Load Flow Analysis of IUT Electrical System

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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 Mahir Ashraf, Arfa Islam and Mehnaz Tabassum Troyee under the supervision of Associate 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 Information derived from the published and unpublished work of others has been acknowledged in the text and a list of references is given.

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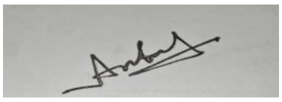

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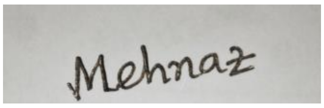

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List of Acronyms

LFA	Load Flow Analysis
KW	Kilowatt
MW	Megawatt
KVAR	Kilovolt-Ampere Reactive
KVA	Kilovolt-amps
PF	Power Factor
LPS	Lightning Protection System
MDB	Main Distribution Board
SBD	Sub Distribution Board
CB	Circuit Breaker
UPS	Uninterrupted Power Supply
PU	Per Unit
DOL	Direct On Line
IEC	International Electro technical Commission
NFPA	National Fire Protection Association
BNBC	Bangladesh National Building Code

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Abstract

Load flow analysis is one of the most commonly used methods for the designing and planning of a power system and also for identifying the faults in a power system. The importance of load flow analysis has made it a field of great research interest. The power system of IUT is currently facing some severe problems and if these issues are not resolved immediately there might be some serious consequences. In order to maintain a healthy power system, the buses must be prevented from being overloaded and faulty equipment must be replaced regularly. So our thesis deals with these problems of IUT and we have tried to solve them by applying load flow analysis. Our objective is to identify the various problems in a power system and proposing solutions to these problems. We achieved this by collecting necessary data from the substation and different buildings of IUT and Implementing these readings on a software named ETAP. Using the results of the simulation, we have proposed solutions with an estimated cost and timeframe. In the following chapters the above mentioned things are discussed elaborately.

Chapter 1
Introduction and Background

The introduction of electrical energy was one the most valuable invention for mankind. It was the most convenient form of energy that proved to have great efficiency at affordable costs. At the beginning, generation of electricity was very limited having huge power losses and transmission to remote areas was not possible. These issues were solved by the invention of transformers and induction motors, which reduced power losses and enabled power to be transmitted over longer distances. Thus the importance of power system became apparent. Modern power system has four major parts:

1) Generation
2) Transmission and Sub-transmission
3) Distributions
4) Loads

It is essential to understand these four components in order to achieve a well-designed and properly working power system. Another very important analysis to maintain a very healthy power system is the load flow analysis A power system may have a variety of issues with its various components, which could lead to the entire system failing. These failures have the potential to result in serious accidents. We can detect these faults and take the appropriate measures to avoid such risks using load flow analysis. Load flow analysis may be used to analyze a variety of issues in planning and operation of a power system. The load flow analysis helps to ensure that generators run at their maximum operation point and demand is met without any overloading facilities. Our thesis mainly focuses on the load flow analysis of power systems and we have used ETAP for our analysis. Electrical Transient Analyser Program (ETAP) is a widely used network modelling and simulation software by which the most complex power system analysis can be performed very easily. Load flow analysis is done on a regular basis to ensure safety and have optimum outputs. So, it is very important to know how the load flow analysis works and how we can use it to change the conditions of a power system for our benefits.

1.1 Basic functionalities of load flow analysis:

Load flow analysis is the analysis of real and reactive power flowing through the components of any electrical system. It is an essential approach to investigate the problems in power system operation. The voltage drops and power losses can be measured easily and necessary approaches can be taken accordingly doing the analysis of load flow. The basic formulas of power system are applied to do the calculations. Thus, for buses where real and reactive powers are injected into the bus, such as generator buses [1], P (real power) and Q (reactive power) have positive values. For load buses where real and reactive powers are flowing away from the bus, P (real power) and Q (reactive power) have negative values.

$$(Pi)^{(K+1)} = Real\left[(Vi)^{*(K)}\left\{(Vi)^{(K)} \sum_{j=0}^{n} Yij - \sum_{j=1}^{n} Yij(Vj)^{(K)}\right\}\right] j \neq i,$$

$$(Qi)^{(K+1)} = Imaginary\left[(Vi)^{*(K)}\left\{(Vi)^{(K)} \sum_{j=0}^{n} Yij - \sum_{j=1}^{n} Yij(Vj)^{(K)}\right\}\right] j \neq i \quad ,$$

Where, Y is the admittance between two respective nodes and V is the supply voltage of respective bus.

1.2 Literature Review:

Load flow analysis plays an important role in the analysis of power systems. Several research papers have been published on the load flow analysis of many substations. Our objective is carry out a load flow analysis of the substation of the campus of IUT. For the simulation we have used the software ETAP. In order to learn how this software is used for load flow analysis we have worked on the published journals on load flow analysis. From these papers we learned about various parameters, we identified the problems and we implemented the circuits on ETAP using the readings.

The first paper we have reviewed [2] is basically the design of a 132 kV grid network which contains 11 kV feeders and rest of distribution networks. In this paper actual readings are used to model the power system equipment.

[3] The second one has given us the results of load flow analysis for IEC projects and based on the ETAP results the parameters of the electrical equipment are selected. We have come to know that when the parameters real power (P) and reactive power (Q) are unknown and voltage (V) and voltage angle are known for swing bus. In case of load bus the values of real power (P) and reactive power (Q) are known and voltage (V) and voltage angle values are unknown.

For generator bus the values of reactive power (P) and voltage (V) are known and reactive power (Q) and voltage angle values are unknown. Thus the unknown values are calculated using the known values.

And the next one [4] discusses the analysis of the power distribution network in Rafah governorate by using ETAP software. Voltage regulation problems, increased system losses, power factor penalties and reduced system capacity are some of the challenges that arise when the system power factor declines as the power distribution system grows. The solutions to these problems are discussed in this paper.

1.3 Thesis Objective:

The main objective of this thesis is to do the load flow analysis of IUT using the ratings of IUT substation and the loads consumed by various sectors of the university campus and propose a solution to meet the new increased demand of the power system and make necessary changes and installations. More specifically,

- To calculate the supply voltage, real power, reactive power, short circuit current of the components of IUT substation.
- To calculate the consumed load of IUT academic buildings, halls of residence, laboratories, administrative and other buildings.
- To calculate the load factor, demand factor, diversity factor in various seasons and discuss the best possible ways to use power efficiently.
- To design a complete simulation model on E-tap and summarizing important conclusion from the obtained results.

1.4 Thesis Organization:

Our thesis is organized in the following ways:

- In **chapter 2** the basic principles of load flow analysis is described. The classifications of bus and the different methods of load flow analysis are described elaborately in this chapter. The problems of the current scenario of IUT are also discussed in this chapter.
- In **chapter 3** we have described the entire methodology of our thesis. We have stated in details about how we took the readings, which technique was used and which software was used for the simulation.
- In **chapter 4** we have shown all the results of our simulation that we have performed using the collected readings and identified various problems. Then we discussed about these results elaborately.
- In **chapter 5** we have described the possible solutions to the problems and also added a cost estimation for the changes and installations for the issues that we are facing currently.
- Finally, in **chapter 6** we have added a concluding statement along with some ideas about our future works.

Chapter 2

Overview of Load Flow Analysis

2.1 Introduction:

The 2000 KVA substation of IUT was built 35 years ago considering a much smaller infrastructure with fewer buildings and laboratories. Over the years the population of students has amounted to around 2500 and so new buildings, workshops, classrooms etc. were built to accommodate this huge number of students. The electrical equipment of the substation are mostly old and out of order. If these faulty equipment are not replaced they might create potential threat. In order to maintain a properly operating and healthy power system, load flow analysis is extremely important. To identify the various problems of a power system in the most effective analysis is the load flow analysis. Load Flow Analysis is the foremost vital and fundamental approach to exploring issues in a power system. Load flow analysis is used for the design, operation and optimization of efficiency in a power station. Our research is based on conducting the load flow analysis of IUT and to propose solutions to the problems we are experiencing.

The objective of a power-flow study is to get total voltages angle and magnitude data for each bus in a control system for the specified stack and generator real power and voltage conditions. Once this data is known, real and reactive power flow on each branch, as well as generator reactive power output, can be systematically decided. Figure 1 below demonstrates a simple power system where the impedances [2] are expressed as per unit on a common MVA base. For simplicity the resistances are ignored and the impedances are converted to admittances since KCL is applied at the nodes.

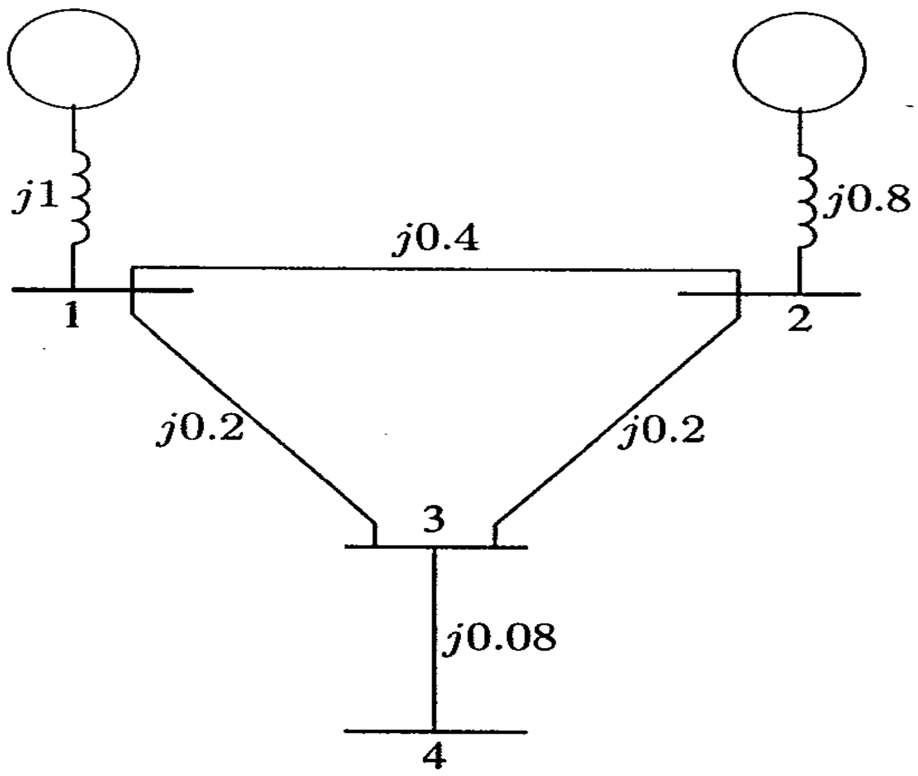

Figure 2.1.1: The impedance diagram of a simple system

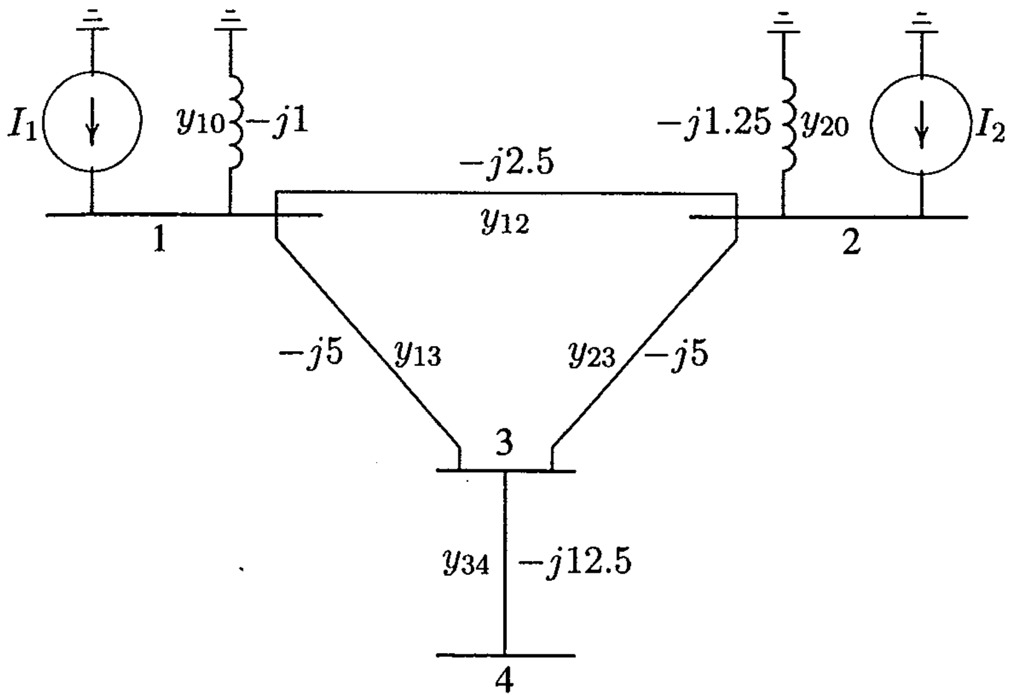

Figure 2.1.2: The admittance diagram for system of figure 2.2.1

The system is redrawn using admittances in Figure 2. Applying KCL at the nodes and simplifying the equations we obtain the following matrix:

$$\begin{bmatrix} \boldsymbol{I_1} \\ \vdots \\ \boldsymbol{I_n} \\ \vdots \\ \boldsymbol{I_r} \end{bmatrix} = \begin{bmatrix} Y_{11} & .. & Y_{1n} & .. & Y_{1r} \\ \vdots & & \vdots & & \vdots \\ Y_{n1} & .. & Y_{nn} & .. & Y_{nr} \\ \vdots & & \vdots & & \vdots \\ Y_{r1} & .. & Y_{rn} & .. & Y_{rr} \end{bmatrix} . \begin{bmatrix} \boldsymbol{V_1} \\ \vdots \\ \boldsymbol{V_n} \\ \vdots \\ \boldsymbol{V_r} \end{bmatrix}$$

or [**I**] = [**Y**] . [**V**],

where [**I**] is the node current, [**V**] is the voltage and [**Y**] is the admittance.

By inverting the nodal admittance matrix and thus solving for the nodal voltages [V], conventional circuit analysis follows directly from the equation above. The lack of uniformity in data about electrical conditions at the buses, however, complicates the load flow issue. To understand these networks more properly we need to know about the different types of buses.

2.2 Bus Classification:

In solving a power flow problem, the system is assumed to be operating under balanced conditions and a single phase model is used [1]. Each bus is linked to one or more lines, generators, and loads. Other than the reference node, buses are the nodes of a device. Each bus is deals with four unknown parameters:

- Real power, Pi
- Reactive power, Qi
- Voltage magnitude, |Vi|
- Voltage angle, δi

Buses are categorized based on which two values out of the four parameters are defined. The buses can be classified into three categories:

a) **Load Bus:** In this type of bus, the generator is not connected. The load bus, also known as PQ bus, is a type of bus where the values of real and reactive power are defined and the magnitude of voltage and phase angle has to be determined using load flow solutions.

b) **Generator bus or voltage controlled bus:** A power system's generator stations are represented by the generator bus, also known voltage-controlled bus. The real power

P and the generator voltage V are specified in this type of bus. The reactive power generation Q and phase angle of the bus voltage must be determined. The field current of the synchronous generator is adjusted to maintain the voltage magnitude of the generator bus. In terms of economic dispatch, each generator's real power production is allocated.

c) **Slack (swing) bus:** The slack bus, also called the swing bus, is a reference bus and thus the phase angle is set as zero. In case of slack bus the real and reactive power P and Q has to be determined using load flow solutions and the known values of the magnitude of voltage and phase of voltage. The slack bus compensates for complicated losses and is still equipped with a generator to meet unmet demand from other buses. The slack bus is where the generation is made available and retains the system's power balance.

Table 2.2.1: Summary of Bus Types [5]

Bus Type	**No. of buses**	**Quantities specified**	**No. of available mismatch equations**	**No. of δ_i, $\lvert V_i \rvert$ State variables**
Slack (i=1)	1	δ_i, $\lvert V_i \rvert$	0	0
Voltage Controlled (i=2,….., $N_g + 1$	N_g	P_i, $\lvert V_i \rvert$	N_g	N_g
Load (i=N_g+2,…,N)	N-N_g-1	P_i,Q_i	2(N-N_g-1)	2(N-N_g-1)
Total	N	2N	2N-N_g-2	2N-N_g-2

2.3 Methods of load flow solutions:

Iterative techniques like Gauss-Seidel and Newton-Raphson are commonly used in load flow analysis. [2] The Newton-Raphson method solves the load flow equations all at a time in polar coordinates until ΔP and ΔQ mismatches at each bus in any iteration does not exceed a specified tolerance. In the Gauss-Seidel method, the load flow equations are solved in Cartesian coordinates one by one until the gap between two successive iterations for each bus voltage is less than a tolerance margin. On convergence both methods obtain same results using bus admittance matrix elements. These two methods are described below:

2.3.1 Gauss-Seidel method:

The Gauss-Seidel approach relies on the substitution of nodal equations into one another. This technique consumes more time bus it is the easiest to understand and was the most commonly used technique until the early 1970s. The Gauss-Seidel method of load flow analysis is an iterative method where a series of nonlinear mismatch power equations is solved in Cartesian coordinates for buses with unknown values of voltage magnitude and/or phase angle until the changes in bus voltages from one iteration to the next are less than a certain value. [2] Initial estimates of (in 0-th iteration) the phase angles of all load buses and voltage controlled buses are made as 0^0. The voltage magnitudes at slack and voltage controlled buses are set at the specified values. The voltage magnitude of the load buses are set in the initial iteration as 1.0 p.u.

The basic mismatch equation to be solved in Cartesian coordinates is as follows. [5]

$\Delta P_i + j\,\Delta Q_i = 0,$

or, $P_{i,sch} - P_i + j(Q_{i,sch} - Q_i) = 0,$

or, $P_{i,sch} + j\,Q_{i,sch} = P_i + j\,Q_i,$

or, $P_{i,sch} - jQ_{i,sch} = P_i - j\,Q_i,$

or, $P_{i,sch} - jQ_{i,sch} = V_i^* \sum_{n=1}^{N} Y_{in} V_n,$

Re-arranging the above equation, we get [5]:

$\frac{P_{i,sch} - Q_{i,sch}}{V_i^*} = V_i^* \sum_{n=1}^{N} Y_{in} V_n,$

Solution for Vi in complex (Cartesian) form in iteration k is :

$V_i^{(k)} = \frac{1}{Y_{ii}} [\frac{P_{i,sch} - Q_{i,sch}}{V_i^{(k-1)*}} - \sum_{j=1}^{j-1} Y_{ij} V_j^{(k)} - \sum_{j=i+1}^{N} Y_{ij} \; V_j^{(k-1)}],$

The equation above is only valid for load buses with defined real and reactive forces. The obtained voltage is multiplied by a constant known as the acceleration factor to minimize the number of iterations needed. The i-th bus voltage is then calculated using this value.

$V_{i,acc}^{(k)} = (1 - \alpha) V_{i,acc}^{(k-1)} + \alpha V_i^{(k)} = V_{i,acc}^{(k-1)} + \alpha (V_i^{(k)} - V_{i,acc}^{(k-1)},$

If a P-V bus is the i-th bus with defined voltage magnitude and the value of reactive power is unknown, then the following equation must be used to calculate the reactive power:

$$Q_i = -Im\left\{v_i^* \sum_{j=1}^{N} Y_{ij}V_j\right\},$$

$$Q_i^{(k)} = -\operatorname{Im}\left\{V_i^{(k-1)^*}\left[\Sigma_{j=1}^{i-1}Y_{ij}V_j^{(k)} + \sum_{j=1}^{N} Y_{ij}V_j^{(k-1)}\right]\right\},$$

Finally, the real and reactive power are calculated using the obtained bus voltage magnitudes:

$$P_n = -|V_i|^2 Gin + |Y_{in}V_iV_n|cos(\theta_{in} + \delta_n - \delta_i)|,$$

$$Q_{in} = -\left\{|V_i|^2\left(\frac{B_{in}'}{2} - B_{in}\right) + |V_i V_n V_{in}|\sin(\theta_{in} + \delta_n - \delta_i)\right\},$$

2.3.2 Newton-Raphson method:

Newton Raphson method is a technique that is used commonly to find the solution of simultaneous algebraic equations. It is a method that uses Taylor's series expansion and the procedure relies on an initial estimation of the unknown. "Consider the solution of a one-dimensional equation given by [5]:

$$f(x) = c\ ,$$

Let $x^{(0)} = initial\ estimate$ and $\Delta x^{(0)} = small\ deviation$, then:

$$f(x^{(0)} + \Delta x^{(0)}) = \text{c},$$

After expanding [5]:

$$f\left(x^{(0)}\right) + \left(\frac{df}{dx}\right)^{(0)}\Delta x^{(0)} + \frac{1}{2!}\left(\frac{d^2f}{dx^2}\right)^{(0)}\left(\Delta x^{(0)}\right)^2 + \cdots = c,$$

The higher order terms are neglected considering $\Delta x^{(0)}$ to be very small and so [5]:

$$\Delta c^{(0)} \cong \left(\frac{df}{dx}\right)^{(0)} \Delta x^{(0)},$$

Where,

$$\Delta c^{(0)} = c - f(\ x^{(0)}),$$

We can find the second approximation by adding $\Delta x^{(0)}$ to the initial estimation [5]:

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

Thus, the following Newton-Raphson algorithm is obtained [5]:

$$\Delta c^{(k)} = c - f\left(x^{(k)}\right),$$

$$\Delta x^{(k)} = \frac{\Delta c^{(k)}}{\left(\frac{df}{dx}\right)^{(k)}},$$

$$x^{(K+1)} = x^{(k)} + \Delta x^{(k)},$$

2.4 Problem statement:

The power supply system of IUT was designed considering a much smaller infrastructure with fewer buildings and laboratories. But as the population of students, faculties, and staff increased, there have been some severe problems in the electrical system. A power system might have various problems in its different equipment which might fail the whole system. These failures can also cause serious accidents. Using load flow analysis we can identify these faults and take necessary precautions to avoid such risks. Damage to electrical equipment and gadgets may be caused by a variety of factors, including the device's and equipment's efficiency, their usage patterns, and the continuity of electric power supply, as well as a lack of adequate protective measures. We tried to narrow down the most important causes, which are mentioned below:

- We find that our connected supply of generators are inadequate while the electricity demand is increasing. The power supply system of IUT was designed considering the load demand when the student population was around 200 and with few laboratories. At present now this campus has around 2500 students, more than 400 faculties, and staff with many classrooms, labs, computer center, new female halls and extension of halls. As a result of this improvisation, substation equipment and bus-bars become overcrowded, which is affecting the substation's safe operation. The substation is old and has a bad ventilation system.

- In the summer the load demand increases as the use of air conditioning, fans, and other electrical appliances increases. As a consequence, it is impossible to have electricity on a continuous basis. As a result, the supply in halls and cafeterias was disrupted during class time, causing students to suffer.

- We discovered that most of the MDB, FDB, and SDB boards used in various IUT buildings have expired. It is clear that some electrical loads, especially in older buildings, were connected to SDB boards without adhering to the standards. Furthermore, the current electrical wiring scheme was not intended to accommodate heavy-duty equipment. After the link, these wirings were not replaced.

- In order to ensure safety and prevent serious consequences to people and equipment, grounding is required in electrical installations. Since most of the buildings (except the 2nd academic building, north hall of residence, and female hall of residence) were built 35 years ago, the earthing system must be checked and re-installed as required.

- The current LPS system in all of the buildings has become obsolete, which is one of the primary causes of electrical equipment damage, especially during thunderstorms. However, using a traditional approach, one LPS system was built in the first academic building last year, which was not capable of covering other buildings.
- Due to the frequent outages of REB power, some of the heavy electrical loads that cannot be fed by UPS experience malfunction or harm. This subject has been discussed with the PBS authority on many occasions. PBS authority guarantees that IUT will not shut down control unless it is absolutely necessary. Electrical outages have become more prevalent in recent days, owing to faults that often occur in the overhead distribution system. The electrical outage in recent days has been primarily caused by faults that often occur in the overhead distribution lines and the feeder substation at Tongi. IUT cannot be fed separately from REB substation because there is no dedicated feeder from the REM substation at Board Bazar to IUT substation.
- Electrical building codes are not properly maintained. Some buildings lack a fire alarm, fire extinguisher, or smoke control system. Even so, all of the air conditioners are not linked via DOL switches, which is dangerous for air conditioner operation.
- Lastly, some unauthorized equipment is being used in the halls of residence. Although the wiring system is not designed to support these heavy devices, there is a potential danger of fire hazard.

Chapter 3

Methodology

We have divided our whole work into some steps:

1. Collecting data and other necessary information from the substation of IUT.
2. Calculating supply voltage, real power, reactive power, short circuit current of the components from the obtained datasets.
3. Calculating the consumed load of different buildings of IUT.
4. Calculating the load factor, demand factor, diversity factor in various seasons and doing comparative analysis.
5. Identifying the peak values among different seasons.
6. Designing a complete simulation model on ETAP using the collected and calculated data.
7. Summarizing important conclusions from the obtained results.
8. Proposing a suitable design to ensure an uninterrupted supply and ensure safety inside the campus.

Now here is the detailed discussion of our workflow:

- **Collecting data and other necessary information from the substation of IUT:**

At first we visited the substation of IUT and talked to the engineer of IUT to know the details about the load flow in the campus. He gave us details how IUT substation works and from where we get our electricity. Electrical substations are auxiliary stations which can be used for the generation, transmission and distribution of power and there voltage is changed over from peak to minimum and the turnaround utilization of transformers. Electric power streams through a few substations between the creating plant and the buyer. All of the individual substations contain some exchanging, security and control hardware in conjunction with control equipment.

The insights for observing all capacities that take place inside each substation is designed in a little building.

And the distribution lines are fed from the substations. The main distribution lines and the feeder substation are located at Tongi. And from there we get our electrical supply. And there's no devoted feeder from the REM (Remote Energy Management) substation at Board Bazar to IUT substation. As IUT do not have the authority to be independently fed from REB substation. This is why IUT has to use the same distribution lines. And the electricity development board of Bangladesh has different schemes to distribute electricity throughout the country. The total connected load of IUT campus is 1724.5 KW.

So for this huge amount of load IUT needs its own substation during power outage. The control supply framework of IUT was outlined considering the stack request of the at that point ICTVTR, when the understudy populace was around 200 and with few research facilities required to allow hands-on preparation to the understudies. In course of time, the centre has overhauled and it took the show frame with around 2500 understudies, more than 400 resources and staff with numerous classrooms, labs, computer centre, an expansion of lobbies of home, and so forward. In any case, when electrical associations were amplified, the substation was extemporized to suit the additional stack. As a result of this act of spontaneity, substation hardware and bus-bars got stuffed. The substation of IUT is encouraged by the REB through PBS subjected to eccentric blackouts. To manage with the visit power blackout from the PBS, IUT introduced two captive diesel generators. Generators are valuable apparatuses that supply electrical control amid a control blackout and anticipate irregularity of day by day exercises or disturbance of commerce operations. Generators are accessible with totally different electrical and physical arrangements to utilize completely different applications.

The ratings of two generator:

Generator 1: Capacity- 508 kW

Maximum kW expedite: 425.1 kW, (September 2019)

Maximum kWh energy expedited: 3300 kWh, (May 2019)

Highest % loading: 83.67%, September, 2019

Fuel consumption: 28627.4 liter

Generator 2: Capacity- 492 kW

Maximum kW expedite: 407 kW, (June 2019)

Maximum kWh energy expedited: 2239 kWh, (May 2019)

Highest % loading: 82.73%, September, 2019

Fuel consumption: 12623.3 liter

- **Calculating supply voltage, real power, reactive power, short circuit current of the components from the obtained datasets :**

From substation we got some other information. We have found the demand chart which was important for our calculations. At first we calculated the supply voltage. Supply voltage is the obtained voltage we get from any power system operation. This voltage is used for designing the complete electrical system [6]. We have calculated the supply voltage of the generators using the formula

$$P = I^2R,$$

$$P = IE,$$

$$P = E^2/R,$$

here, p = power,

I = current through the line,

R = resistance,

E = Supply voltage.

If we know any two values of the Voltage, Current or Resistance amounts. Then we are able to utilize Ohm's Law to discover the final lost esteem. Ohm's Law is utilized broadly in hardware equations and calculations. So, it is very imperative to get it and precisely keep in mind these equations.

After calculating the supply voltage from the datasets we have been given we have calculated the real power (P) and the reactive power (Q) of the components. The power which is actually consumed in the system or in the circuit is the real power. We use Kilowatt or Watt as the unit of real power. The equation for real power is:

$$P = |\text{V}|\ |\text{i}|\ \cos(\Phi),$$

Here, V = supply voltage,

I = Current through the line,

Φ = the phase angle.

Phase angle is the angle between the resistive current and the total current. The greatness of the potential distinction between the comparing stages will show the stage point contrast between the two sources. It is necessary to keep the phase angle low for the power factor improvement. High power factor means less electrical energy is wasted. As the power factor depends on the cos (Φ). So, if the power factor is high this means the real power is high. If the real power is used more that means less energy is wasted. Generally capacitor banks are used to improve power factor. As the capacitor bank corrects the power factor lag in the power system. Capacitor bank is a combination of capacitors.

Beside real power we had to calculate the reactive power also. The control which streams back and forward which means it moves in both the bearings within the circuit or responds upon itself, is called responsive Control or the reactive power. We use kilo volt ampere reactive (KVAR) or MVAR to measure the reactive power. In power system analysis the reactive power needs to be low. We use the following equation to calculate reactive power:

$$Q = |\mathrm{V}|\ |\mathrm{i}| \sin(\Phi),$$

Here, V = supply voltage

I = Current through the line

Φ = the phase angle

From the real power and the reactive power we have also calculated the power factor. And we have observed the power factor of different connected loads. By seeing the percentage of power factor we can find out how much energy is actually being used. We had to calculate the apparent power also. The item of root mean square (RMS) esteem of voltage and current is Clear Control or apparent power. This control or power is measured in kVA or MVA.

We learnt that control is expended as it were in resistance. An unadulterated inductor and an unadulterated capacitor don't devour any control since in a half cycle anything control is gotten from the source by these components, the same control is returned to the source. This control or power which returns and streams in both the heading within the circuit, is called Receptive control or Reactive power. This responsive power does not perform any valuable work within the circuit. It wastes energy. Current stays in the same phase with applied voltage in the purely resistive circuits. But in inductive or in the capacitive circuit mostly the current is out of phase by 90 degrees. So, if we want to ensure the highest real power consumed by the component we will definitely have to keep the power factor high.

And we have calculated the short circuit current also. At first we have to find out the active and the reactive component of current. The active current is in stage with the circuit voltage and contributes to the dynamic or genuine control of the circuit. On the other hand the reactive current is 90 degrees out of stage to the circuit voltage and contributes to the receptive control or the reactive control of the circuit. And after that we have calculated the short circuit current. Short circuit current is the current when the voltage through the load or the component is zero. This current is generated due to the era and collection of light-generated carriers. When two or more conductors of diverse stages come in connection with each other in a control line, control transformer or any other control component, at that point the portion of the impedance mostly shunted out of the circuit and it occurs due to an expansive current stream within the un-faulted stages and this current is known as the short circuit current. This current diminishes the effect of impedance within the circuit when the current inside the circuit begins to rise. We have calculated the short circuit current using the following formula:

$$I = V/R,$$

Here, I = short circuit current,

V = Supplied voltage,

R = Resistance.

- **Calculating the consumed load of different buildings of IUT :**

At first we calculated the ratings of different components of different rooms. Inside hall rooms generally there are 2 fans and 6 lights. The corridors have 3 lights. And in the toilets there are 4 lights. There are a total of 300 rooms in North and South halls of residence. So if the connected load of a single room is 200 watts then the total connected load of 300 rooms is 60 kilowatts. And in the utility building there are 20 rooms on each floor. The north cafeteria, TV centre, gymnasium are also located inside the utility building. So we have counted the ratings of connected loads of each room and then we have multiplied those numbers. And added them up to get the total connected loads in the halls of residences. In the academic buildings there are 2 air conditioners with 6 fans and 4/6 lights. There is also a projector in every classroom. And 6/8 lights in the corridors. Lifts run for approximately 11/12 hours in the working days. There are also computer centre and some electrical labs. We couldn’t find all the detailed information of the connected loads in the academic buildings so we had to make some assumptions while doing our work. We have also calculated the connected loads of the administrative building, student centre, mosque, D-type buildings, medical centre, bungalow, female hall of residence, northern/middle/southern workshops and street lights. And while collecting the data and doing the calculations we have observed some problems in the distribution boards and in some other sections. In the upcoming chapters we have discussed those issues and proposed our solutions.

So firstly we have calculated the individual loads of different components of the connected loads. And we have multiplied and added them up to get the total loads of the buildings. And finally we have summed up the loads of the buildings and got the total connected load of the campus. The total connected load of the campus is 1724.81 KW. We had to adjust some of our calculations to adjust the total connected load of the campus.

- **Calculating the load factor, demand factor, diversity factor in various seasons and doing comparative analysis**

After calculating the total and the individual loads of different buildings we have calculated the demands and various factors in various seasons. At first we tried to find out the average load of the campus in different seasons. And we have got some datasets to study the average loads in different seasons. The average load in summer was almost twice the average load of winter. Then we have calculated the load factor [7]. As we know the load factor is

Load factor = Average load / Maximum demand,

As the maximum demand reaches highest in summer so the load factor stays lowest in summer. Maximum kilowatt per hour demand was recorded in July 2019 during summer class time. And it was recorded 59796 kWh. And maximum off peak hour load was 180711 kWh and it was recorded in July 2019 also. And as the average yearly kilowatt demand was 526.33 kW. So from this data we have calculated the load factor. And the maximum load factor was found in winter as the maximum demand in winter stays lowest. The minimum kilowatt hour consumption was 31221 kWh and that was recorded at December 2019 during the two months of vacation of the university as most of the native students leave their halls of residence and stay at home during this vacation. The associated stack and utilization design of the power have been analyzed by considering the already accessible information. By and by, under–COVID-19 circumstance, scholastic exercises are being conducted completely online and as it were a little number of understudies are dwelling within the lobbies of homes of IUT. As a result, the genuine picture of the electrical utilization was not accessible. So we have done all the calculations with the available data in our hand.

Then we have calculated the demand factor [7]. We have used the known formula

Demand factor = Maximum demand / Connected load,

As we already know the maximum demand of different seasons and the total connected load which is 1724.81 kilowatts. So it was an easy calculation to find out the demand factor. For the first generator (508 KW) the maximum kilowatt recorded was 425.1 kW which was also recorded in September 2019. And for the second generator (492 KW) maximum kilowatt recorded was 407 kW which was recorded in June 2019. So here the demand factor was (425.1 + 407) KW / 1724.81 KW = 0.4824 in summer. And in winter it was less than half. And the ratings were diverse in different seasons. As the fans, lights and air conditioners are used more in the summertime. So the maximum demand in this assigned period was more than twice. And maximum monthly KW demand was 696 kW which was recorded in September 2019. Where minimum monthly KW demand was 212 kW which was recorded in January 2019. So the diversity factor in different seasons was very much different. Here we have used the known formula to calculate the diversity factor [7].

Diversity factor = Sum of individual maximum demand / Maximum demand on power station,

So, the diversity factor from the data we had. The greatest requests of the person buyers of a gathering don't occur simultaneously. Hence, there are differing qualities within the event of the stack. Due to this different nature of the stack, full stack power supply to all the customers at the same time isn't required. As the peak hour monthly consumption was recorded 59796 kWh in July 2019. And the off-peak hour monthly consumption was recorded 180711 kWh in July 2019. And the average yearly kWh consumption was 16540.92 kWh in 2019. And for the first generator (508 KW) maximum kWh energy dispatched was 3300 kWh and it was recorded in May 2019. And for the second generator (492 KW) maximum kWh energy dispatched was 2239 KWh and it was also recorded in May 2019. We have also received the data percentage of maximum loading in our calculation for the first generator it was 83.67% recorded in September 2019 and for second generator it was 82.73% recorded in September 2019. After doing all of these calculations we have done our comparative analysis.

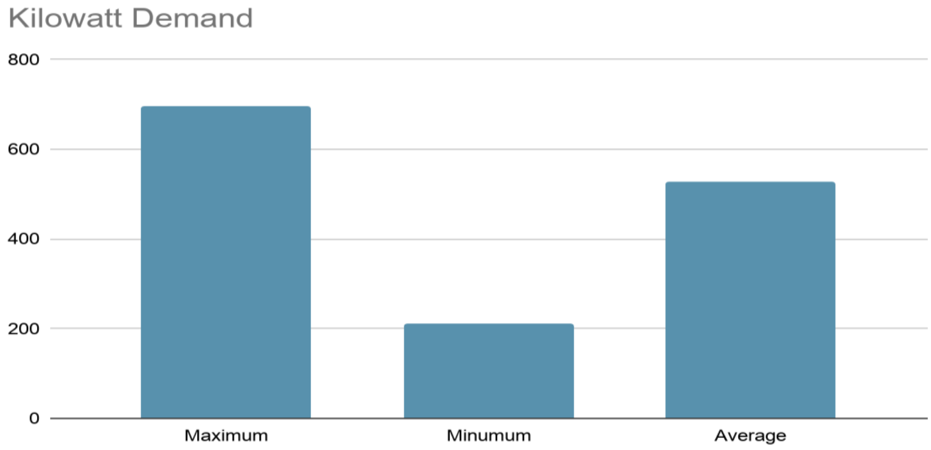

Figure 3.1: Maximum and minimum kilowatt demand

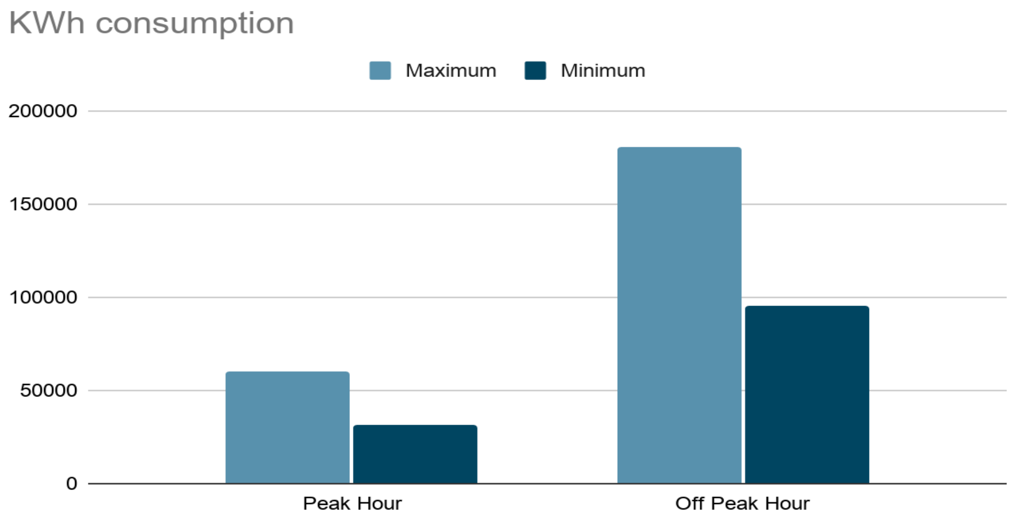

Figure 3.2: Peak hour and off peak hour kilowatt demand

Keeping all these data and calculations in mind we have made the following strategy and suggested some proposals accordingly.

- **Identifying the peak values among different seasons**

Our next job was identifying the peak values as we had to use the peak values in our simulation to get the best possible result in the worst case scenario. As we had the data of different seasons and we had already calculated the various factors and demand in different seasons so identifying the peak values among them was an easy task for us. As the ratings of most of the components were given in the root mean square value. So we had to convert those values to peak values by multiplying those values with root two. We were able to spot a few designs on the off chance as we committed a huge amount of time and exertion, but in the event that we haven't however subscribed to an information collection benefit giving us with interim information from the meters. We analyzed the data in the spreadsheet and identified some important factors from there. As we knew both the minimum and the maximum kilowatt demands so we had to use the maximum demand in our calculations and in the simulation. Because we had to find out the solution when the substation is overloaded and it mostly stays overloaded in the summer class time. And if we want to observe the maximum loading capacity of the generator then we will have to use peak values. And we found that the maximum loading capacity was almost 83.64% which was so close to the practical value that we found. And the maximum loading capacity of the second generator was 82.73%.

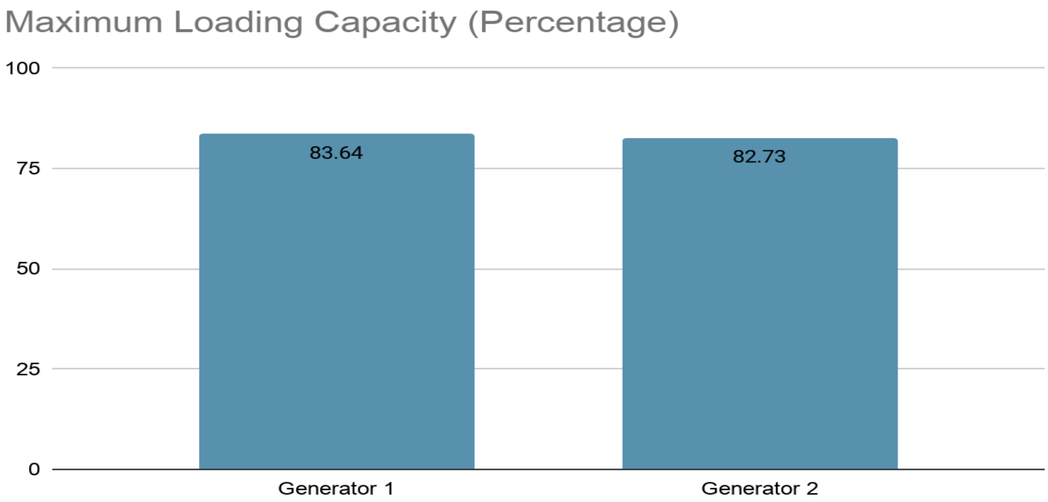

Figure 3.3: Maximum loading capacity of generators

We have also observed the previously calculated results. The factors in different seasons and the demands in different seasons. For continuous and secure operation of the sub-station as well as to meet the modern stack request of IUT campus, it is vital to alter or altar diverse parts of the sub-station agreeing to the display standard. For illustration, in January 2019, Generator 1 was required to supply the request on 12 occurrences, and among those occurrences the most extreme sum of stack that it provided was around 400 kW. So also, other values can be gotten for the remaining months. In December 2019, Generator 2 was required to supply the request on 13 occurrences, and among those occasions the greatest sum of stack that it provided was roughly 170 kW. So also, other values can be gotten for the remaining months. In July 2019, Generator 1 supplied the request 36 times, and among those occurrences the most extreme sum of kWh that it provided was roughly about 3000 kWh. In 2019, Generator 2 supplied the request for 7 times, and among those occasions the most extreme sum of kWh that it provided was around 2400 kWh.

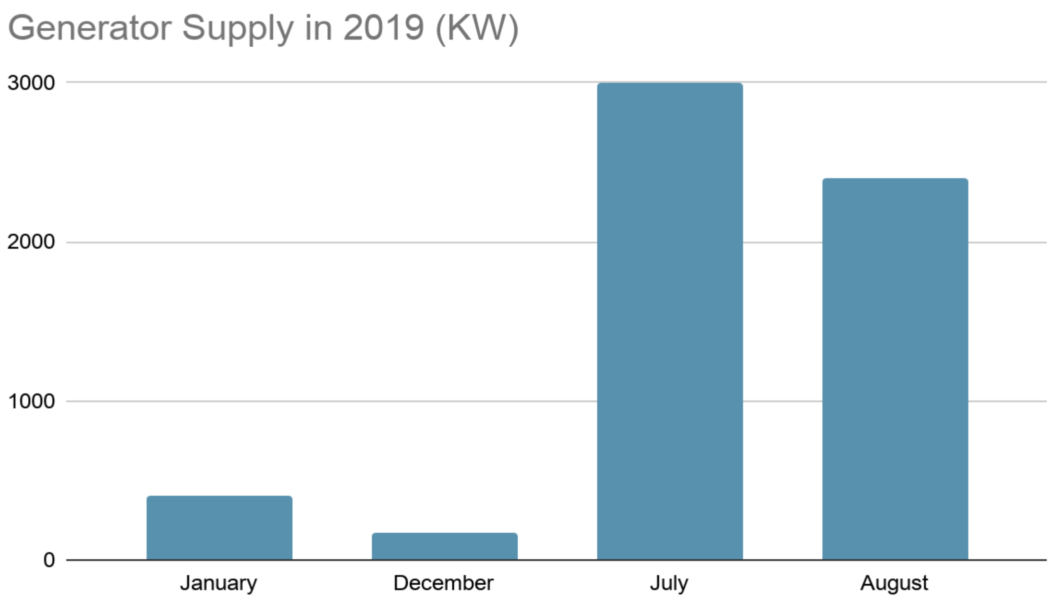

Figure 3.4: Supply from generator in different months

In July 2019, Generator 1 supplied the request for 36 times, and among those occasions the most extreme rate stacking was around 78%. In December 2019, Generator 2 supplied the request for 13 times, and among those occasions the greatest rate stacking was around 36%.Similarly, other values could be obtained for the remaining months.

- **Designing a complete simulation model on ETAP using the collected and calculated data**

For a long time electrical engineers have relied on the control of centralized server computers to analyze and plan control frameworks. Few years later microcomputers brought the power of centralized server computing for the desktop, paving the way for straight-forward and most importantly simple to use engineering applications which are especially designed for the individual computer. This part was the most challenging task for us. We used ETAP for the design and simulation. ETAP (Electrical Transient Analyzer Program) is an engineering analytical software where very complex problems and designs of power systems can be solved so easily. We used the cracked version of this software to design and simulate our project. At first we had studied some papers and completed the simulations or some part of simulation of those papers and tried to find the actual results which were shown in those papers. Then we started designing the electrical diagram or one line diagram of IUT.

At first we studied and designed the model of the paper Interactive simulation of power system. [8] And from this paper we have got the theoretical idea of simulation. For practical idea at first we have followed Power System Analysis of a Micro grid using ETAP [9]. The project of this paper was so basic and we got our knowledge from that paper. Then we have implemented some other projects to get a good idea about Etap, we have watched a lot of YouTube videos to know about all the functions of Etap. Some other papers we have worked on are Determination of Bus Voltages, Real and Reactive Power Losses in the 'Northern Nigeria 330Kv Network Using Power System Analysis Tool (PSAT)' [10] and 'Analyses and monitoring of 132 kV grid using ETAP software' [2] . Here from those papers we learnt about the bus bars and how it works on ETAP. As previously energy sources and bus bars were separately observed but here in this project we have observed those simultaneously. In the paper 'Design of Electrical System Based on Load Flow Analysis Using ETAP for IEC Projects' [3] we learnt about IEC projects in detail and we learnt how to adjust all the inputs and do the comparative analysis. By using the data from our previous calculations we have designed a complete electrical diagram of IUT. We added every single building of IUT. The north and south halls of residence, first, second and third academic buildings, female halls of residence, bungalow, medical centre, student centre, utility building, administrative building, laundry, D-type building, mosque, auditorium and street lights. We have used the peak demand values in our calculations. At first we used the generators with proper data we had (508 kw and 492 kw). And then we connected all the loads and buildings of IUT using the transmission line, circuit breakers and bus bars. As we have different bus bars for different buildings of IUT it helped us to do the things easily. Busbars are modern pieces of innovation that make difficult control conveyance simpler, less costly and more easily usable. In electrical applications, a busbar is a basic component for conducting noteworthy current levels between capacities inside the gathering. Busbars are utilized in any number of setups, extending from vertical risers to bars inside a dispersion board. And we had few data about the cables and transmission lines of IUT so we had to assume some data while using the transmission lines in our simulation. And IUT has DC electrical connection only in workshops so we had to add the relevant data accordingly. As the total connected load to IUT is 1724.81 KW and total connected supply is less than 1000 KW so we had to switch off some power connection while doing the simulation. We used basic and given admittance for the transmission lines and for the lengths we had to assume some values. And for selecting the type of inductor mostly we used the basic built in models given in the software. We have used circuit breakers in every possible load connection. And in most of the cases we have taken the power factor between 80 to 90 percent. As for most of the calculation Newton-Raphson and Gauss-Seidel methods are used so we have done some theoretical calculations to check whether it matches the simulation result or not. From the paper 'Design Analysis of 220/132 KV Substation Using ETAP' [11] we have gained the idea of isolation switches and we applied those isolating switches in our simulation. We have observed all the outputs in the auto generated report of Etap. And for all types of cables we can select the conductors for the conductor lab. The conductor is the sort of metal which permits the electrical current to stream through it. The significant part of electrical conductors is made up of metals like copper and aluminum and their amalgams. In an electrical conductor, the electrical charges move from molecule to particle when the potential contrast is connected over them. The electrical conductors are utilized within the frame of the wire. We have chosen conductors by considering the different variables like loss (corona), ductile quality, and weakness quality nearby conditions and fetched. So, for most of the cases we have used T&D book type conductors. And we have added a ground earthing system in every cable. The detailed calculation of loads and power flow between the transmission lines of different loads are given in the next section. We have observed the results and proposed our present plans and future plans from the results. All of the details of those information are added in the upcoming chapters.

Chapter 4

Results and Discussions

Putting the calculated data in Etap we have run our simulation. We interchanged data to get different results. And used the trial and error method in some cases to get the best output. We have used 440 volt voltage lines in our simulation.

4.1 Simulations:

The data we have used for our simulation is given below.

Table 4.1.1: Total KW and KVA Used for Simulation

Building	**Total Connected KW**	**Total Connected KVA**
Administrative building	62.31	67.97
First Academic Building	262.45	305.78
Second Academic Building	366.28	423.74
North hall	134.13	147.71
South hall	142.45	158.51
Utility Building	101.62	113.04
Central Cafeteria Building	35.52	39.95
Auditorium	72.81	79.34
Mosque	9.45	11.38
Female hall	69.26	79.58
Third Academic Building	143.72	161.05
D-type buildings	31.09	34.36

Bungalow	41.03	45.34
Workshops	252.59	298.59
Total	1724.81	1966.34

Total amount of electricity flowing through different buildings of IUT is given below.

Table 4.1.2: Total Current Flowing Through the Bus Bars of Each Building

Building	**Total Current (Amp)**
Administrative building	89.18
First Academic Building	362.93
Second Academic Building	553.2
North hall	313.22
South hall	208.58
Utility Building	148.32
Central Cafeteria Building	52.42
Auditorium	104.11
Mosque	14.94
Female hall	103.67
Third Academic Building	211.32
D-type buildings	45.08
Bungalow	89.21
Workshops	253.53
Total	2549.71

After completing the single line diagram of IUT campus we have used the above mentioned value to get the power flow inside the bus bars and loads. We had to adjust, scale up and scale down some ratings to get the total connected load 1724.81 kilowatts. We have observed all the alert views to bring the necessary changes. The alert view shows all the warnings when there is any potential danger or overflow or any other problem. We have observed the result in the load flow analyzer and noticed the critical conditions of bus bars as the connected load is more than connected supply. Using the load flow analyzer we have observed the reports of general info, bus result, branch result, loads and sources. The results are given in the next segment. We had to export values to different projects to get a comparative idea about the results of the simulation. We have used the ideas we have learnt from the paper A Detailed Study for Load Flow Analysis in Distributed Power System [12]**.** After that we have changed the display options to observe all the outputs one by one individually. We have observed the real power and reactive power through the different bus bars. We have also observed the load terminal voltages and line and cable voltage drops. We have also done the short circuit analysis to get the comparative information. Checked the stability and transient stability of different connection lines. We have done the reliability assessment, checked voltage stability and optimal power flow. Some of the results are shown in the result section. We have observed all the reports from the report manager of Etap. And finally we have done the contingency analysis.

4.2: Results:

Here are some results of power flow through various bus bars**.**

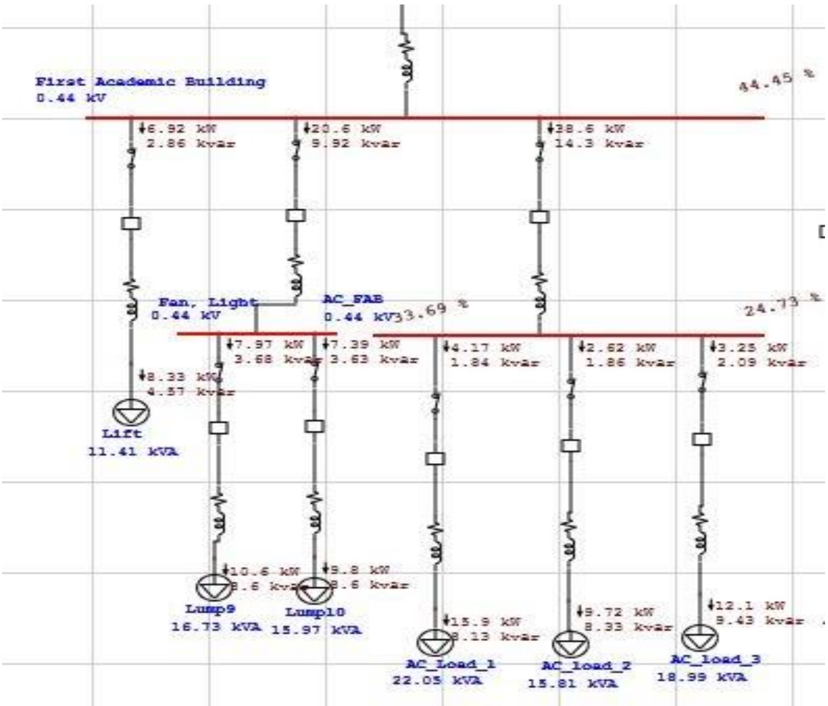

Figure 4.2.1: Power flow through different loads of first academic building

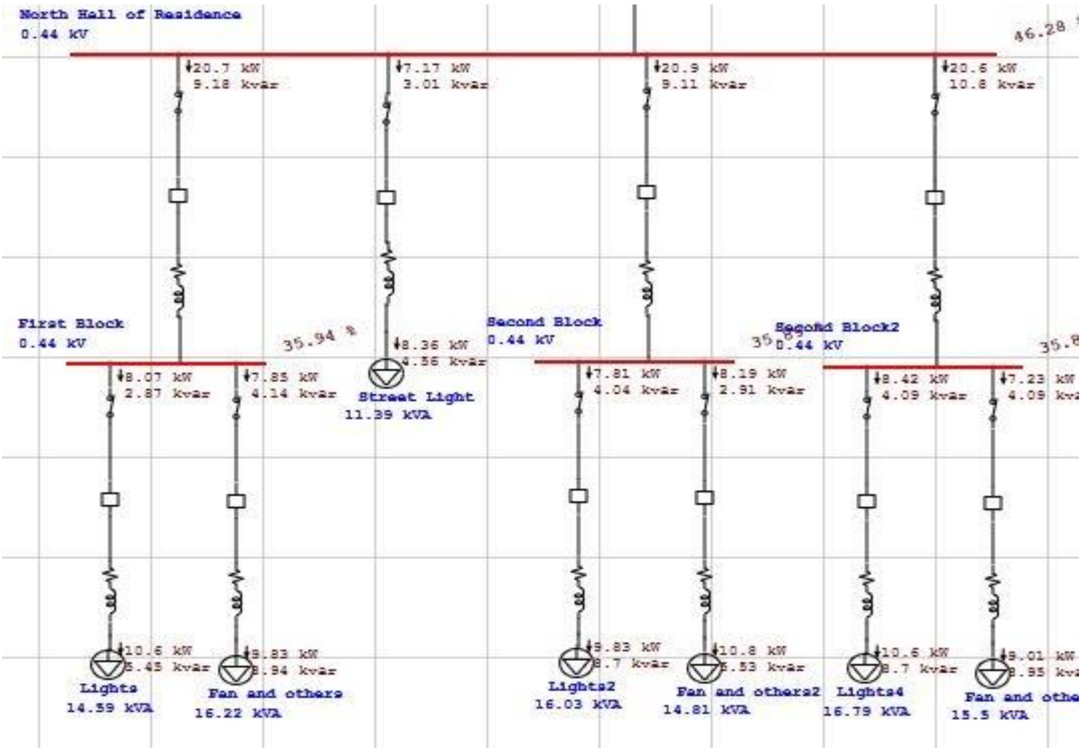

Figure 4.2.2: Power flow through different loads of north hall of residence

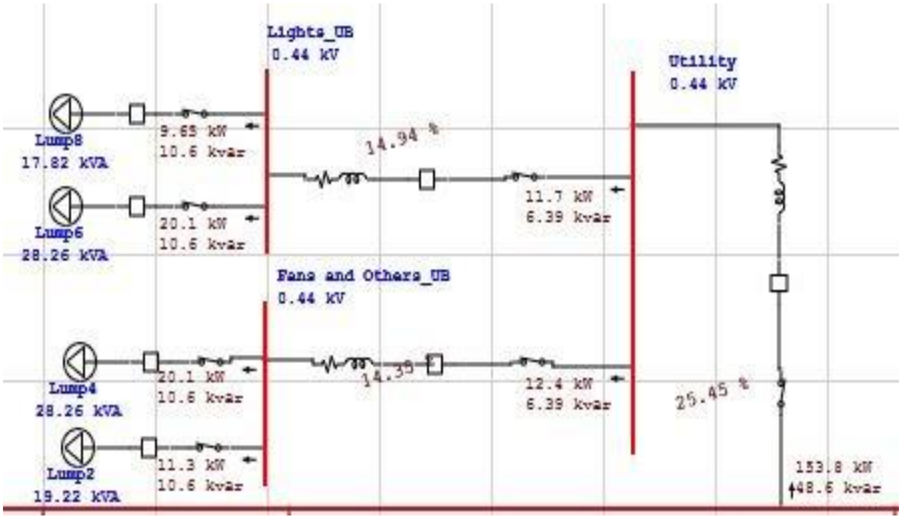

Figure 4.2.3: Power flow through different loads of utility building

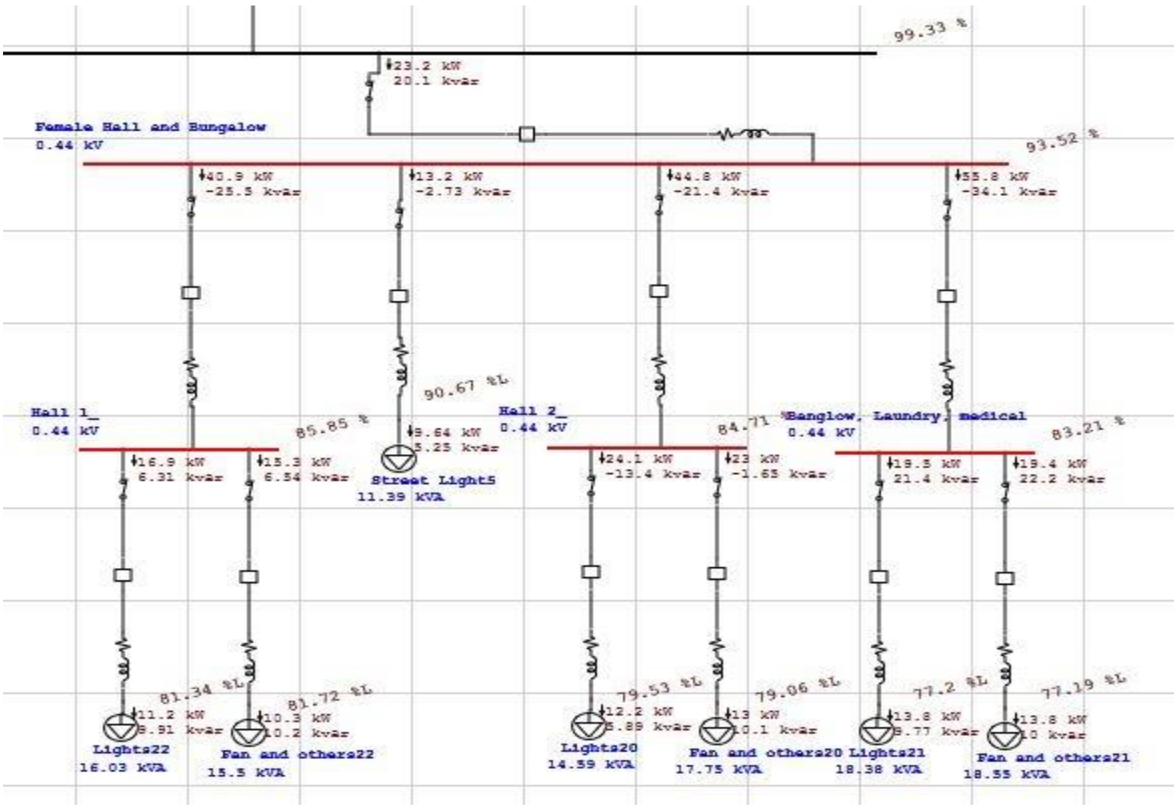

Figure 4.2.4: Power flow through different loads of female hall and bungalow

Here is electricity through different branches of different buildings.

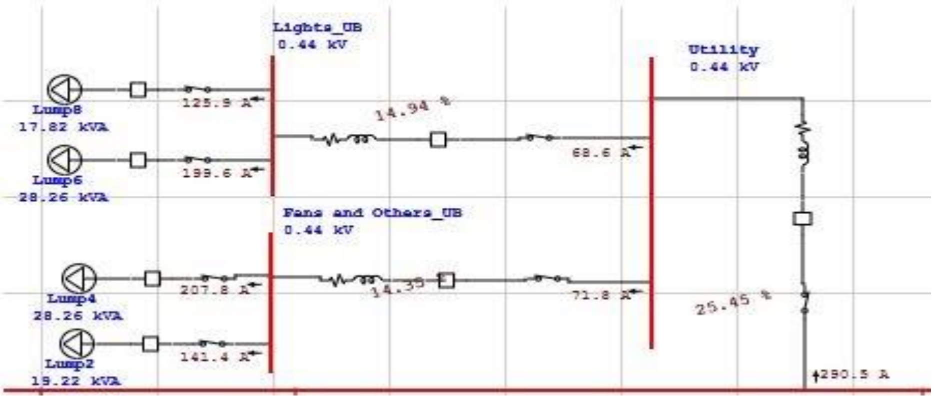

Figure 4.2.5: Electricity through different branches of Utility Building

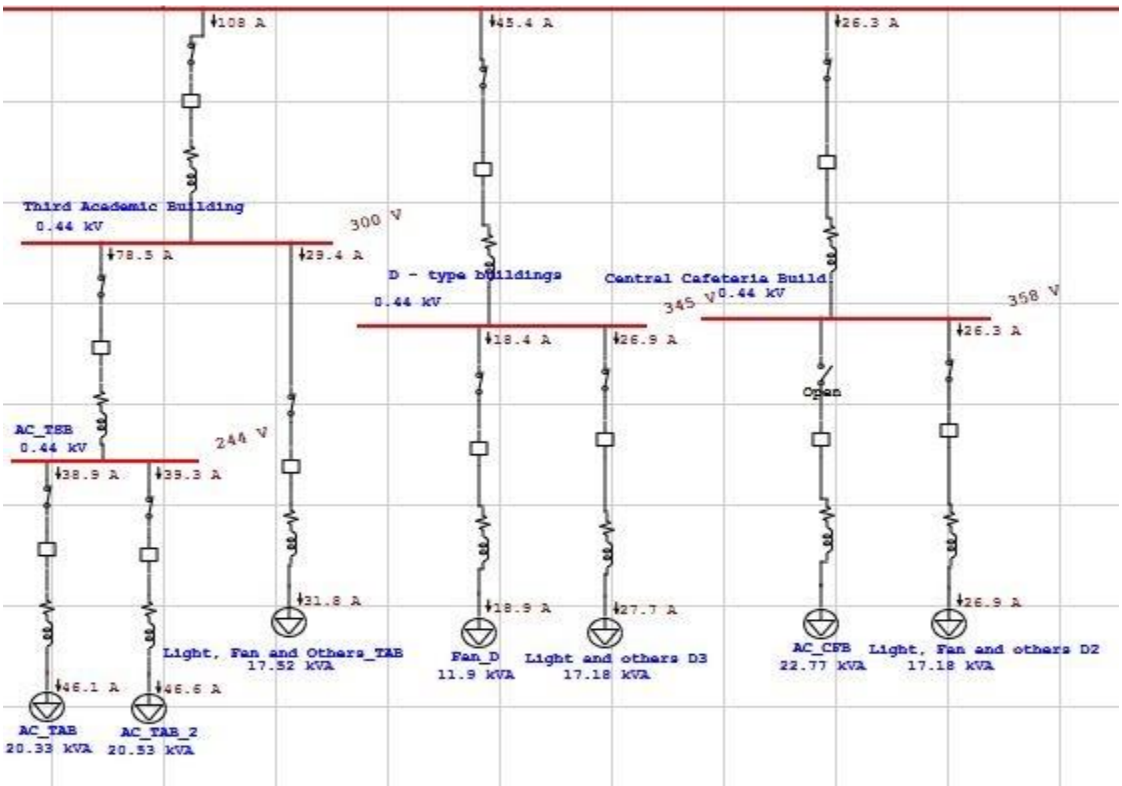

Figure 4.2.6: Electricity through different branches of Third Academic Building, D-type Building and Central Cafeteria Building

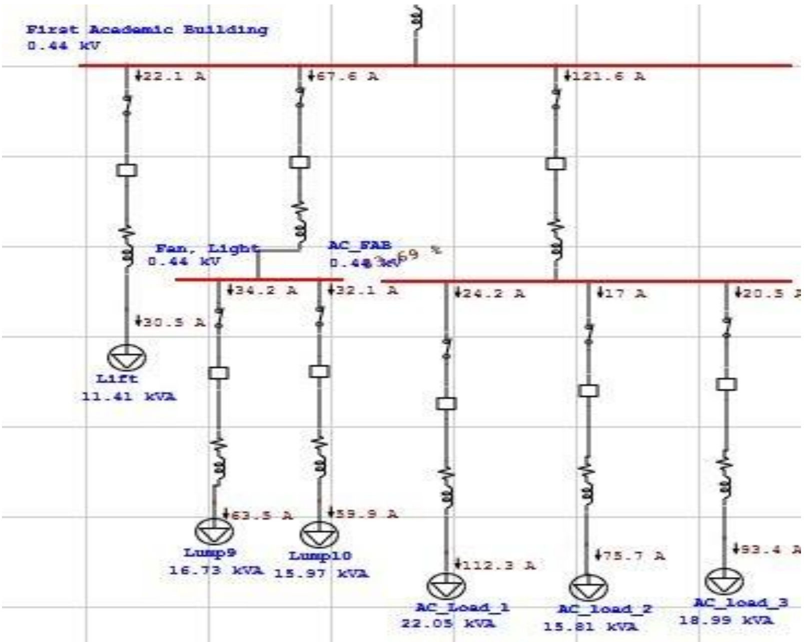

Figure 4.2.7: Electricity through different branches of First Academic Building

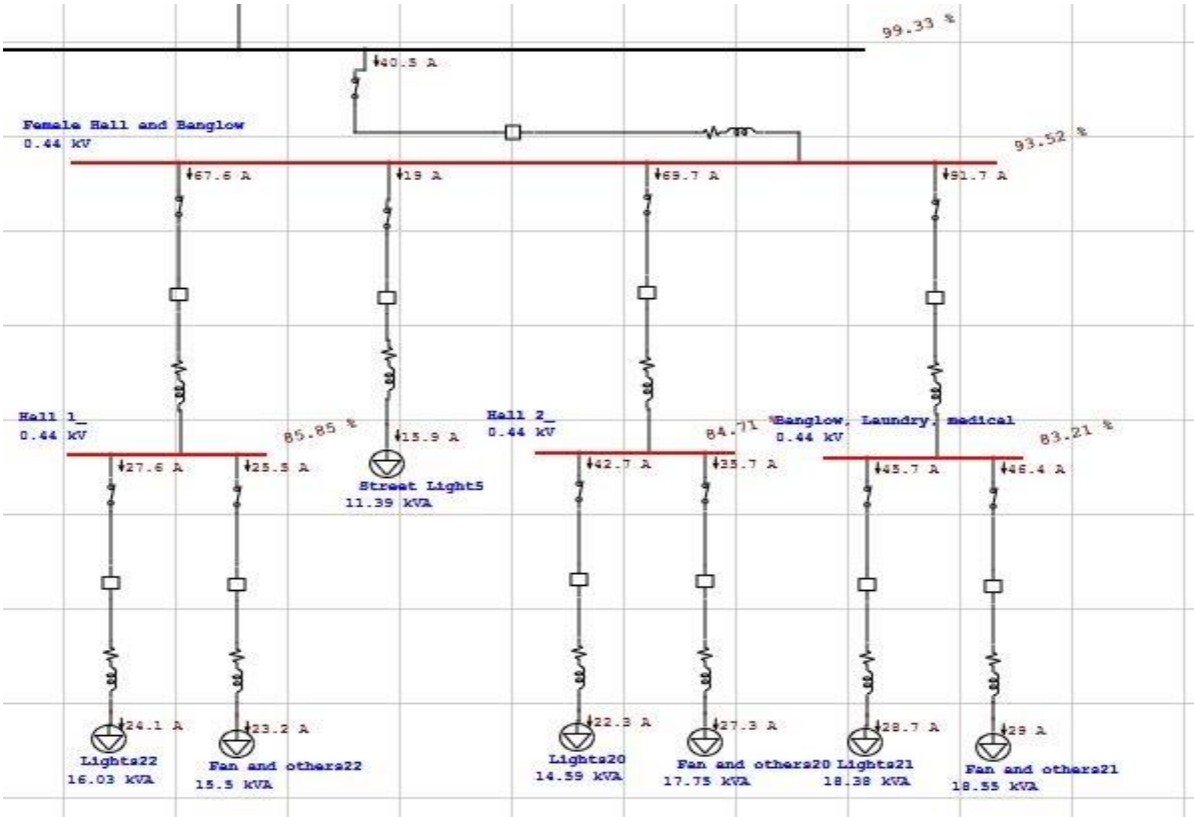

Figure 4.2.8: Electricity through different branches of Female hall and Bungalow

Here is line and cable voltage drop through different branches of different buildings.

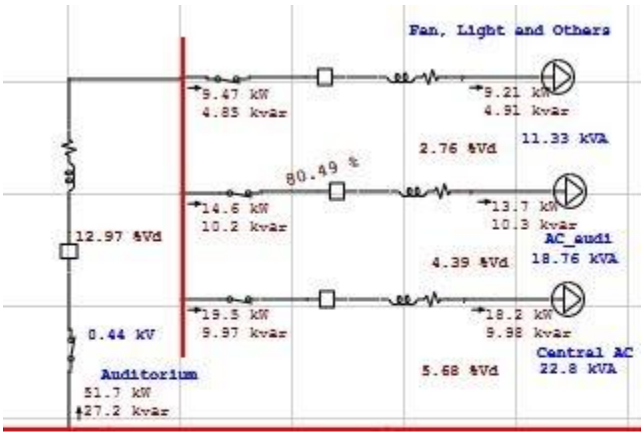

Figure 4.2.9: Line and cable voltage drop through different branches of Auditorium

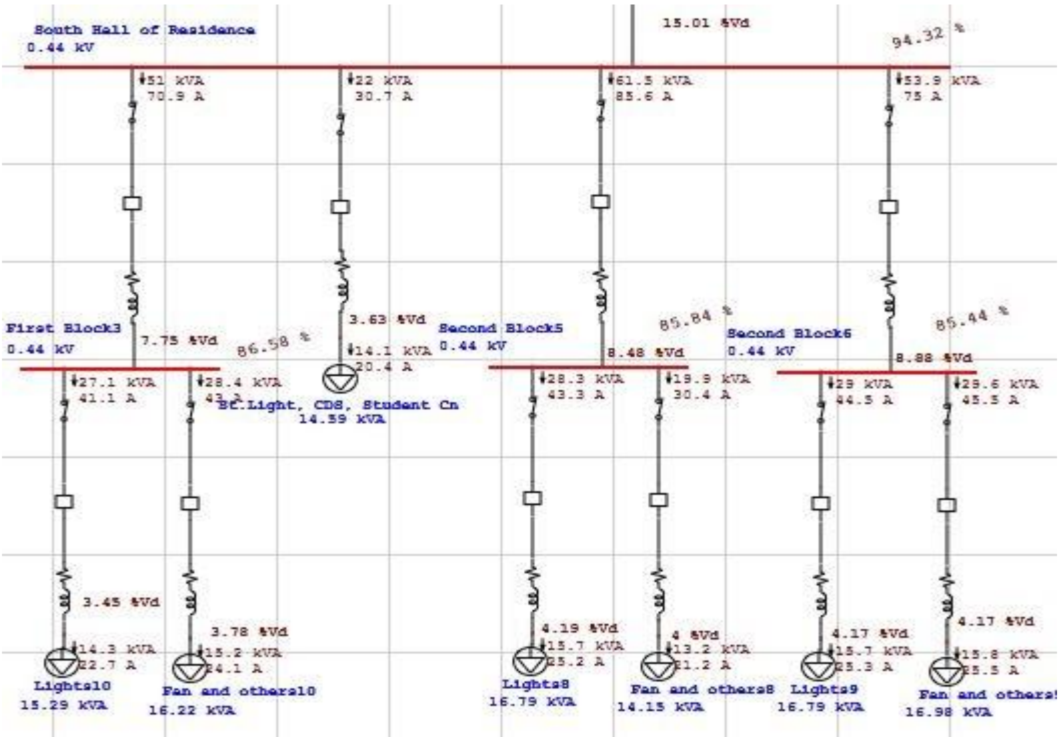

Figure 4.2.10: Line and cable voltage drop through different branches of South Hall

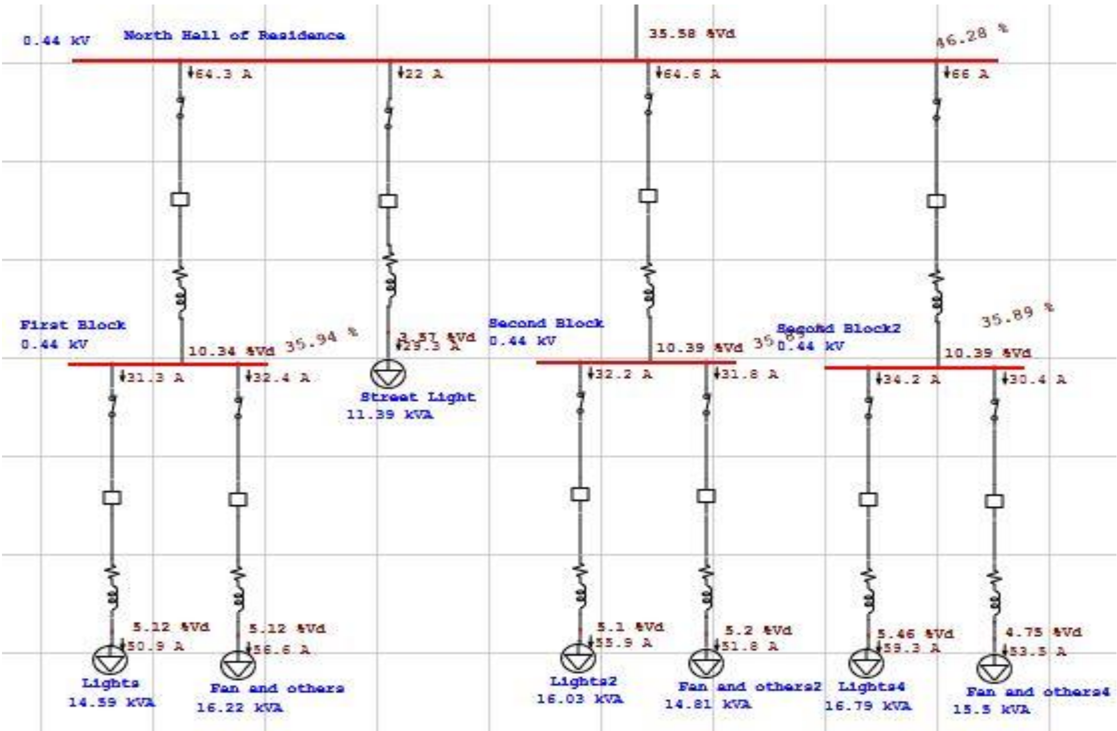

Figure 4.2.11: Line and cable voltage drop through different branches of North Hall

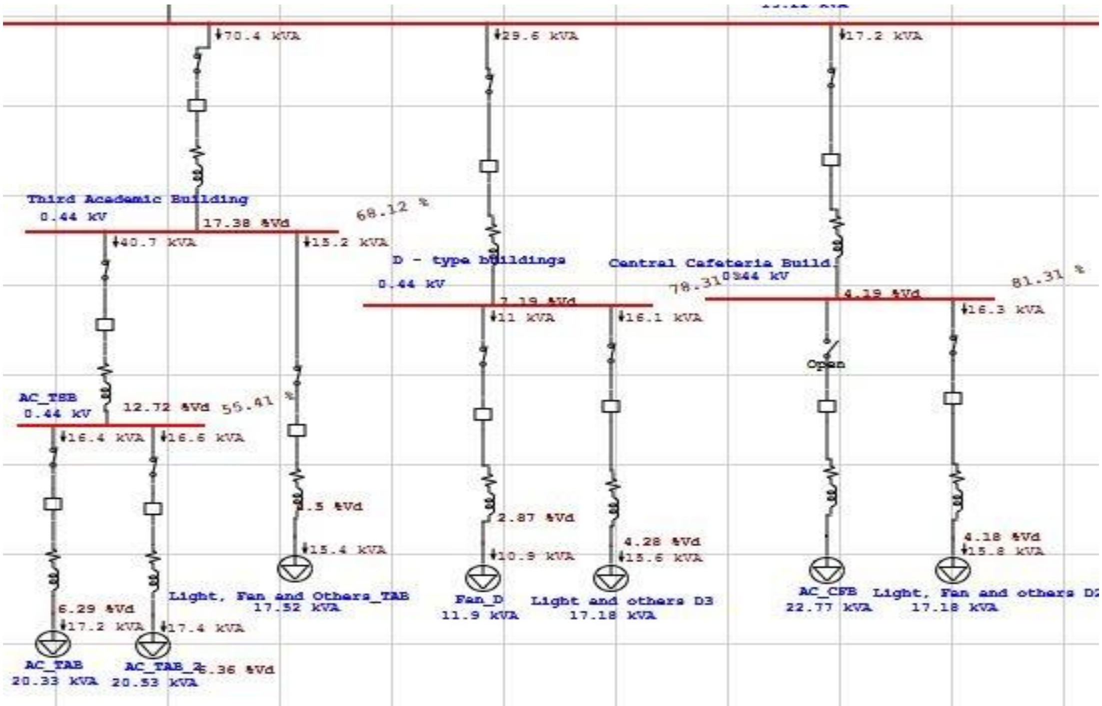

Figure 4.2.12: Line and cable voltage drop through different branches of Third Academic Building, D-type buildings and Central Cafeteria Building

Here is the terminal voltage of different loads of different buildings.

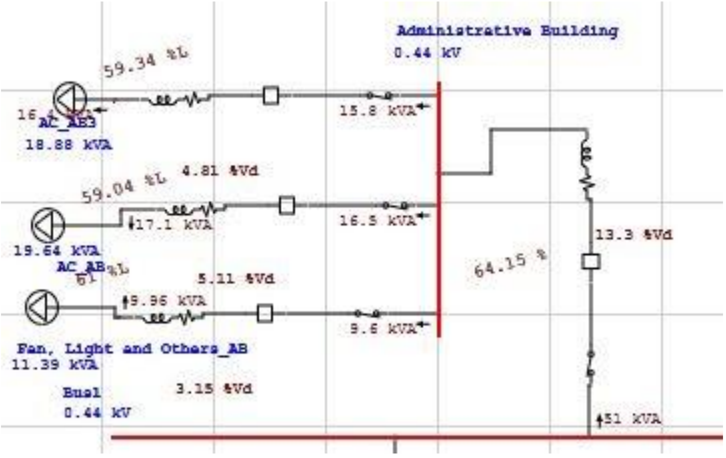

Figure 4.2.13: Terminal voltage of different loads of Administrative Building

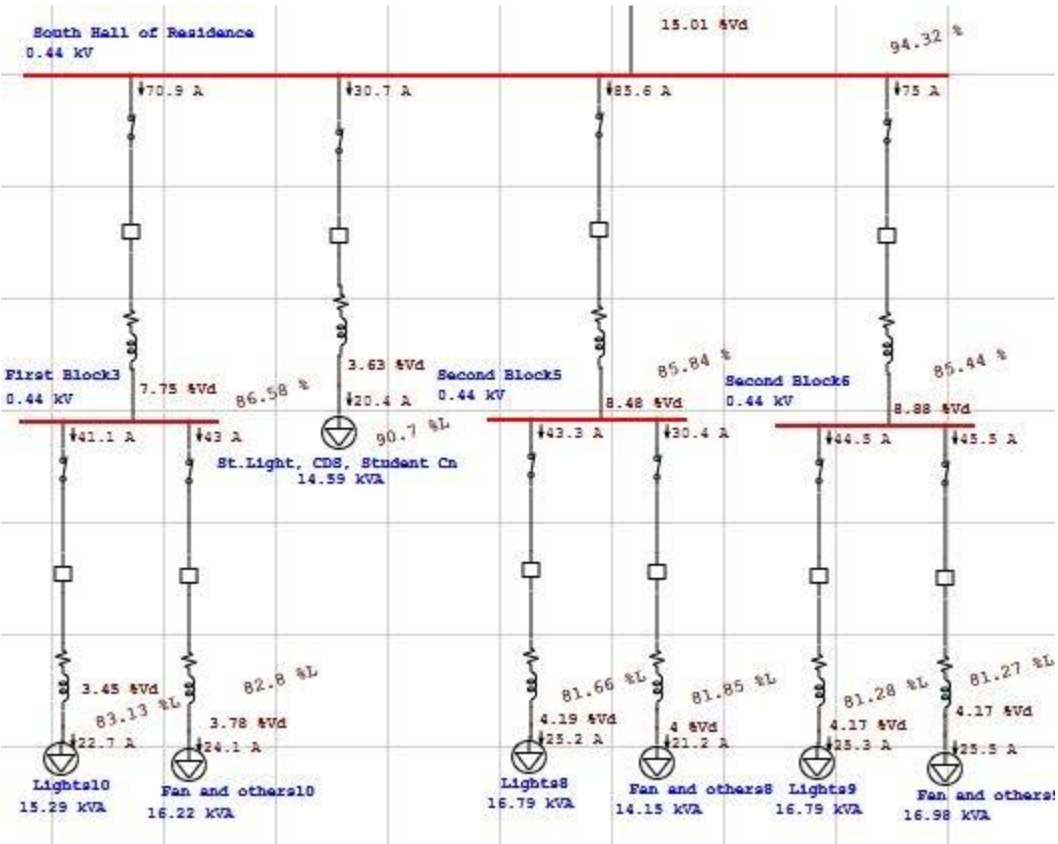

Figure 4.2.14: Terminal voltage of different loads of South Hall of Residence

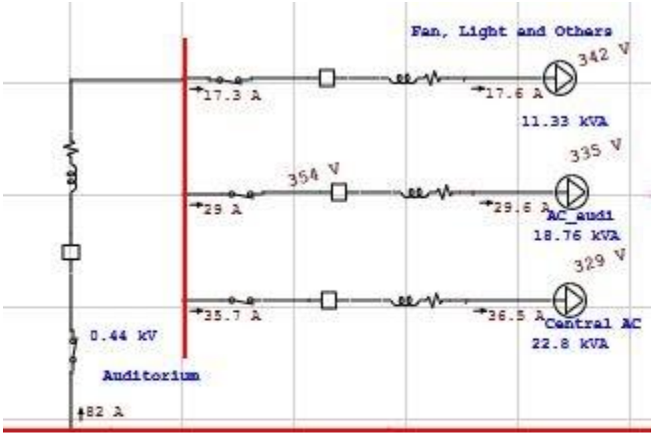

Figure 4.2.15: Terminal voltage of different loads of Auditorium

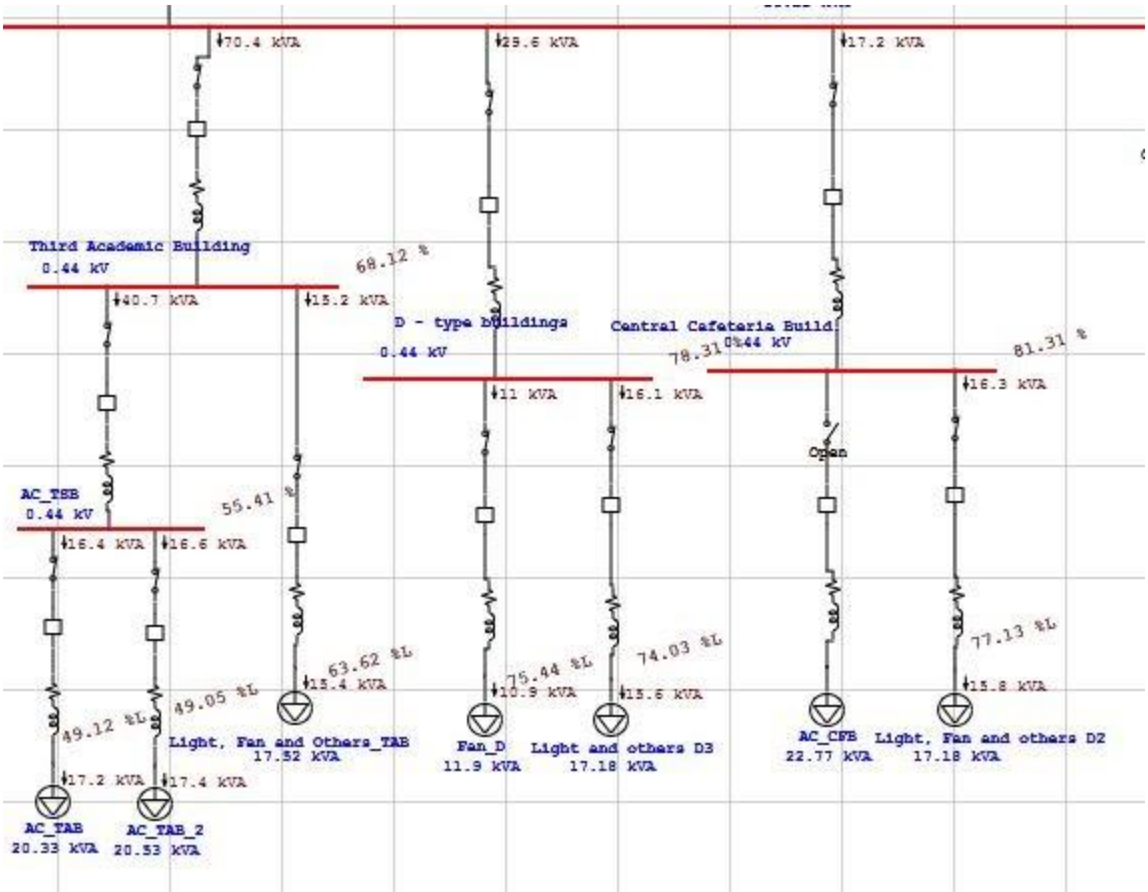

Figure 4.2.16: Terminal voltage of different loads of Third Academic Building, D-type buildings and Central Cafeteria Building

Then we have generated report on load flow analysis of single line diagram of IUT. Some results are shown below.

ID	Type	MW Flow	Mvar Flow	Amp Flow
Line3	Line	0.306	0.0913	419.4
Line5	Line	0.306	0.0913	419.4
Line7	Line	0.0082	0.0071	67.11
Line9	Line	0.002	0.0013	16.73
Line11	Line	0.0025	0.0024	26.33
Line13	Line	0.0018	0.002	24.55
Line31	Line	0.0023	0.0024	24.67
Line63	Line	0.0029	0.0016	15.25
Line65	Line	0.0027	0.0015	15.25
Line122	Line	0.004	0.0038	25.94
Line127	Line	0.0015	0.0008	7.542
Line131	Line	0.0014	0.0008	7.544
Line133	Line	0.0082	0.0055	57.99
Line135	Line	0.0037	0.0021	32.73
Line137	Line	0.0025	0.0016	32.61
Line141	Line	0.0027	0.0024	25.77
Line149	Line	0.0043	0.0025	23.62
Line152	Line	0.0037	0.0022	23.64

Figure 4.2.17: Report of power flow through different branches

ID	Rating/Limit	Rated kV	kW	kvar
AC_AB3	18.88 kVA	0.44	11.36	10.28
AC_load_2	15.81 kVA	0.44	9.65	8.27
AC_TAB	20.33 kVA	0.44	14.52	7.44
Fan	5.69 kVA	0.44	4.08	2.22
Fan, Light and Othe	11.33 kVA	0.44	8.14	4.34
Fan_D	11.9 kVA	0.44	8.14	5.25
Lift	11.41 kVA	0.44	8.07	4.43
Light, Fan and othe	17.18 kVA	0.44	12.17	6.8
Light, Fan and Othe	17.52 kVA	0.44	11.3	8.5
Lights20	14.59 kVA	0.44	10.52	5.1
Lights21	18.38 kVA	0.44	12.01	8.51
Lights22	16.03 kVA	0.44	9.61	8.51
Lump2	19.22 kVA	0.44	11.31	10.64
Lump8	17.82 kVA	0.44	9.7	10.65
Lump9	16.73 kVA	0.44	10.45	8.47
Street Light5	11.39 kVA	0.44	8.03	4.38

Figure 4.2.18: Report of power flow through different loads

	Load Flow				XFMR
ID	MW	Mvar	Amp	%PF	%Tap
Third Academic Building	-0.026	0.007	40.0	-96.3	
Bus144	0.029	-0.017	49.8	-85.7	
Bus1	-0.018	-0.004	24.2	97.8	
Bus182	0.018	0.001	24.0	99.9	
Bus1	-0.012	-0.002	15.6	97.9	
Bus62	0.012	0.002	15.5	98.8	
Bus164	0.018	0.032	58.4	50.4	
Female Hall and Bungalow	-0.022	0.012	40.5	-87.4	
Bus2	0.033	-0.038	62.5	-65.5	
Bus4	0.033	-0.038	62.5	-65.5	
First Academic Building	0.012	0.003	15.6	97.9	
Auditorium	0.012	0.003	15.6	97.9	
South Hall of Residence	0.102	-0.046	140.1	-91.3	
Administrative Building	0.019	0.004	24.2	97.8	
Third Academic Building	0.050	0.003	62.7	99.8	
Central Cafeteria Build.	0.019	0.004	24.3	98.3	
Female Hall and Bungalow	0.095	-0.033	126.6	-94.5	
Utility	0.039	0.003	48.9	99.6	
D - type buildings	0.012	0.003	15.9	97.6	

Figure 4.2.19: Part of total load flow report

Branch Losses Summary Report

	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
Branch ID	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
Line135	-0.026	0.007	0.028	-0.007	2.0	0.4	88.4	94.3	5.90
Line137	0.029	-0.017	-0.026	0.018	3.1	0.7	88.4	82.6	5.81
Line122	-0.018	-0.004	0.019	0.004	0.7	0.2	100.6	104.6	4.00
Line267	0.018	0.001	-0.018	-0.001	0.7	0.2	100.6	96.6	3.91
Line63	-0.012	-0.002	0.012	0.003	0.3	0.1	102.0	104.6	2.57
Line65	0.012	0.002	-0.012	-0.002	0.3	0.1	102.0	99.4	2.56
Line241	0.018	0.032	-0.014	-0.031	4.2	0.9	82.2	76.0	6.18
Line243	-0.022	0.012	0.024	-0.012	2.0	0.4	82.2	87.3	5.14
Line3	0.033	-0.038	-0.028	0.039	4.8	1.0	104.6	100.0	4.55
Line5	0.033	-0.038	-0.028	0.039	4.8	1.0	104.6	100.0	4.55
Line7	0.012	0.003	-0.012	-0.002	0.3	0.1	104.6	102.0	2.58
Line120	0.102	-0.046	-0.078	0.051	24.2	5.2	104.6	87.0	17.58
Line133	0.050	0.003	-0.045	-0.002	4.8	1.0	104.6	94.3	10.21
Line149	0.019	0.004	-0.018	-0.003	0.7	0.2	104.6	100.5	4.01
Line208	0.095	-0.033	-0.076	0.037	19.7	4.3	104.6	87.3	17.21
Line210	0.039	0.003	-0.036	-0.003	2.9	0.6	104.6	96.5	8.01

Figure 4.2.20: Part of branch losses summary report

Critical Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Gen1	Generator	Under Power	0.000	MW	-0.028	0.0	3-Phase
Gen2	Generator	Under Power	0.000	MW	-0.03	0.0	3-Phase
Hall 1_	Bus	Under Voltage	0.440	kV	0.37	83.3	3-Phase
Hall 2_	Bus	Under Voltage	0.440	kV	0.37	83.1	3-Phase
Lights_UB	Bus	Under Voltage	0.440	kV	0.41	93.0	3-Phase
Second Block5	Bus	Under Voltage	0.440	kV	0.36	82.6	3-Phase
Second Block6	Bus	Under Voltage	0.440	kV	0.36	82.6	3-Phase
South Hall of Residence	Bus	Under Voltage	0.440	kV	0.38	87.0	3-Phase
Third Academic Building	Bus	Under Voltage	0.440	kV	0.42	94.3	3-Phase

Marginal Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus1	Bus	Over Voltage	0.440	kV	0.460	104.6	3-Phase
Bus108	Bus	Under Voltage	0.440	kV	0.42	96.6	3-Phase
Bus182	Bus	Under Voltage	0.440	kV	0.43	96.6	3-Phase
Utility	Bus	Under Voltage	0.440	kV	0.42	96.5	3-Phase

Figure 4.2.21: Alert view report

And we also did the short circuit analysis, optimal power flow, reliability assessment, fault insertion and checked the voltage stability. Some parts of the results are shown below.

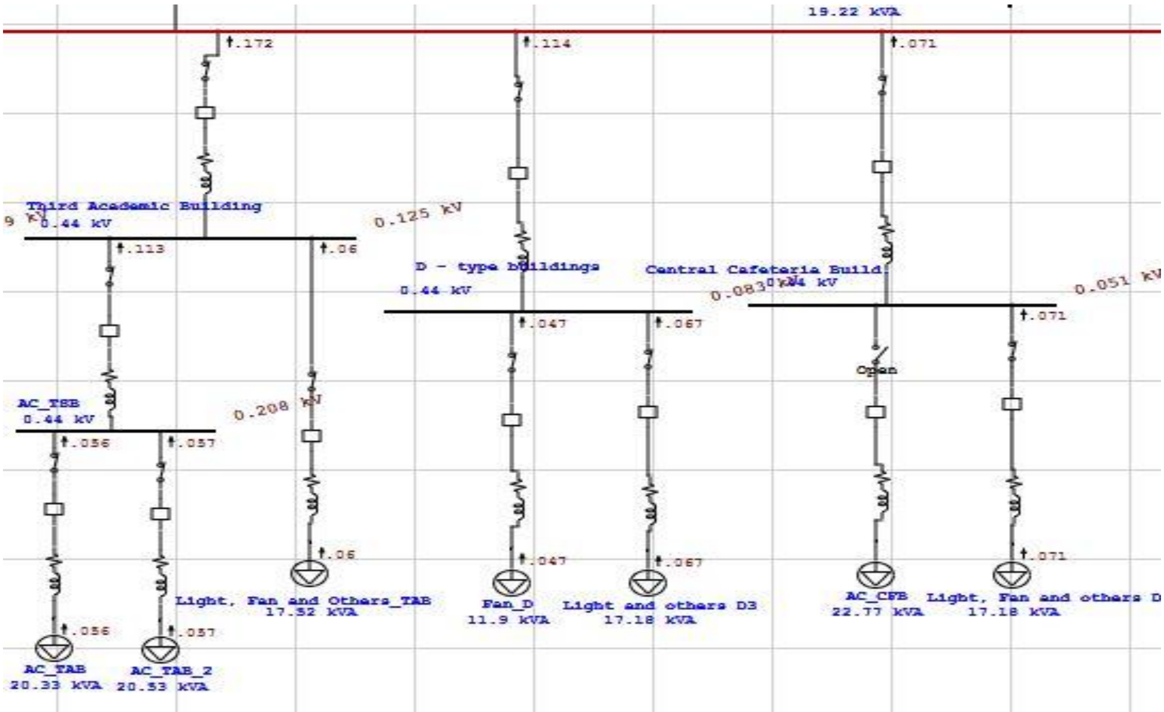

Figure 4.2.22: Short circuit analysis of Third Academic Building, D-type buildings and Central Cafeteria Building

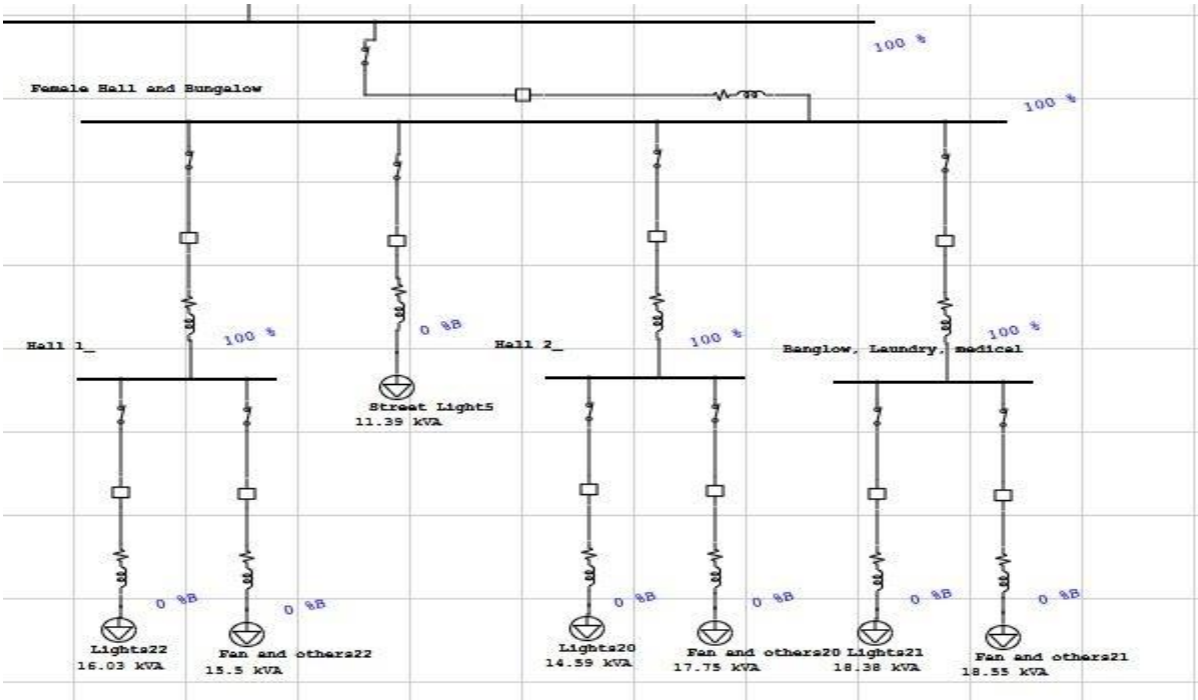

Figure 4.2.23: Voltage stability of Female hall and Bungalow

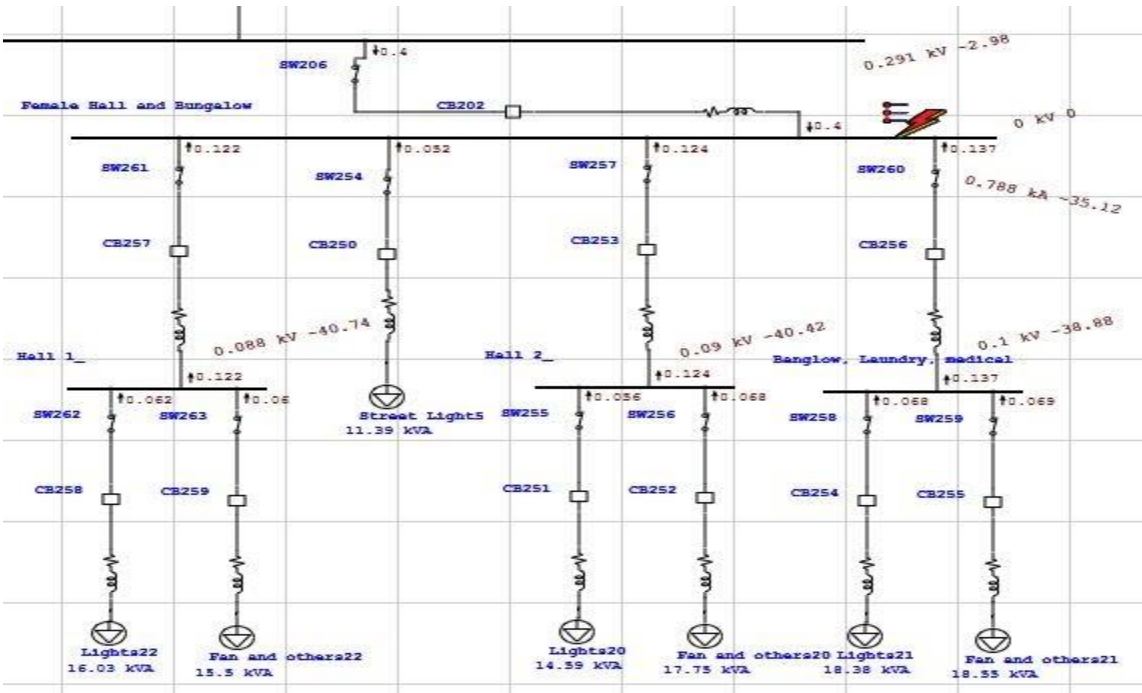

Figure 4.2.24: Fault insertion of Female hall and Bungalow

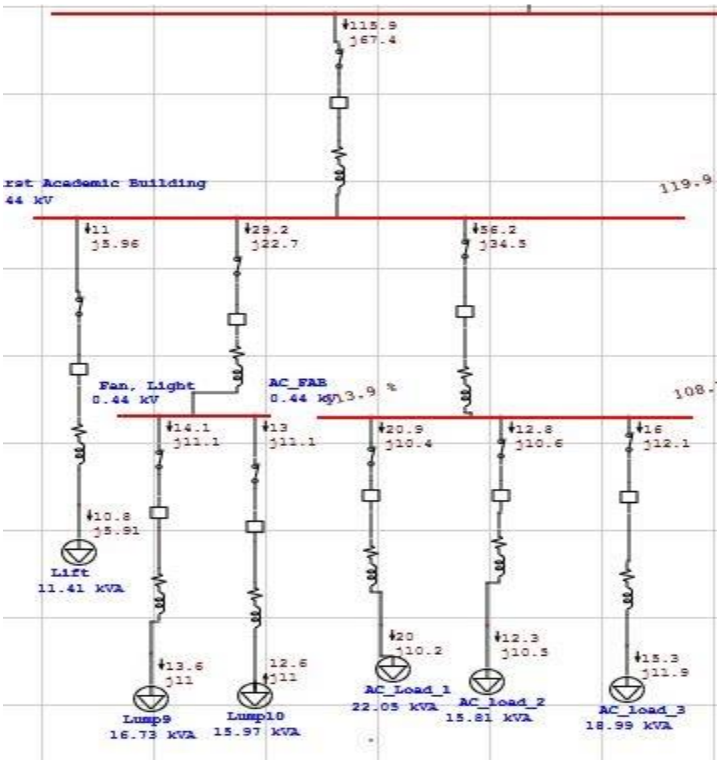

Figure 4.2.25: Optimal power flow of First Academic Building

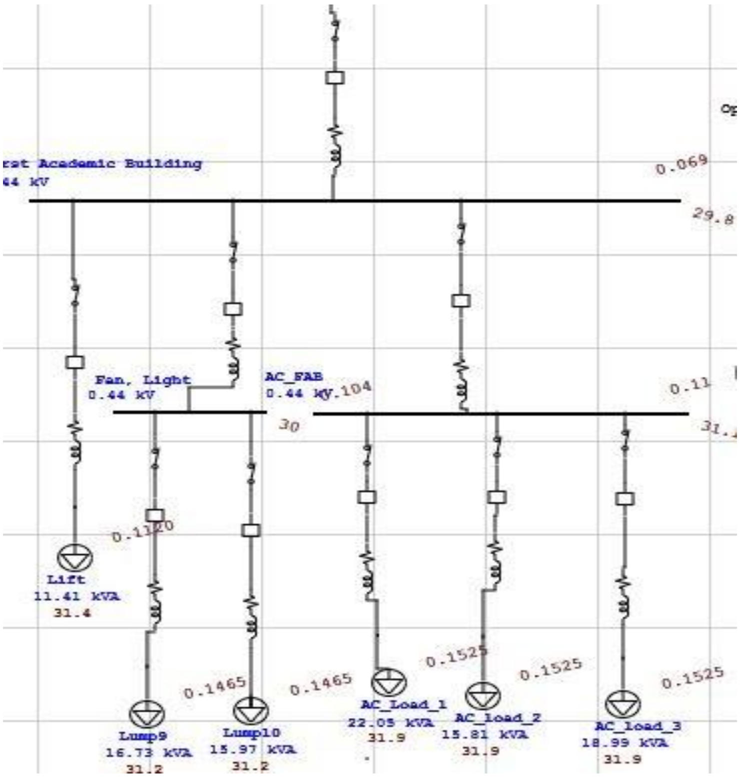

Figure 4.2.26: Reliability assessment of First Academic Building

4.3: Discussion:

At first we observed the load flow rate in different loads of different buildings. And we have identified the overloaded bus. In most of the cases the overloaded buses were the buses where heavy loads were installed. The electrical system was designed for 220 students with no heavy load instruments. But because of increasing numbers of students and installing heavy loads causes an overload in a good number of buses. From the load flow report we have identified that the loads in the academic buildings are huge. As the new air conditioners were installed which draw heavy electricity, So, during class hours most of the air conditioners of first, second and third academic buildings run on full load. This thing causes the overload in those buses. And most importantly the cables of these bus bars were not designed for this huge amount of load flow so it causes more transmissions loss and creates danger. In the report we have observed the details of the load flow. The method which was used for this calculation was Adaptive Newton-Raphson Method. And the maximum number of iteration was 99. Then we have observed the detailed load of each load. We have observed the voltage, power, amplitude, power factors etc. From the alert view report we have identified the overloaded buses. The first overloaded bus was the first academic building. Because of installing a lift and air conditioners in different rooms, and increasing the capacity of the labs the total power consumption of this building was huge and it was showing the alert view. The second academic building and the third academic building also had the alert view. Because electrical circuits are all designed to support a certain amount of power. A circuit overload occurs as it draws more power than the circuit can accommodate. Trips on circuit breakers aid in the ‘breaking' of the circuit and hence the flow of current. The overload would cause the circuit wiring to overheat if there were no breakers. This could cause the wire insulation to melt or even cause a massive accident. In the second academic building new heavy loads were installed also. A huge number of air conditioners and two lifts were installed. Also the number of classes as well as the number of students increased. And the third academic building is a new building adjacent to the second academic building. And it has some air conditioners also. We have used different circuit breakers for different loads. As the academic buildings consume more power than other buildings so the ratings of circuit breakers in these buildings were higher than other buildings. The north and south halls of residence were not overloaded but it was in the marginal region. Though the number of students in the campus increased but the number of students in the north hall of residence and south hall of residence didn’t increase that much. This is why the overall power consumption in those buildings were almost the same as previous. But the number of floors in the utility building increased and a new hall (Female hall of residence) was made for the female students, these two buildings were also major reasons for the critical electrical condition. Most of the distribution boards in the old buildings were damaged. And the frequent load shedding also causes huge problems in the real life scenario which was not possible to show in the simulation. Surges, also known as transients, are brief overvoltage bursts or disruptions in a power waveform that can damage, weaken, or kill electronic equipment. There are electrical voltages that are 10% or higher than standard or prescribed. They will overwhelm the electrical equipment and inflict significant harm if left unattended. The loads of administrative building also increased. So, after identifying the overloaded buses we have discussed the possible solutions for these problems which includes installing a new generator. The details about the solution is added in the next chapter.

After doing the load flow analysis we have also completed the short circuit analysis to test the safety systems in a faulted state and at various voltage levels for various operating scenarios. [13] A short circuit is a low-resistance path that passes an irregular large volume of current by mistake. As a short circuit happens in an instant, a very low impedance path is generated to which the whole device voltage is applied. The resulting current would be several times that of the usual circuit current, so if the connection is not activated and the current is broken, significant harm will result. To safeguard against the negative effects of short circuits, it is necessary to predict or measure the value of the potential current that will exist under short circuit situations, and to ensure that the protection equipment installed to stop that current are designed to endure and stop that current. We have selected the circuit breakers and the ratings of circuit breakers after doing the short circuit analysis.

After doing the short circuit analysis we have checked the voltage stability of different loads of different buildings as a number of buses were either in under voltage or in over voltage condition, so checking out the stability of the connected loads were necessary. The voltage stability is related to maximum power transfer of any network. It is the ability to maintain steady voltage after any disturbance. Weak buses operate in under voltage condition and the buses which cross the upper limit work in the over voltage condition. [14] The buses of the utility building and the halls of residence were operating at under voltage condition. After this we have tested the fault insertion in different buildings. Fault insertion testing is a type of software testing that intentionally introduces errors into a system to make sure that it can withstand and recover from them. Fault insertion testing is commonly performed basic training to identify any potential flaws created throughout the supply of electricity. It is used to identify the weakness in the system and take necessary measurements. We have attached the result of fault insertion in the female hall of residence. It gives an idea what type of protection devices can be used to protect the equipment. In IUT the lightning protection system is not up to the mark anymore. So we have suggested our proposal about using the protective devices to ensure minimum system disruption [15] in the next chapter. Then we have checked the optimal power flow of different loads of different buildings. The Optimal Power Flow is used to solve the problem of deciding the best operating levels for electricity generation in order to meet demand across a transmission system while minimizing operating costs. We used this result to do the comparative analysis between normal power flow and the optimal power flow and later we used to predict the cost for our proposed solution as it is a necessary step to investigate the problems. Load flow analysis solves the steady operating state with node voltages and branch load flow in the power system depending on a given generation state and transmission network structure. We have reviewed the paper 'Optimal Power Flow Analysis for 23MW Micro grid using Etap' [16] to get the necessary idea to do the optimal load flow calculation. And finally we have done the reliability assessment to evaluate the overall reliability. It provides a cost effective solution to provide uninterrupted power supply. The result of the reliability assessment of the first academic building is attached here. We have used the result for our calculation for solution. If any new generation equipment is added then some technical problems arise [17]. So reliability assessment is necessary to take the proper decision. All the proposed solutions for these problems and the contingency plans are given in the next chapter.

Chapter 5

Possible Solutions and Cost Estimation

5.1 Possible solutions:

From the discussions so far we can conclude that the substation of IUT might face severe damage if necessary actions are not taken. We have discussed the problems elaborately now we will propose solutions to the problems. There are various precautions and safety protocols that we can apply to mitigate the risks and create a safer environment of the substation. We have also suggested necessary changes and installations for the optimization of power. These solutions are discussed below:

- **Substation upgradation:**

The 2000 KVA substation of IUT was built 35 years ago considering a much smaller infrastructure with fewer buildings and laboratories. Over the years the population of students has amounted to around 2500 and so new buildings, workshops, classrooms etc. were built to accommodate this huge number of students. Over the last three years a new hall of residence was built and the classrooms were all equipped with heavy duty ACs but no significant modification has been made to the substation. [18] To create an uninterrupted and safely operating substation and also to meet the new load demand of IUT campus, it is necessary to change or modify different parts of the sub-station according to the present standard (IEC, NFPA and BNBC). The upgradation must be done following the proper protection protocol and during the upgradation process, installation of heavy duty equipment must be strictly prohibited. Most importantly to meet this increased demand and avoid overloading a new generator must be installed. IUT currently has two captive diesel generators to cope with the frequent electricity outage from the PBS. One generator is installed in a room adjacent to the substation with poor ventilation and other issues that are affecting the safe operation of the sub-station. So a new generator must be installed which should be placed somewhere with a proper ventilation system

- **Replacement of the distribution boards:**

Main Distribution board (MDB) is a panel or enclosure where the fuses, circuit breakers, and ground leakage safety units are placed and where electrical energy is taken in from the transformer or an upstream panel and used to transmit electrical power to multiple individual circuits or user points**.** The MDB feeds the Sub Distribution Boards (SDB) which are typically located where a large distribution cable ends and a series of smaller sub-circuits begins**.** These switchboards are larger than a final distribution board (FDB) circuit, despite having identical construction**.** After the inspection of the MDB, FDB, and SDB boards of IUT campus it was found that some of them are mostly overloaded or expired. [19] It was also found that some of the electrical loads, especially in the old buildings were connected with the SDB boards without following the standards. As a result, the MDB, FDB and SDB boards must be replaced in order to reduce the risk of an accident and also to prevent the electrical equipment from further damage.

- **Installation of lightning protection system and testing of earthing system:**

Since most of IUT's buildings were built 35 years ago, the earthing system must be tested and reinstalled as needed. It is absolutely important to install a Lightning Safety System in order to ensure a fully protected electrical system. A lightning protection system is a system that protects a structure from damage caused by lightning strikes by intercepting the strikes and safely passing their exceptionally high currents to earth. [20] Thus, fire hazards and damages are mitigated using a lightning protection system. So, it is recommended to install LPS in the different buildings of IUT and the task must be done by a licensed authorized company in order to maintain proper building code.

- **Protection system for all ACs:**

Currently, Direct on Line (DOL) switches are installed in some of the ACs in different buildings. However, in order to mitigate the damage of the ACs, all the ACs must be connected via DOL switches. The air conditioners should be checked and cleaned at least once every two months, with a deep cleaning once a year when the ACs are cleaned more properly.

- **Removal of unauthorized equipment:**

Residential students (mostly expatriate students) have carried prohibited electrical equipment to campus and into the halls of residence over the years. The main reason behind bringing those unauthorized equipment is lack of security system. As a result, the number of electrical devices is also increasing. Despite the fact that strict measures are in place to prevent unauthorized equipment from reaching the hall, removing it has proved to be a difficult job. Several notices demanding the removal of heavy-duty equipment have been sent, but the students have become persistent in their desire to keep them. The existing electrical wiring system was not designed to handle heavy-duty devices. With an increased number of unauthorized devices, there will be potential danger of fire hazard. As a result, strict measures must be taken to remove such illegal electrical devices from the halls of residence. A separate, low-capacity circuit breaker should be placed in each hall room that will not allow heavy-duty devices. In the premises of the Halls, an allocated room could be constructed where students could pay for the use of a limited range of equipment such as a freezer, microwave, and washing machine. Zero tolerance toward any new entry of unauthorized equipment. Security personnel has to ensure that at the campus main gate. For the complete removal of unauthorized equipment from the campus, all offices (Provost Office, Engineering Office, and Registrar's Office) must work together.

- **Installation of UPS:**

An uninterruptible power supply or uninterruptible power source (UPS) is an electrical device that delivers immediate power to a load when the input power source or mains power fails. A UPS is usually used to secure hardware such as computers, data centers, telecommunication facilities, or other electrical equipment from power outages that could result in accidents, casualties, severe business interruption, or data loss. A UPS, unlike an auxiliary or emergency power system or a backup generator, offers near-instantaneous protection from input power interruptions by providing energy stored in batteries, super capacitors, or flywheels. So UPS must be installed in individual electrical equipment to protect them from power outages. To protect electrical equipment from damage, the UPS must have overvoltage, under voltage, overload, short circuit, battery overcharge, and deep discharge protection systems, as well as a continuous electrical supply. It should also have Lighting, Transient, Spike and Surge Protection devices. It must not be overloaded with higher capacity loads.

- **Appropriate use of power:**

To avoid wasting of electrical energy and to prevent damage of electrical equipment various measures can be taken. In order to use power more efficiently, Energy-saving / LED lights should be installed in pathways, corridors, rooms, cafeterias, mosques, and auditoriums. As part of routine maintenance, the modification could be made once a year. Consumers must be made aware of the importance of conserving electricity. This can be accomplished by encouraging them to switch off the lights and electronics as they leave the building, keep the temperature of the air conditioners above 24 degrees Celsius, reduce the use of appliances and use natural light as much as possible.

- **Following building code:**

The International Code Council (ICC) has established a model building code called the International Building Code (IBC) (ICC). Based on prescriptive and performance-related standards, the IBC addresses both health and safety issues for buildings. All other published ICC codes are highly consistent with the IBC. The provisions of the code are designed to ensure public health and safety while preventing excessive costs and preferential treatment of particular materials or construction methods. Following the International Building Code and installing required protective equipment such as fire alarms, fire extinguishers, and smoke control systems is recommended to create a safer environment.

- **Sincerity:**

Awareness and sincerity is really necessary to avoid wastage of electrical energy and mitigate hazards. The damage of electrical equipment can also be reduced by operating the equipment according to operating instructions, maintaining a proper cooling system in the electrical equipment room as per instruction of machine catalogue, keeping the environment clean and dust-free and providing adequate free space for natural cooling and air circulation for each piece of electrical equipment.

- **Approaching REB:**

Due to the frequent outages of REB power, some of the heavy electrical loads that cannot be fed by UPS experience failure or harm. This subject has been discussed with the PBS authority on many occasions. PBS authority guarantees that IUT will not shut down control unless it is absolutely necessary. In the recent days, the outage of electrically is mainly due to the faults that frequently occur in the overhead distribution lines and the feeder substation that is located at Tongi. As there is no dedicated feeder from the REM substation at Board Bazar to IUT substation, IUT cannot be independently fed from REB substation. The chairman of the committee discussed the issue with the PBS authority. They are exploring to build a 33 kV substation near National University. IUT authority can approach REB emphasizing the need for uninterrupted supply of electricity to IUT campus as it is the only International University in this area where students from OIC countries are studying and living in the in campus dormitories.

The above mentioned points must be followed to create a power system that would not only meet the current demand but also ensure that the system is not hazardous and would not fail in the long run as well.

5.2 Cost and Time Estimation:

We've calculated the approximated expense and time of our proposal.

Table 5.2.1: Estimated Cost For Modification

SL no.	Particulars	Approximate cost
1	Electrical Equipment	60,00,000
2	Service Cost	30,00,000
3	Labor Cost	10,00,000
4	Rented Generator Cost	5,00,000
5	Other Costs	10,00,000
	Total Cost (Approximated)	1,15,00,000

Table 5.2.2: Step-by-Step Instructions and Time Predictions

SL. No.	Description of Work	Approximate time required	Power supply status
01	Cable trance and development, as well as HT cable installation	60 Days	No power drop
02	500 KW generator Base making		
03	04 set 250 feet depth Earth Boring		
04	Creating new space for the making of Fuel Tank		
05	Work for store room backing		
06	500 KW Diesel Generator shifting work	14 Days	Power-supply from Generator- 2
07	HT and transformer room making with trance and base making	30 Days	No power drop
08	HT and Transformer shifting work	07 Days	Power-supply from generator-2
09	After removing the HT panel from its current location, automatically begin creating the MS base for the synchronizer and the RCC base for the PFI		

10	Rewiring and re-connection of the LT line, as well as the installation of a new MDB for the air conditioners	07 Day	Power-supply from generator-2
11	Installation and reconnection of the synchronizer and PFI in a new location	07 Days	Complete power drop. Rental generator is needed for power supply.
12	System commissioning	01 Day	No power drop
13	Final commissioning and device calibration, as well as the installation of a power monitoring system	07 Days	No power drop
Required Time (Approximate)		**133 Days**	

Chapter 6
Future Work and Conclusion

6.1 Future work:

We designed our future work plan according to the plan of IUT. IUT has a plan to extend the female hall up to tenth floor. So, the demand for electricity will be higher by that time and the number of students will also increase. So, demand for electricity won't be mitigated even if IUT installs a new 500 KW generator. So, IUT will need another 500 KW generator to fulfil the demand for electricity by that time. So the details of our future work:

- **In house detailed calculation:**

In-house detailed calculation of every individual load of campus. We must quantify all individual loads, which include academic buildings, residential halls, cafeteria, library, and administration buildings, to get a precise outcome of power flow analysis.

- **Installing new generator:**

By that time the total rated supply of generators will be 1500 kilowatts. But right now the total connected load of campus is 1724.81 kilowatts. So after completing the extension of the female hall of residence the demand will increase. And the number of the students will also increase. So more classrooms and laboratories will be needed. So the total connected demand will rise up to 2500 kilowatts. So, IUT will need to install at least another 500 kW generator to fulfill the demand of electricity especially during summer class time. Before installing the new generator the following works need to be done.

1. Increase the allocated space for substation.
2. At first Base making and earth boring for new generator should be done properly.
3. New room should be made for the fuel tank and backing works.
4. After these works are completed the generator should be shifted and synchronizer should be installed.
5. Ensuring proper cooling system for the upgraded substation.

- **Making new software for operating substation:**

As the substation of IUT is still controlled manually it creates some problems for managing different issues during operation. So, a software which will be made only for the use of IUT electrical services. Which can accurately and reliably conduct power flow analysis and voltage drop calculations. All the load flow calculations, alert views and other important factors should be monitored and controlled by the software. New features via modern innovations can be phased out to substation automatically and centrally, with hardly any danger. [21] So, monitoring the substation will be a lot easier. The software should have the following features:

1. The power flow through different transmission lines and loads can be monitored.
2. Alert view report should be generated.
3. For any dangerous situation power supply can be turned off.
4. Power switching can be controlled.
5. Voltage drop and power loss through different transmission lines and cables can be calculated.
6. Optimal power flow and reliability assessment can be done.
7. All the data should be saved for future research works.

6.2 Conclusion:

We can conclude from our research that the substation of IUT must be upgraded immediately in order to solve the issues of overloading, for continuous electric supply and also to mitigate risks. In our thesis, we have collected the readings from the substation and the different buildings of IUT. We believe we have taken these readings appropriately and we were successful in implementing these readings on Etap. We discovered the key defective overloaded lines using ETAP and attempted to resolve the issues. The obtained results were promising and this motivated us to go forward with our project. We attempted to mitigate the issue after assessing all of the deficiencies and suggested several steps to ensure the safety of the campus. Using these results we were able to propose various solutions for the upgradation process. From our investigation, we also discovered that IUT has a variety of serious electrical problems: an overloaded substation, outdated MDB SDB and other electrical equipment, a faulty earthing system, an obsolete LPS system, and many more. We have discussed these problems in detail in our thesis and we have also proposed effective solutions for these problems for example making necessary changes of the faulty equipment and using energy efficient equipment to conserve energy. If these changes are made and necessary precautions are taken, the electrical issues and health hazards can be mitigated.

We were very clear in explaining our objective and motivation for our thesis. The importance of power flow studies and the current scenario of the electrical system of IUT motivated us to choose this topic. The electrical system of IUT needs to be upgraded for providing more sustainable electrical supply in the future. We have also discussed how load flow analysis can solve this problem and why we are using load flow analysis in our thesis. We have also stated the basics of load flow analysis and used appropriate equations that were needed for our analysis.

In our research, we have explained our entire work elaborately. We tried to provide a clear concept of load flow analysis to make our topic more understandable. After that we have explained our entire methodology. We have stated about how we took the readings, how we implemented them on ETAP and we have also attached the results from our simulations. We have discussed the results thoroughly and also discussed the solutions.

Overall, our thesis was successful. We could complete our work without any inconvenience and we are satisfied with the obtained results. We hope that the solutions that we proposed would bring the most effective results for the betterment and safety of IUT. We have also discussed the estimated cost and timeframe for our entire plan of installation and replacements of equipment. So, we can conclude that from our thesis we were able to find the problems that we were looking for and using our results and solutions we can move forward with our project and suggest ideas for our future works.

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