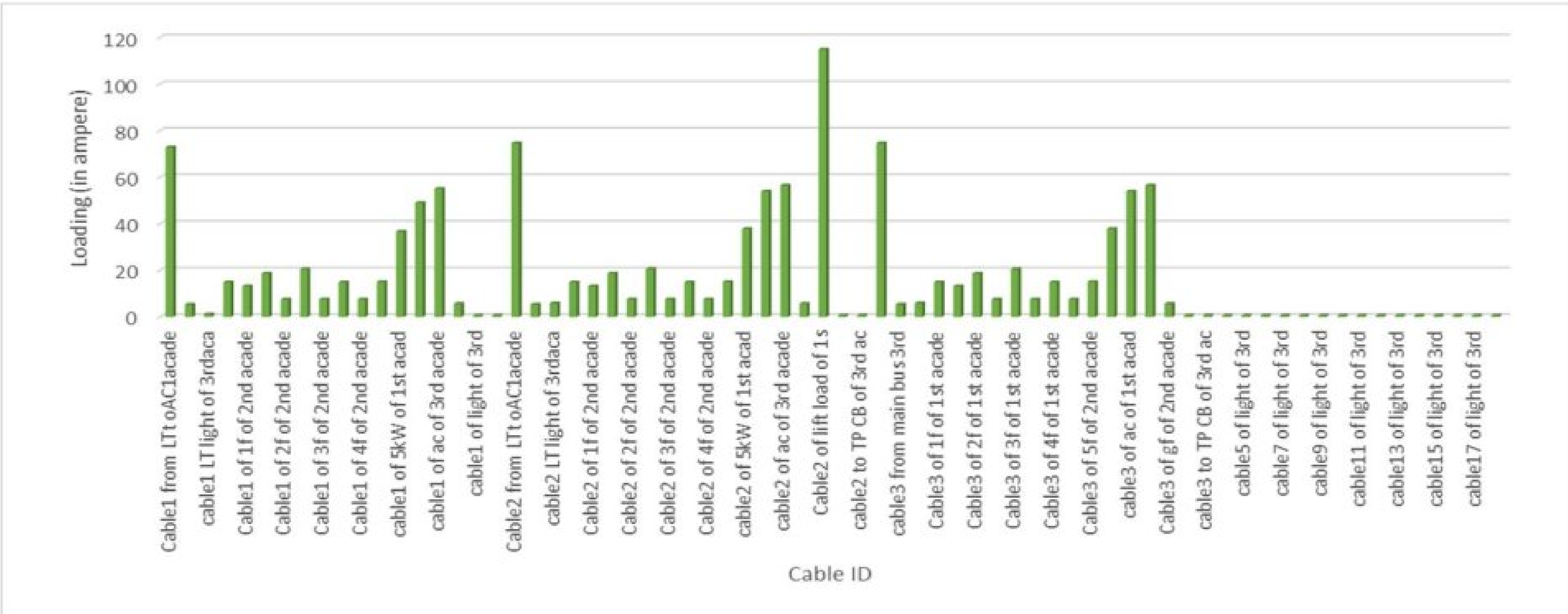


Figure 5.39: Column plot showing cable and its corresponding loading (in Ampere unit) on the substation of IUT(by taking a portion of the table generated)

5.4 Observations

From the simulation results, we can have the observations that is mentioned below:

1) Real and reactive power demands are more at the distribution side.
2) Apparent losses of both the real and reactive power are more on the distribution side.
3) The system mismatch with the original power system of the substation in terms of real and reactive power are more.
4) Total constant loads in each of the 1^{st},2^{nd} and 3^{rd} academic buildings are almost none.
5) More number of iterations have been taken to complete the optimal power flow study case analysis.
6) In most of the cases, while obtaining the voltage as well as real and reactive power ratings in each of the buses and loads, the %pf or percentage in terms of the power factor is seen to be much less and in most of the cases it is lagging.

7) Two of the buses are observed to be undervoltage than the rated one.
8) There were also shown critical reports that showed that many of the buses were under overload.
9) The critical report also showed that most of the buses were in overvoltage condition.
10) Much of the reactive power losses were seen for which in many cases reactive power compensation did not give appropriate results.
11) The load flow curve of figure in each of the buses are remaining constant but in some of the instances the load flow is seen to be increasing, specially at the larger size and current rating buses.
12) There can be seen many peaks within the current flow in each of the buses within the substation that indicates that in many of the buses, the current flow is higher and in other cases the current flow is remaining constant. This constant maintenance of current is near to zero in most of the buses.
13) In many of the cases, the power factor of each of the buses are remaining above 95 percent which is a good sign that can be seen clearly from the column graph of figure
14) The current carrying capacity or ampacity of many of the cables are seen to have much than the other cables that is depicted clearly in the figure
15) The current loading of some of the cables are seen to have high value unlike the ampacity value. The current loading pattern is seen to be repeated after some cables and the pattern shows that the current loading is gradually increasing and decreasing and then again starting its gradual increasing pattern.

5.5 Discussions on the simulation results

Based on the simulation results, we were able to come in the following decisions or conclusions for the present substation condition of IUT:

5.5.1 Observation-1: substation side issues

We found a couple of issues on the substation, i.e., from the main grid up to the transformer LT side. These are:

1) According to industry standards, the LT panel has multiple distribution bus bars, which is not recommended.
2) Two generators are not able to operate synchronously.
3) HT, LT, and distribution transformers are not placed according to BNBC (Bangladesh National Building Code) rules and regulations. -REF. BNBC 2006, VOL 3, SEC 1.3.23.2
4) The bus bar is not covered with a transparent ebonite plate on the HT and LT sides.
5) No phase marker is seen in most of the cases.
6) There are multiple bus bars in the LT panel, resulting in too much cable gathering.
7) Phase imbalance is seen as an asymmetric load supplied to each phase.
8) There are three sources of input to the LT panel, which should not be as it is. (ATS of G1, ATS of G2, BREB power through transformer)

5.5.2 Observation-2: distribution side issues

On the distribution side, there were also a couple of problems as well. These issues are being divided into two major parts. These are:

i) Panel faults/issues
ii) Busbar faults/issues

5.5.2.1 Panel faults

The two types of issues with panels that we have observed is:

1. Cable crunch is unused and not well protected.
2. Very congested bus bar holes. Standard guidelines are overruled.
3. Due to no secondary substation, the distance between the substation and distribution panels increases; resistance and loss increase.

5.5.2.2 Busbar faults

The different types of issues with busbars or buses that we have observed is:

1. With busbars, there is no ampere tube in most cases.
2. No heat exhaustion mechanism.
3. The cable joint via nut and bolt increases with the copper loss or I^2R loss.
4. There is not sufficient depth inside the panels for maintenance.
5. Mostly, there is no cable shoe while connecting them with the busbar.
6. There were many unnecessary holes in the busbar that led to a decrease in the current rating of the busbar.

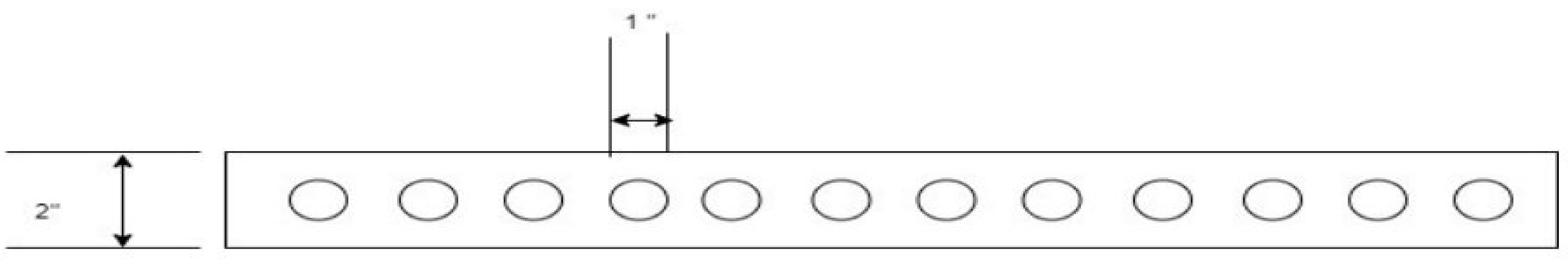


Figure 5.40: Standard busbar size

5.5.3 Observation-3: Underground cables resistance and insulation faults

We have found the following problems while going through a test that a company named ADEX ACL has made on the IUT substation a couple of months ago on the previous year:

ADEX-ACL

SOP: 601485

Date: 29.12.2021

Project Name: Islamic University of Technology.	
Project Address: Board Bazar, Gazipur, Bangladesh.	

Test Kit Details	**Test Perform By**
Test Kit Name: Digital Insulation Tester.	Signature:
Model Number: KEW3125A.	Name: Md Murad Mridha
Origin: KYORITSU, Japan.	Designation: Asistant Engineer-Project

Cable Details: 3Cx70Sqmm XLPE Cable

Cable Location Details	Description	Terminal Details	Result (MΩ)		Remarks
			30 Sec	60 Sec	
BREB Metering pole to 11kV HT Panel Incoming	Phase to Earth	E-L1	49.90	45.50	Not Satisfactory
		E-L2	53.30	53.00	
		E-L3	48.60	48.20	
	Phase to Phase	L1-L2	190.00	200.00	
		L2-L3	199.00	210.00	
		L1-L3	162.00	179.00	

Figure 5.41: Cable Testing done by ADEX-ACL

From the above testing above, the company have gone to the decision as remarks which is given below:

"Note: *We have tested IUT Substation on December 29, 2021 and found that 3Cx70 sq mm HT XLPE Cable has been used for 2000kVA substation, which is not suitable for the system. We recommend to use suitable cable size (e.g. 1855gmm). We found that existing HT Cable (70Sgmm) IR (Insulation Resistance) Test Result is not good enough for that system. As per IEC Standard minimum IR (Insulation Resistance) required (more than or equal) >1000M Ohms."*

Moreover, based on these concepts, the decisions that we have taken are:

1. The insulation resistance of the cable is significantly less. It should have been in the giga-ohms ($G\Omega$) range, but it is in the megaohms ($M\Omega$) range.

2. The phase to earth and phase to phase resistance did not give a more fair value of the resistance reading than expected.
3. The cable size used all over the IUT substation is not the proper one for which it fails to provide a satisfactory insulation resistance.
4. The cable sizing and the insulation resistance failed to maintain the IEC standards.

5.5.4 Observation-4: Breaker mismanagement faults

After going through the survey and the simulation results, we came to the following solutions when we observed the circuit breakers:

1. The electricians within the substation have made TP MCCB by adding three SP or vice versa.
2. If the cable size is less than the requirement, it will burn in the event of an overcurrent before the breaker can trip, causing a short circuit and even igniting a fire in the panel. This type of the same configuration is being done on the IUT, which is a concerning issue.

5.5.5 Observation-5: Reactive power compensation- an economical approach

Though we have found many bad conditions on many electrical components, such as cable connections, breaker connections, etc., IUT has an excellent provision for reactive power compensation within the whole substation. This is due to having the necessary number of capacitive banks in the LT panel. The considerable information that we have obtained after thorough surveying of the LT side is as follows:

1. Reactive power compensation capabilities should be more than 60% of the maximum demand. Our demand is around 1600 kW, 60% of that of 960 kVAR. The capacitor bank must install this much reactive power compensation capability.
2. However, the IUT has 1000 kVAR compensation capabilities, which is more than enough. Sometimes, sections of capacitor banks are kept unused for appropriate compensation.
3. This is strictly followed as BREB tariff system adds extra charges for low power factors, and economically concerned IUT substation designers give this their maximum priority.

5.6 Sum up of the overall observations from the survey and simulations of the IUT substation

If we want to conclude and want to make some final points on the overall surveying of the IUT substation as well as through the simulations in ETAP software:

1) Miss management in substation design and maintenance
2) Unorganized Distribution side
3) Economical concern over Safety and better load management.

Chapter 6

Solution of the Existing Issues of the IUT Substation and Proposing a Feasible Plan

6.1 Introduction

This chapter mainly focuses on the solution to the connection problem and the mismanagement of different electrical components within the IUT substation. This chapter also focuses on the proposition of a feasible plan to improve the current connections and patterns of the IUT substation by proposing a new substation model containing all the electrical components and connection patterns that can give a solution to all the problems the IUT substation is currently facing.

6.2 Proposition of a new substation design

The first and foremost proposition out of all the feasible plans out there that we are proposing is construction of a new substation design. Our new model of the substation design is clearly stated on the figure 6.1.

6.3 Proposed solutions for the improvements up to the LT panel

Our proposed substation model contains the following considerable improvements:

1) Two generators are interconnected with synchronizer in where the synchronization process is accomplished by using microcontrollers or PLCs. Two generators can be synchronized only when there is seen an equal magnitude of the following quantities:
   i) Voltage magnitude
   ii) Frequency
   iii) Phase angle and
   iv) Phase sequence

Figure 6.1: Synchronizer used to synchronize the generators

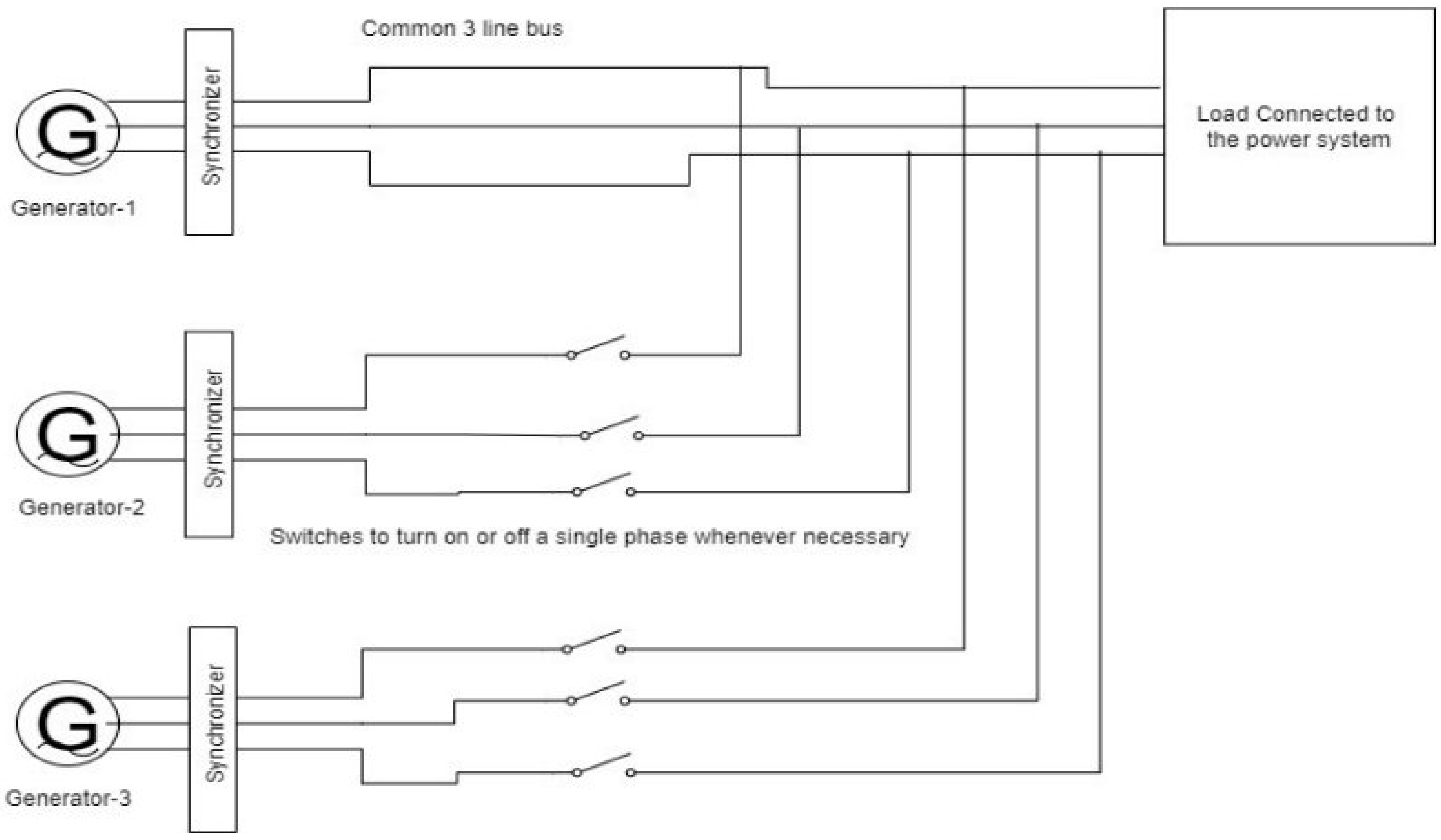


Figure 6.2: Process of running generators running parallel synchronously

2) Installation of HT switchgear alongside pre-existing VCB.
3) Using CT, a kind of instrumentation transformer that will be used for current reading and an overcurrent relay for protection (An overcurrent relay is mainly a type of relay that energizes when the load current exceeds a pickup or predetermined value).

Figure 6.3: Overcurrent Relay[22]

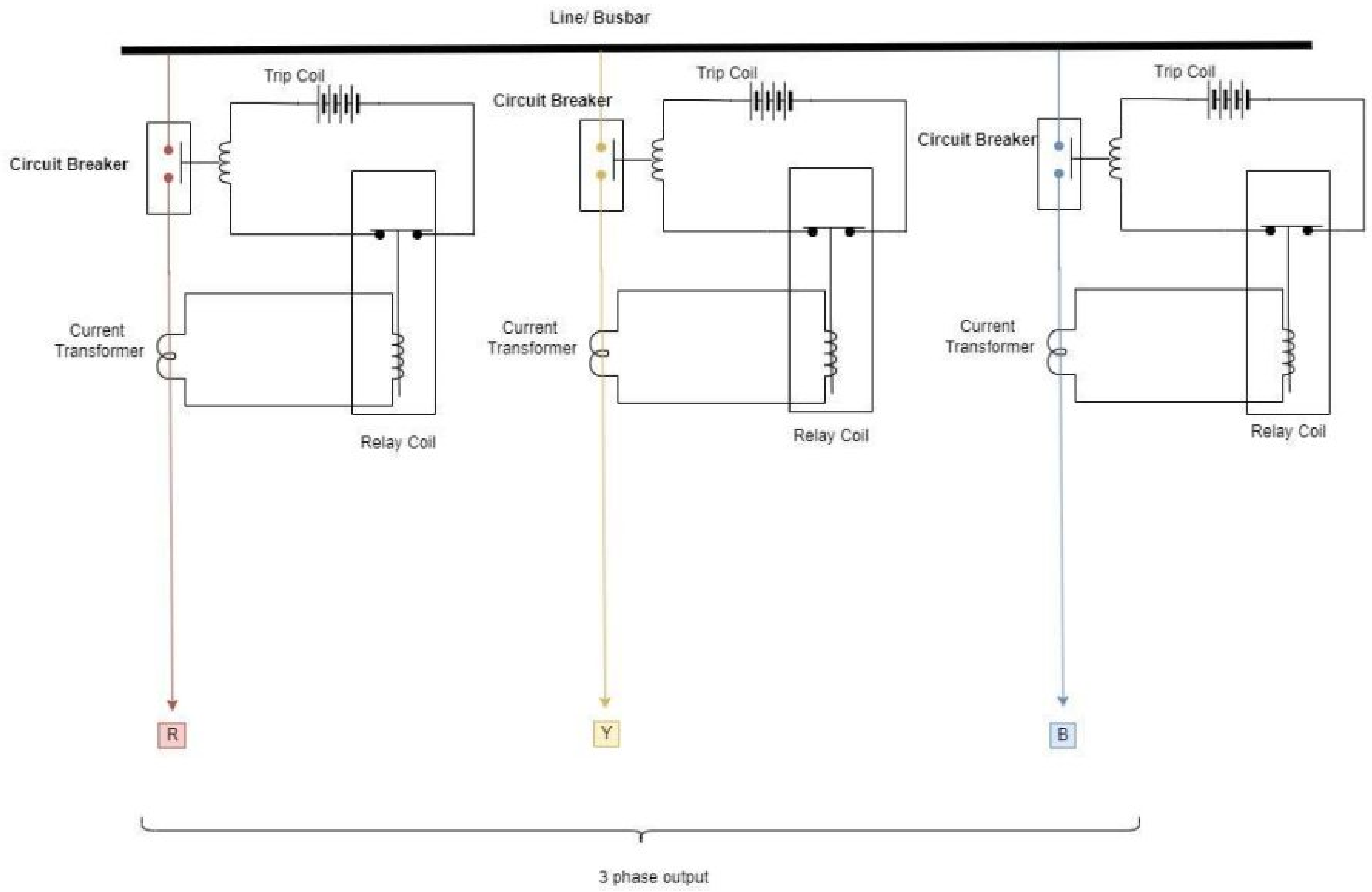


Figure 6.4 :Overcurrent Relay Configuration

4) Introduction of electrical interlocking and bus-coupler for solving issues at LT panels and ensuring smooth operation of Generators and transformers at the same time.

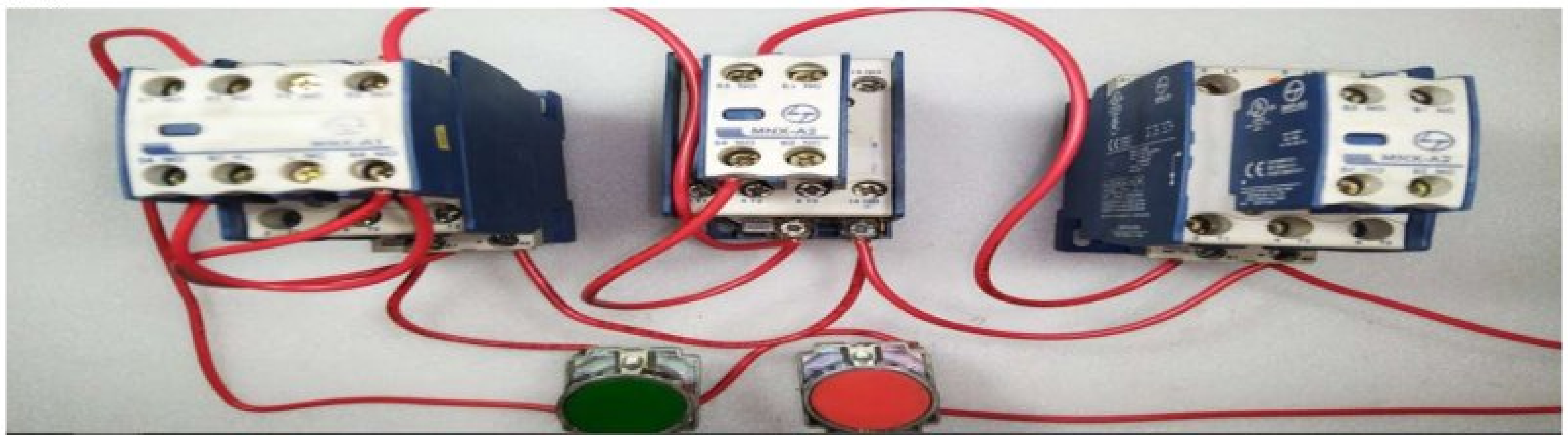


Figure 6.5: Electrical Interlocking sample[23]

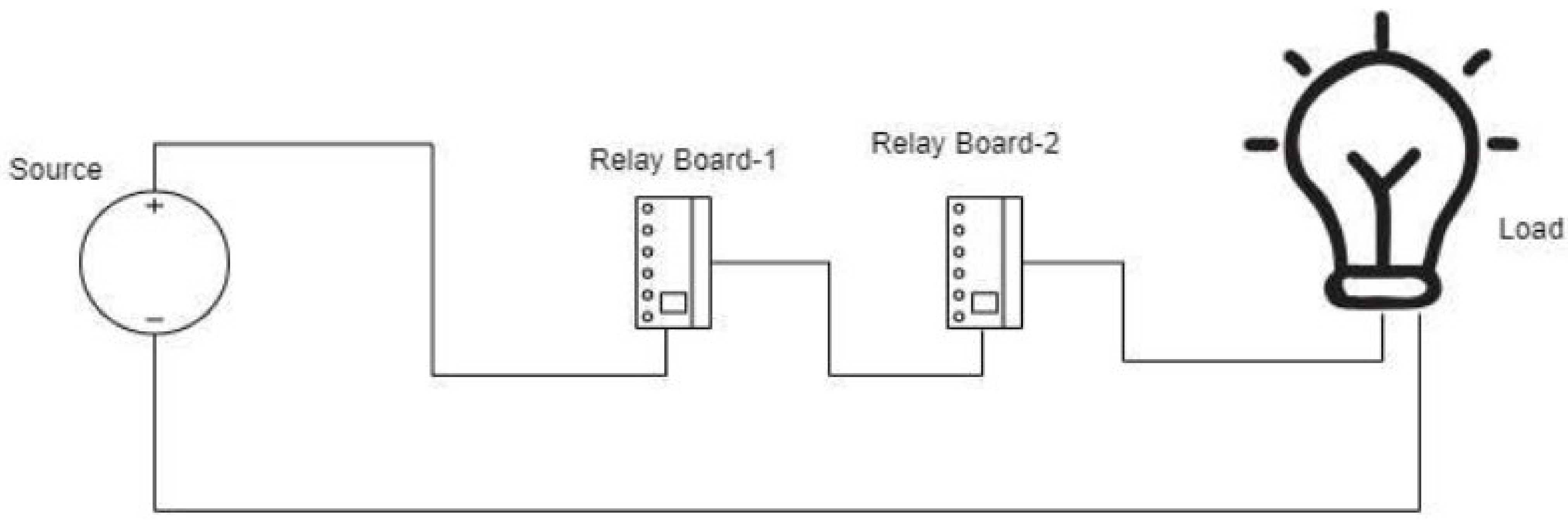


Figure 6.6 : Electrical Interlocking

5) New Grounding switches are needed to be introduced with the LT side to get rid of voltage surge and ground currents that can lead to ground faults.

6) Additional spare CBs are also required to be introduced – for operation under heavy load and expansion in future.
7) Placement of distribution side transformer according to BNBC Guidelines.

6.4 Proposed solutions for the improvements for the distribution side through distribution panel modification

We also proposed some of the possible solutions that can help improve the distribution side of the IUT substation that will ensure optimal power flow and help solve and mitigate all types of problems as mentioned in sub-section 5.4.2 of section 5.4 of chapter 5. The proposed solutions are:

1. Cable crunch, mainly the holes that are sealed to protect the cable, must be sealed with silicon to keep the panel dry and moisture-free. It also helps or protects against pests and insects.
2. The number of holes on the busbar must be considered considering the busbar size.
3. Proper phase labeling should be done and ensured.
4. Cable RM and size should be chosen according to the load and standards.
5. The heat exhaustion mechanism must be done by the exhaust fan of the heat sink.
6. Transparent Ebonite protection in front of the busbars should be placed.
7. The cable size should be greater than the breaker requirements.
8. Appropriate use of SP and TP breakers
9. The current unbalance among phases must be due to two reasons.
10. Voltage unbalance (source unbalance— not our concern or BREB concern)
11. NEMA standards allow 1-2% voltage unbalance and a 6-12% current imbalance to make a balanced load for each phase as a solution to voltage unbalance.
12. There should be cable shoe placement. It is a type of layer mainly used for cable safety and needs to be placed over every cable possible within the substation.
13. There should be an ampere tube, a type of cover laid over the busbar where there are holes through which cable is inserted, which should be placed upon each busbar. These ampere tubes will also serve the purpose of phase marking (as 3 phases) as red, yellow, and blue (RYB) and will also be used for the safety of the busbars.

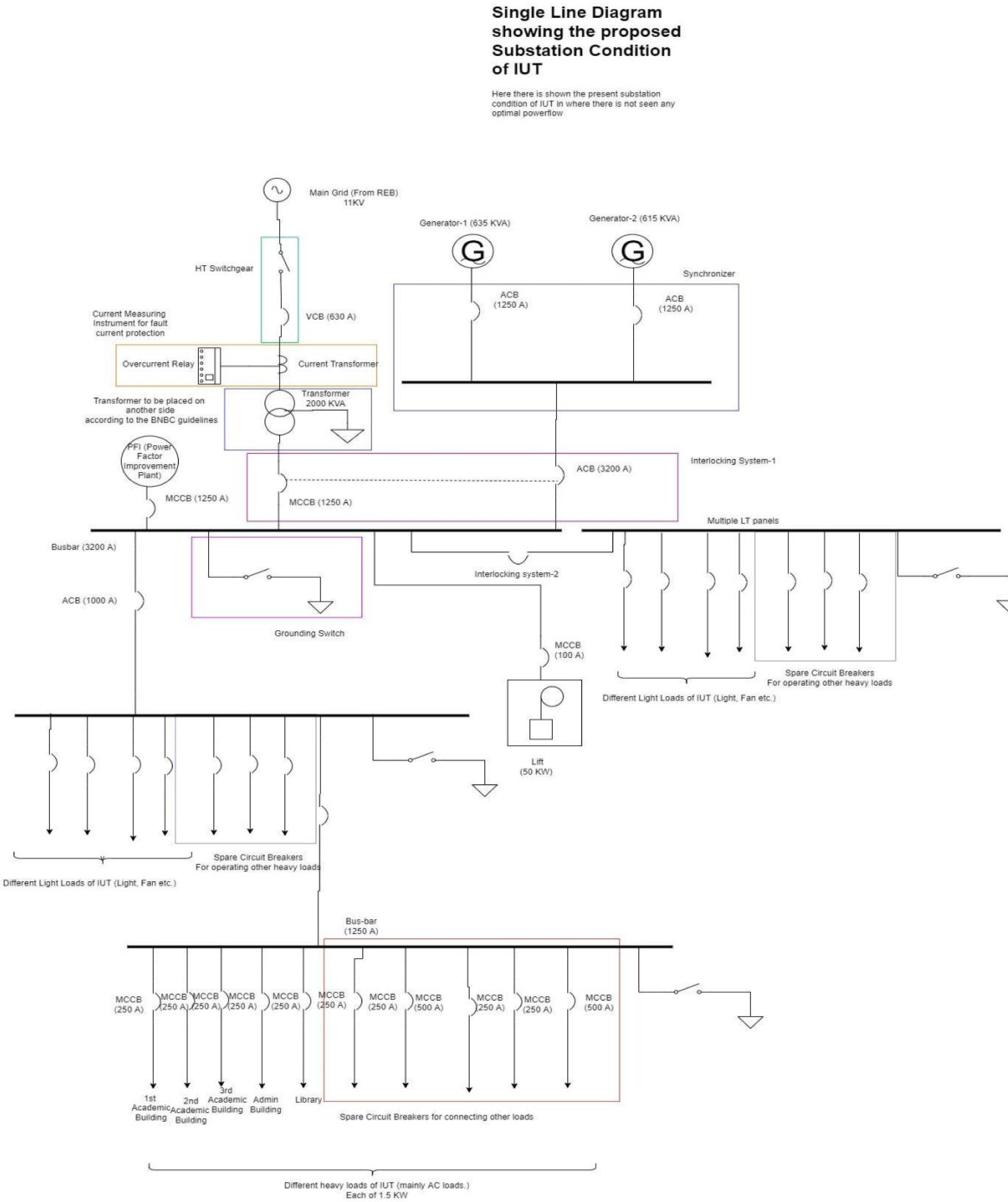


Figure 6.7: Proposed substation design of IUT

6.5 Comparison of the simulation results with the present substation and the proposed substation model

In this section of the chapter, we have tried to compare the simulation results of the load distribution side of the first, second, and third academic buildings of the present substation of IUT with those of the proposed substation model of IUT. Unlike the previous sections of chapter 5, we have also done all the simulations using the ETAP software and have generated a table based on the simulation results to compare the results of both the substations.

6.5.1 Simulation result table

This subsection discusses mainly about the table that is generated automatically due to the simulation of the load distribution side of the 1st,2nd and 3rd academic building.

Table 6.1: Summary of total generation, loading and demand table of the present IUT substation

SUMMARY OF TOTAL GENERATION , LOADING & DEMAND

	MW	Mvar	MVA	% PF
Source (Swing Buses):	0.281	0.062	0.288	97.68 Lagging
Source (Non-Swing Buses):	0.000	0.000	0.000	
Total Demand:	0.281	0.062	0.288	97.68 Lagging
Total Motor Load:	0.162	0.051	0.169	95.39 Lagging
Total Static Load:	0.028	0.009	0.030	95.42 Lagging
Total Constant I Load:	0.000	0.000	0.000	
Total Generic Load:	0.000	0.000	0.000	
Apparent Losses:	0.091	0.002		
System Mismatch:	0.104	0.067		

Number of Iterations: 1

Table 6.2: Summary of total generation, loading and demand table of the proposed IUT substation

SUMMARY OF TOTAL GENERATION , LOADING & DEMAND

	MW	Mvar	MVA	% PF
Source (Swing Buses):	0.281	0.053	0.286	98.25 Lagging
Source (Non-Swing Buses):	0.000	0.000	0.000	
Total Demand:	0.281	0.053	0.286	98.25 Lagging
Total Motor Load:	0.161	0.052	0.170	95.16 Lagging
Total Static Load:	0.028	0.000	0.028	99.99 Lagging
Total Constant I Load:	0.000	0.000	0.000	
Total Generic Load:	0.000	0.000	0.000	
Apparent Losses:	0.074	0.001		
System Mismatch:	0.009	0.066		

Number of Iterations: 1

6.5.2 Theoretical discussions on more observations from the simulations of both the substations

From the simulation table as mentioned in the subsection 6.5.1, we have observed the following points after observing the simulation results:

1) The power factor has improved a lot in the proposed substation design than the current substation design.
2) Much of the buses are observed undervoltage than the rated one whereas a less amount of buses are observed in such a condition.
3) Critical report in ETAP software have shown that much of the buses were in overload condition and at the same time were under overvoltage condition in case of the present substation of IUT whereas the critical report have shown this overload and overvoltage condition to be less in number in case of the proposed substation.
4) The apparent losses on the proposed substation is much less than that of the present substation that results in smooth and more real power flow through the proposed substation.
5) The system mismatch is also seen the less in the proposed substation which makes the system much more stable in case of the proposed substation than that of the present substation.
6) Loading at the output side of the transformer is more in case of the proposed substation than that of the present substation.
7) Though the total demand in the real power is seen the same in both the stations, the total demand for the reactive power reduces much in case of the proposed substation.
8) Though the real power flow in the static loading is seen the same for both the present and proposed IUT substation, the MVAR or reactive power flow through the static load is seen to be zero in the proposed substation which means that a successful static load characteristics is found that only consumes real power.

Chapter 7

Future Plans and Conclusion

7.1 Future plans

Although we have done the load flow analysis from the REB main grid up to the first, the second, and third academic buildings on the distribution side, we have yet to do the load flow analysis on the other distribution sides as well, such as the North and South halls of residence, the North and Central Cafeteria, the Utility Building, the Auditorium, the Library, and administrative buildings. So we plan to create a single line diagram of each of these distribution sides after more thorough surveying of all of these distribution side loads and will propose a suitable complete solution based on the issues that we shall face and observe while surveying all of these distribution side areas. We shall also perform a simulation after drawing the exact single line diagram that we will draw or make an estimated sketch while surveying all of these distribution side areas.

We shall also calculate all of the final proposed substation models that we shall present after the complete surveying and load flow analysis using the ETAP software. At the same time, we will also try to add some of the modifications necessary to build up the proposed substation model after this complete surveying of the distribution side.

We shall also try to introduce more software like MATLAB, Python, R, and technology such as a machine learning approach for the data analysis of the load and current flow through each of the cables and buses that we shall obtain after the complete analysis of the whole substation of IUT. We shall also analyze the data that we shall get after the simulation of the proposed complete substation model of IUT. We may also introduce some qualitative analysis based on our final research, alongside the quantitative analysis that we have mentioned before within this paragraph

7.2 Conclusion

Though we have made a partial survey and load flow analysis of the whole IUT substation, we can conclude from all of this analysis through field and simulation analysis that the present IUT substation is not ideal. This substation needs to be repaired, and in some cases, new electrical equipment must be introduced to ensure optimal power flow through each of the buses, cables, and loads. And also, it is necessary beforehand to draw a single line diagram of each of the electrical components before placing them all over the substation. Besides, the present IUT substation is old and based on the 90s pattern of the substation, which has excluded many modern loads in their plans, like lifts, ACs, refrigerators, TV electronic devices, power electronic devices, and many others. So the whole IUT substation can be replaced by a new one such that such types of modern loads can be connected quickly all over the substation. Moreover, new generators are also required to be introduced, if possible, to ensure proper backup of electricity or electrical power through each of the loads, including the heavy loads when there will be load shedding or the occurrence of any types of faults. If these steps are not taken as soon as possible or near future soon, the whole substation can face serious consequences in terms of fault occurrence as well as from the electric distribution authority as in many of the cases; proper building code has not been maintained during the construction of all of these equipment right from the time when the IUT was established.

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