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LOAD FLOW STUDY ON A STANDARD GRID SUBSTATION

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This is to certify that the work presented in this thesis is an outcome of the experiments, study, simulation and real time work carried out by the authors under the supervision of Prof. Dr. Md. Shahid Ullah, Head, Electrical & Electronic Engineering Department & co-supervision of Mohammed Assistant Professor of EEE Department, Islamic University of Technology (IUT).

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** ABSTRACT**

Electricity the most common form of energy is the indicator of economic development of a country. The demand of safe and reliable electricity is going up in such a rate that the present grid system cannot deal with the demand response. The traditional power grid is based on centralized generation plants that supply end-users via long-established, unidirectional transmission and distribution systems. But times are changing. Today's demands for increased power supplies with higher reliability from cleaner and preferably renewable energy sources cannot be met with today's grid infrastructure. We need an intelligent system that can receive power of all qualities from all sources – both centralized and distributed – and deliver reliable supplies, on demand, to consumers of all kinds.

This thesis work is focused on this issue within a small scale grid designing which can be enlarged by proper implementation techniques. Performance analysis and data collection is done by surveying some local substations. The integration of renewable sources and other modern technologies to the grid made it more complex and time consuming to analyze the grid manually. So the use of software based simulation is the only way to perform any analysis with comparative results.

The project endeavored to study the need and analysis of the performance of present power system to identify the weakness as well as to find a way to improve it within limited resource. ETAP is such a software tool that serves the purpose of analysis and possible development of the system using the simulation to provide the result. That's why for some elementary system analysis ETAP is used with the practical data collected from substation survey

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Finally, we beg pardon and apologize for the faults and any unintentional mistakes that might be recurred in this thesis paper even after all the care that was taken.

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CHAPTER 1

INTRODUCTION

The absence of adequate and modern infrastructure is seen as critical among the many reasons that restrict economic growth for a country. This is specially so when it comes to electrical power. For many contraries the per capita consumption of electricity is very low compare to some developed countries .In spite of those developed countries ambitions plan to increase production, the annual growth in capacity remains modest and not adequate to provide for the desired increase in economic growth. The utilities are burdened with debt and new technologies to improve efficiency and availability are not being adequately pursued. To facilitate greater consumption of electricity will require aggressive steps in all sectors of power industry. To have a considerable amount of generation capacity would require some years and a good amount of annual investment, In addition to capital; it would require the newest and most efficient technologies, not only in production but also in transmission, distribution, storage and consumption. Technology is alone not enough. Innovative and effective policies must be enacted to ensure that management of generated power is made efficient and free pressures from various quarters that affect pricing, uses and distribution that debilitate the industry today.

The use of modern technologies in power system is advantageous in many ways. Now a day's power systems are so large and complex that it is impossible to analyze manually.

But using digital computers (software) we can save our time and get more reliable results. Power quality has become increasingly important for indusial and commercial electrical power customers, particular as today's manufacturing and control process rely on computerized equipments which is sensitive to power system interruptions and disturbance. Use of modern technology with technically sound personnel can provide solution to existing power quality problems, alleviate problems that may be looming in power system and provide recommendations to ensure optimal power quality for facilities under construction or renovation.

Power quality problems can affect our productivity and out bottom line. So, we have to have the experience, know-how and technology to identify, solve and oftentimes prevent problems. Site surveys, computer simulations and equipments sensitivity assessment are invaluable tools for improving power system performance.

As software we have been used ETAP which is a product of ETAP software, ETAP is the most comprehensive analysis platform for the design, simulation, operation, control, optimization, and automation of generation, transmission, distribution, and industrial power systems.

The project endeavored to study and analysis of the performance of present power system to find a way to improve it within limited resource. ETAP is such a software tool that serves the purpose of analysis and possible development of the system using the simulation to provide the result. That’s why for some elementary system analysis ETAP is used with the practical data collected from substation survey.

CHAPTER 2

SWITCHGEAR AND PROTECTION

2.1 General background:

Everyone is familiar with low voltage switches and rewritable fuses .A witch is used for opening and closing an electric circuit and a fuse is used for overcurrent protection. Every electric circuit needs a switching device and a protective device. The switching and protective devices have been developed in various forms. Switching is a general term covering a wide range of equipment concerned with switching and protection.

A circuit breaker is a switching and current-interrupting device in Switchgear. The circuit-breaker serves two basic purposes:

(l) Switching during normal operating conditions for the purpose of operating and maintenance.

(2) Switching during abnormal conditions such as short circuits and interrupting the fault currents.

The first function mentioned above is relatively simple as it involves normal currents which are easy to interrupt. The second function is complex as the fault currents are relatively high and they should be interrupted automatically within a short time of the order of a few cycles. One cycle in 50 Hz system take 1/50 second. There are several types of faults and abnormal conditions. The fault currents can damage the equipment and the supply installation if allowed to flow for a longer duration. In order to avoid such damage every part of the power system is provided with a protective relaying system and an association switching device. The protective relays are automatic devices which can sense the fault and send instruction to the associated circuit-breaker to open. The circuit breaker opens and clears the fault. All equipment associated with the fault clearing process are covered by the term 'switchgear'. Switchgear is an essential part of power system and also that of any electrical circuit. In addition to circuit-breaker and protective relays, the associated equipment for controlling, regulating and measuring can also be considered as switchgear devices. Switchgear includes switchgears fuses, circuit-breaker, isolators, relays, control panels, lightning arresters, current transformers and various associated equipments.

Switchgear is necessary at every switching point in the power system,

Between the generating station and final load point, there are several voltage levels and fault levels. Hence, in the various applications the requirement of switchgear varies depending upon the location, rating and local requirements. Besides the supply network, switchgear is necessary in industrial works, industrial projects, domestic and commercial buildings. A control gear is used for switching and controlling power-consuming devices.

2.2 Substation Equipment:

In every electrical sub-station, there are generally various indoor and outdoor switchgear, equipment. Each equipment has a certain functional requirement. The equipments are either indoor or outdoor, depending upon the voltage rating and local conditions. Generally indoor equipment is preferred for voltage upto 33 kV. For voltage of 33kV and above outdoor switchgear is generally preferred. However, in heavily polluted areas indoor equipment may be preferred even for higher voltages. SF6 Gas Insulated Substation (GIS) are preferred in large cities for voltages above 33 kV.

The outdoor equipment is installed under the open sky. The indoor switchgear is generally in form of metal enclosed factory assembled units called metal-clad switchgear.

Circuit-breaker are the switching and current interrupting devices. Basically a circuit-breaker comprises a set of fixed and movable contacts. The contacts can be separated by means of an operating mechanism .The separation of current carrying contacts produces an arc; the arc is extinguished by a suitable medium such as dielectric oil, air, vacuum, sf6 gas. The circuit breakers are necessary at every switching point in the sub-station.

Isolators are disconnecting switches which can be used for disconnecting a circuit under no current condition. They are generally installed along with the circuit breaker. An isolator can be opened after the circuit breaker. After opening the isolator, the earthing switch can be closed to discharge the trapped electrical charges to the ground, the current transformers and potential transformers are used for transforming the current and voltage to a lower value for the purpose of measurement, protection and control. Lightning arresters divert the over-voltages to earth and protect the substation equipment from over-voltages.

2.3 Faults and Abnormal Conditions:

A fault in electrical equipment is defined as defect in its electrical circuit due to which the current is diverted from the intended path. Faults are generally caused by breaking of conductors or failure of insulation. The other causes of faults include mechanical failure, accidents, excessive internal and external stresses, etc. The fault impedance being low, the fault currents are relatively high. During the faults, the voltages of the three phases become unbalanced. The fault currents being excessive, they can damage the faulty equipment and the supply installation. During the faults, the power flow is diverted towards the fault and the supply to the neighboring zone is affected.

The faults can be minimized by improving the system, design, quality of the equipment and maintenance. However, the faults cannot be eliminated completely.

For the purpose of analysis, the faults can be classified as:

- ❖ Single line to ground fault
- ❖ Double line to ground
- ❖ Three phase fault
- ❖ Line to line fault
- ❖ Simultaneous
- ❖ Open circuit etc.

The other abnormal conditions include:

- ❖ voltage and current unbalance
- ❖ over-voltages
- ❖ reversal of power
- ❖ power swing
- ❖ under frequency
- ❖ temperature rise
- ❖ Instability, etc.

Some of the abnormal conditions are not serious enough to call for tripping of the circuit-breaker. In such cases the protective relaying is arranged for giving an alarm. In more serious cases, the continuation of the abnormal condition can be harmful. In such cases, the faulty part should be disconnected from the system without any delay. This function is performed by protective relaying and switchgear.

As a fault occurs in a power system, the current increases to several times the normal current because of the low fault impedance. The value of the fault current depends on the voltage at the faulty point and the total
Impedance upto the fault. The voltage at the fault location changes from its normal value. During the fault, the current and voltage undergo a continuous change and the phenomena observed are called 'transient phenomena'. The word 'transient 'refers to 'temporary happening' which last for a short duration of time. The fault current varies with time. During the first one to three cycles, the fault current is very high but decreases very rapidly. This zone in which the current is very high, but decreases very rapidly is called Sub-transient State.
After the first few cycles, the decrease in current is less rapid. This region of slow decreases in the short-circuit current is called the Transient State. The Transient state lasts for several cycles. After the transient state, Steady State is reached. During the Steady State the r.m.s value of the short-circuit current remains almost constant.

The circuit-breakers operate during the Transient State.

2.4 Fault Calculations:

The knowledge of the fault currents is necessary for selecting the circuit breakers of adequate rating, designing the sub-station equipment determining the relay settings, etc. The fault calculations provide the information about the fault currents and the voltages at various points of the power system under different fault conditions.

‘’the per-unit system is normally used for fault calculation. The symmetrical faults such as three phase faults are analyzed on per phase basis. For calculations on unsymmetrical faults, the method of Symmetrical Components is adopted. The network analyzer and digital computers are used for fault calculations of large systems.

2.5 The Fault Clearing Process:

The protective relays are connected in secondary circuits of current transformers and/or potential transformers. The relays sense the abnormal conditions and close the trip circuit of the associated circuit-breaker. The circuit-breaker opens its contacts. As arc is drawn between the contacts as they separate. The arc is extinguished by suitable medium and technique.

The stresses occurring on the circuit breaker while interrupting the arc, can be analyzed by studying the following transient phenomena:

- Transient variation
- Transient variation of the voltage after final arc interruption (transient recovery voltage)
- The arc extinguishing phenomena

After final arc extinguishing phenomena, a high voltage wave appears across the circuit-breaker contacts tending to re-establish the arc. This transient voltage wave is called Transient Recovery Voltage (TRV). The TRV comprises a high frequency transient component superimposed on a power-frequency recovery voltage. These phenomena have a profound influence on the behavior of the circuit-breaker and the associated equipment.

2.6 Protective Relaying:

The power system is covered by several protective zones. Each protective zone covers one or two components of the system. The neighboring protective zones overlap so that no part of the system is left unprotected.

Each component of power system is protected by a protective system comprising protective transformers, protective relays, all-or-nothing relays, auxiliaries, trip-circuit, trip coil, etc. During the abnormal condition, the protective relaying senses the condition and closes the trip circuit of the circuit breaker. Thereby the circuit-breaker opens and the faulty part of the system is disconnected from the remaining system.

The various power system elements include generators, transformers, bus-bar, transmission lines, motors, etc. The protective relaying requirements of the various elements differ. Various types of protective systems have been developed to satisfy their requirements. For example, the over-current protection responds to increased currents. The differential protection responds to the vector difference between two or more similar electrical quantities.

The protective schemes for large electrical equipment comprise several types of protective systems. For low voltage equipment of relatively small rating, fuses and thermal relays are generally adequate. The protective scheme of large power system-equipment are generally designed with due regards to power swings, power system stability and associated problems.

2.7 Neutral Grounding (earthing) and Equipment Grounding:

The term Grounding or Earth refers to the connecting of a conductor to earth. The neutral earthing has several advantages such as:

- Freedom from persistent arcing ground. Such alternate charging and discharging produces repeated arcs called Arcing Grounds. The neutral grounded eliminates the problem of 'arcing grounds' substantially.
- The neutral grounding stabilities the neutral point. The voltages of healthy lines with respect to neutral are stabilized by neutral earthing.
- The neutral earthing is useful in discharging over-voltages due to lightning to the earth.
- Simplified design of earth fault protection.
- The grounded systems require relatively lower insulation levels as compared with ungrounded systems.

2.8 Over-voltage and Insulation Co-ordination:

The over-voltage surges in power systems are caused by various causes such as: lightning, switching, resonance etc.

The power system elements should withstand the over-voltage without insulation failure. The insulation level of power system elements refers to its values of power frequency and impulse voltage withstand. The insulation levels of various power system elements are graded in such a way that the damage caused by the over-voltages is minimum and the design of insulation of the equipment is economical. The protective
Measures against over-voltages due to lightning include.

- Use of overhead ground wires
- lower tower footing resistance
- Use of lightning arresters

2.9 Voltage levels in Network and sub-stations:

The network has various voltage levels for generation, transmission, distribution, utilization, control and protection.
Generation is at voltage up to 30 kV AC rms (line to line). This is due to design limitation of AC generators.
Long distance high power transmission is by EFIV AC lines rated 220kV, 400 kV, 760 kV AC. For longer distance and higher powers, higher voltages are economical and essential. In special cases, HVDC transmission is preferred. The rated voltages of long distance HVDC Transmission are ± 250kv, ±400kv, ± 500kv, ±6ookv.
Backbone transmission network is by EHV AC transmission lines (400 kV AC and220 kV AC)
Distribution is at lower AC voltages between 132kV AC and 3.3 kV AC.
Utilization is at low voltage (up to 1kV) and medium voltages up to11kv.
The factory sub-station receive power at distribution voltage such as 3.3kV and step it down to 440 volts AC. Lager factories receive powers at 132 kV have internal distribution at 3.3 kV, to 440 volts AC.

2.10 Functional Responsibilities of power Engineers:

Electrical Network comprises the following:

- Generation Stations
- Transmission Systems
- Receiving Stations
- Distribution Systems
- Load Points

And electricity Supply Company aims at the following:

- Supply of required electrical power to all the consumers continuously at all times.
- Maximum possible coverage of supply network over the given geographical area.
- Maximum security of supply.
- Shortest possible fault-duration.
- Optimum efficiency of plants and the network.
- Supply of electrical power within targeted frequency limits.
- Supply of electrical power within specified voltage limits.
- Supply of electrical energy to the consumers at the consumers at the lowest coast.

As a result of these objectives; there are various tasks closely associated with the generation, transmission, distribution and utilization of the electrical energy. These tasks are performed by various manual, semiautomatic and fully automatic switchgear and protective gear devices located in generating station and substation.

The tasks associated include the following:

- ✓ Protection of transmission system generating system loads etc.
- ✓ Controlling the exchange of energy.
- ✓ Ensuring steady state and transient stability.
- ✓ Load shedding and prevention of loss of synchronism.
- ✓ Maintaining the system frequency within targeted limits.
- ✓ Voltage control; reducing the reactive power flow by compensation of reactive power, tap-changing.
- ✓ Securing the supply by providing adequate line capacity and facility for changing the transmission paths.
- ✓ Data transmission via power line carrier for the purpose of network monitoring; control and protection.
- ✓ Determining the energy transfer through transmission lines and tie-lines.
- ✓ Fault analysis and pin-pointing the cause and subsequent improvements.
- ✓ Securing supply by feeding the network at various points.
- ✓ Establishing economic load distribution and several associated functions.

CHAPTER 3
SHORT CIRCUIT SITUATION IN A POWER SYSTEM

3.1 Short Circuit Application:

Short circuits (often referred to as "faults") are quite important in power systems, for several reasons:

- Short circuit are relatively common occurrences in the system, and the system must be able to "with stand" them without permanent harm.
- Short circuit can result in extremely large currents through the system. These currents, if allowed to remain for too long, can create permanent damage, both due to heating of components and due to the physical stress forces generated from nearby conductors carrying very large currents.
- The protection equipment (namely, the "breakers") in the system must be able to not only withstand without damage the fault currents, but actually. The main rating of a breaker is its ability to break a certain amount of current. A breaker may be rated "230 kV and l0 kA", for example. It's undesirable to buy a breaker that is "too big" for the job, but it can be catastrophically damaging to buy and install a breaker that is not capable of interrupting a given fault current.
- The fault detection equipment (the "protective relays" that measure voltage, currents and power must "know" when a fault has occur. Thus, it is important to calculate and estimate given fault current levels for purposes of "setting and coordinating relays".)
- Interestingly, faults can also give rise to over voltages, sometimes significant. It is important to calculate and estimate the magnitudes of these over voltages.
- A breaker is not a switch. A switch can only withstand the fault current but cannot open it.
- Breakers work by creating and arc. The breakers" quenches" the arc at it is "natural' zero current crossing (120 times per second). If you interrupt the arc prematurely (as if for example, you buy a breaker way too big for the application) you can make the over voltage worse.
- A corollary is that is it almost impossible to have “DC breaker” least not "naturally". Since DC currents do not have a "natural" zero-current crossing time. Although faults are, by their very nature, "transient" events, it is common practice to pretend that they are actually a quasi-steady state phenomenon and to restore to linear calculation methods to estimate the likely "sustained" values of the various fault current and voltages. However, since things change (mainly, certain circulating currents that are established at the onset of most faults tend to decay rapidly), it is common to "divide" the calculation of fault currents into three periods:

The sub transient period: this period encompasses the first new cycles after the occurrence of a fault. It effectively ends when the eddy and dumper winding current that are established inside most generators at the onset of any fault have decayed sufficiently. During this period. The machine is generally presented by its sub transient(s), denoted with a double prime. This values are often available as part of the machine specification.

The sub transient period is of greatest interest in mechanical design to calculate peak forces, and also to calculate what instantaneously acting relays will "see" as a result of a particular fault. In addition to the "steady state" component, during this period there tends to be a significant "DC offset" of the currents, depending on the instant at which the fault actually occurred. It is common practice to use some "fudge factor" between 1.5 and 1.7 to account to this effect.
The transient period: this period encompasses from a few cycles to a second to two. It is the period which the field current in generator has not yet decayed from its initial post-fault onset value to its eventual steady-state value, but prior to the automatic voltage regulator (AVR) for the generator has a chance to react. Machines are generally characterized by their transient reactance. This period during is the period during which the fault will actually be interrupted in most cases (the relay has signaled to breaker it is time to trip, and the breaker has started to open).
The synchronous period: during this period, all values in generators are back to their normal value but the AVR system has not yet had a chance to respond. Generally, only the generator models are the ones affected by the timeframe. The models for lines and transformers are (roughly) the same regardless of time period of interest. When doing fault calculation for actual power systems it is important, thus to find out what the purpose of calculation is (the timeframe of interest). It is also important to ask about the kind of fault that one must apply and why. There are several types of faults to consider: solid vs. through impedance, single line to ground, double line to ground, line to line, double line to ground and three phase, to name the most important ones. Another key difference occurs with respect to mutual coupling between lines. While the mutual coupling between lines is weak when one considers the positive and negative sequence models of a system, this coupling can be strong when considering the zero sequence. Consequently, it is generally NOT ok to neglect zero sequence mutual couplings.
This portion of the course describes the use of Matlab to determine short circuit currents and voltages for power systems problems. Our objective will be to come up with a working knowledge of how to calculate fault currents in practical cases. First we illustrate the calculation of some "short circuit" in simple "single phase" circuits, before moving to actual power system.

3.2 The Short Circuit Problem in Power Systems:

The short circuit problem is characterized by a set of definition in the phase domain. However, all calculations are often best performed in the sequence domain. Three types of "faults" are considered:

- ❖ Three phase faults within an otherwise balanced network.
- ❖ Single line to ground faults (SLG) within an otherwise balanced network.
- ❖ Arbitrary simultaneous faults at a single node via an unbalanced impedance network.

It is useful to review the formulas and methods suitable for the study of each of these faults.

3.2.1 Three Phase Faults:

Let Y1 represent the positive sequence nodal admittance matrix for a given balanced network. Remember that in constructing this (or any of the other sequence) nodal admittance matrices for purposes of doing fault studies you must:

- ❖ Replace all generators with an appropriate shunt to ground. For the zero sequence, the connection to ground depends on the time of grounding used. For ungrounded neutral in a generator, the model for the zero sequence is an open circuit. Likewise for transformers.

- ❖ High precision is not critical. Taps can often be ignored, and more assume a solid fault occurs at node i at a time when the balanced positive sequence voltage at bus i was Vi. The following formulas permit the calculation of the total fault current and the voltages anywhere in the grid:

$$Z_1 = Y^{-1}$$

$$I_i^f = \frac{-V_i^1}{-Z_{ii}^1}$$

$$\Delta V_j^1 = Z_j^1 I_i^f$$

$$\Delta I_{jk}^1 = \frac{\Delta V_j^1 - \Delta V_k^1}{Z_{jk}^1}$$

The following notation is understood:

- $Z_{ii}^I$is a diagonal entry of the nodal impedance matrix Z_1 which is the inverse of the nodal admittance matrix.
- DV_j^1 is the change in positive sequence voltage at bus I as result of the fault.
- Z_{jk}^1 is the impedance of the branch from j to k.
- D_{jk}^1 is the positive sequence flow on the line from j to k.

Once these sequence currents are known, the actual physical currents anywhere can be found by means of the inverse symmetrical component transformation. For the three phase fault, this is trivial since the positive sequence current equal the phase a currents, and everything remain balanced.

3.2.2. Single Line to Ground Faults:

The formulas for the SLG fault require not only the positive sequence nodal admittance matrix Y1 but also the zero and negative sequence matrices Y0 and Y2. If we assume that Y1=Y2, the equation simplify slightly.

$Z_1 = Y_1^{-1}$ $\quad$ $Z_0 = Y_0^{-1}$ $\quad$ $Z_2 = Y_2^{-1}$

$$I_0^f = I_1^f = I_2^f = \frac{-V_i^f}{Z_{ii}^0 + Z_{ii}^1 + Z_{ii}^2}$$

$\Delta V_j^1 = Z_{ij}^1 I_j^f$ $\quad$ $\Delta V_j^0 = Z_{ij}^0 I_j^f$ $\quad$ $\Delta V_j^2 = Z_{ij}^2 I_j^f$

Reconstruction of phase currents in this case makes us of the formulas:

$$\begin{bmatrix} \Delta I_{jk}^a \\ \Delta I_{jk}^b \\ \Delta I_{jk}^c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}^{-1} \begin{bmatrix} \Delta I_{jk}^0 \\ \Delta I_{jk}^1 \\ \Delta I_{jk}^2 \end{bmatrix}$$

CHAPTER 4

LOAD FLOW STUDIES

4.1 Introduction to Load Flow Studies:

Load flow or power flow analysis provides the steady-state solution of a power network for specific network conditions which include both network topology and load levels. The power flow solution gives the nodal voltages and phase angles and hence the power injections at all buses and power flows through lines, cables and transformers. It is the basic tool for analysis, operation, and planning of distribution networks.

System Buses	Known	Unknown
Slack Bus or, Swing Bus	$\|V\|$ and δ	P and Q
Load Bus or, P-Q Bus	P and Q	$\|V\|$ and δ
Regulated Bus or, P-V Bus	P and $\|V\|$	Q and δ

Table 4.1The System Buses General Classification.

In a power system, each bus bar is associated with four quantities:

- Magnitude of voltage ($|V|$) its angle (θ),
- Real power injection (P) and
- Reactive power injections (Q).

For power flow analysis, only two of these quantities are specified, and the remaining two are obtained by the power flow solution. Depending upon the specified and unspecified quantities, the bus bars are classified into three types as shown in Table 4.1. The power flow can be formulated as a set of nonlinear algebraic equations and then a suitable mathematical technique such as the Gauss-Seidel, Newton-Raphson, or fast-decoupled method can be chosen for the solution of the equations.

4.2 The Classical Methods of Studying Load Flow:

The traditional load flow techniques used for distribution load flow are characterized by:

- Distribution systems are radial or weakly meshed network structures
- High X/R ratios in the line impedances
- Single phase loads handled by the distribution load flow program
- Distributed Generation (DG), other renewable generation, power supplies installed in relative proximity to some load center
- Distribution systems with many short line segments, most of which have low Impedance values.

For the purpose of load flow study we model the network of buses connected by lines or switches connected to a voltage - specific source bus. Each bus may have a corresponding load composite form (consisting of inductor, shunt capacitor, or combination).

The classical methods of studying load flow include:

- Gauss – Seidel
- Newton – Raphson
- Fast Decouple

We summarize each of them here for easy reference.

4.2.1 Gauss– Seidel Method:

This method uses Kirchhoff's current law nodal equations given as Injection current at the node. Suppose I injection = current at the node of a given connected load, then

$$I_{in(j)} = \sum_{i=1}^{n} I_{ji}$$

Where $I_{in(j)}$ (j) is the injection current at bus j and I_{in}= current flow from jth bus to ith bus. Rewriting, we obtain $I_{in(j)}$ (j) = Y bus V bus where Y bus admittance matrix is given as V bus vector of bus voltages. If we sum the total power at a bus, the generation and load is denoted as complex power. The nonlinear load flow equation is:

$$S_{inj-k} = P_g + jQ_g - (P_{LD} + jQ_{LD}) = V_k \left(\sum_{j=1}^{n} Y_{kj} V_j \right)^*$$

This equation is solved by an iterative method for Vj if P and Q are specified.

Additionally, from:

$$S_{inj-k} = P_g + jQ_g - (P_{LD} + jQ_{LD}) = V_k \left(\sum_{j=1}^{n} Y_{kj} V_j \right)^*$$

Where Y_{ij} are the elements of bus admittance matrix, and Pisch and Qisch are scheduled P and Q at each bus. After a node voltage is updated within iteration, the new value is made available for the remaining equations within that iteration and also for the subsequent iteration. Given that the initial starting values for voltages are close to the unknown, the iterative process converges linearly. Notably, the classical method performance is worse in a radial distribution system because of the lack of branch connections between a large set of surrounding buses. It should be noted that the injection voltage correction propagates out to the surrounding buses on the layer of neighboring buses for each iteration.

4.2.2 Newton–Raphson Method:

The Newton – Raphson Method assumes an initial starting voltage use in computing mismatch power ΔS where

$\Delta S = S_{ij-i}^{sch} - \left(V_i^{|k|}\right)^* \left(\sum Y_{ij} V_j^K\right)$ The expression ΔS is called the mismatch power. In order to determine convergence criteria given by ΔS ≤ ε, where ε is a specific tolerance, accuracy index, and a sensitivity matrix is derived from the inverse Jacobian matrix of the injected power equations:

$$P_i = |V_i| \sum |Y_{ij}||V_j| \cos(\theta_i - \theta_j - \psi_{ij})$$

$$Q_i = |V_i| \sum |Y_{ij}||V_j| \sin(\theta_i - \theta_j - \psi_{ij})$$

Where θi is the angle between Vi and Vj, and ψij is admittance angle. The complex power ΔS can be expressed in polar or rectangular form

$|\Delta V| = (\Delta e + \Delta f)\ or$

$\Delta V = |\Delta V| < \theta v\ or\ \Delta S = \Delta P + \Delta Q$ respectively.

This method is excellent for large systems but does not take advantage of the radial structure of distribution and hence is computationally inefficient. The method fails when the Jacobian matrix is singular or the system becomes ill -conditioned as in the case of a low distribution X/R ratio.

4.2.3 Fast Decouple Method:

The fast decouple method simplifies the Jacobian matrix by using small angle approximations to eliminate relatively small elements of the Jacobian. The method is one of the effective techniques used in power system analysis. However, it exhibits poor convergence with a high R/X ratio system. The interaction of V and θ magnitudes with active and reactive power flows cause poor convergence as well. A variation solves current injection instead of model power injection power equations.

4.2.4 Distribution Load Flow Methods:

Due to the limitation of the fast decouple method in solving an ill - conditioned system with a high X/R ratio; the distribution load flow techniques above require alternative methods. We summarize the commonly used methods.

- ***Forward/backward sweep methods*** solves branch current or load flow by using the forward sweeping method
- Compute the nodal voltages using backward sweep approach
- ***Newton method*** uses power mismatches at the end of feeders and laterals to iteratively solve the nodal voltage
- ***Gauss method*** on the bus impedance matrix equation solves iteratively for the branch currents.

Method 1*: Forward/Backward Sweep:*

This method models the distribution system as a tree network, with the slack bus denoted as the root of the tree and the branch networks as the layers which are far away from the root nodal. Weakly meshed networks are converted to a radial network by breaking the loops and injection currents computation.

The backward sweep primarily sums either the line currents or load flows from the extreme feeder (leaf) to the root. The steps of the algorithm are:

1. Select the slack bus and assume initial voltage and angle at the root, node, and other buses

2. Compute nodal current injection at the Kth iteration.

$$I_i^{(k)} = \left[\frac{S_i^{sch}}{V_i^{(k-1)}}\right]^*$$

3. Start from the root with known slack bus voltages and move toward the feeder and lateral ends
4. Compute the voltage at node j

$$V_j^{(k-1)} = V_i^k - Z_{ij} I_{ij}^{(k)}$$

Where Zij is the branch impedance between bus i and j and Vj is the latest voltage value of bus j.

5. Compute the power mismatch from and check the termination criteria using.

$$\Delta S_i^{(k)} = S_i^{sch} - V_i^{(k)}\left(I_i^{(k)}\right)^* \leq \varepsilon$$

6. If step above is not reached repeat the previous steps until convergence is achieved.

In Step 2 from each known load power S, the lateral voltages are computed or assumed.

This involves V_i^{k-1} as the k − 1 past iteration of bus voltage and $I_i^{(k)}$ is the Kth current iteration of injected current. We do this by starting from the last branch.

From the lateral feeder and moving back through the tree node. This is done using the Expression as before for all interconnected branches.

$$I_i^{(k)} = \left[\frac{S_i^{sch}}{V_i^{(k-1)}}\right]$$

Method 2: Bus Impedance Network:

This method uses the bus impedance matrix and equivalent current injection to solve the network equation in a distribution system.

It employs a simple superposition to find the bus voltage through the system. The Voltage in each bus is computed after specifying the slack bus voltage and then computing the incremental change ΔV due to current injection $f_1$owing into the network.

The steps are:

1. Assume no load system.
2. Initialize the load bus voltage throughout the system using the value of the slack bus voltage.
3. Modify nodal voltages due to current flow which are function of loads connected.
4. The injection current is modified in Kth iteration as level changes.
5. Use $\mathrm{I}_i^{(k)} = \left(S_i^{sch}/V_i^{k-1}\right)$for the first equivalent current injection until getting Ijk at the$\mathrm{I}_0^{(k)}$

6. Compute the vector of voltage denoted as ΔV using $\Delta V_{bus}^{(k)} = Z_{bus} I_{inj}^{(K)}$ where $Z_{bus}$is $\eta \times \eta$ bus impedance matrix.
7. Determine the bus voltage updates throughout the network as $V_i^{k-1} = V_o - \Delta V_i^{(k-1)}$ where $V0$ is slack bus voltage at root node.
8. Check mismatch power at each load bus using specified and calculated values to obtain $\Delta S = S^{spec} - \sum V_i^{calc} \mathrm{I}_{ij}^{calc}$and stop if the value of $\leq \varepsilon$.
9. Otherwise, go to step 3.

The load flow techniques for transmission or distribution system are not sufficient for smart grid load flow. These methods can easily be implemented using

- Sparsity techniques,
- Implicit bus matrix, or
- Computational techniques**.**

4.3 LOAD FLOW FOR GRID DESIGN:

Load flow tools that incorporate the stochastic and random study of the grid could be modeled with the following implementation algorithm. Conditioning the load flow topology will require a new methodology and algorithm that will include feeders and the evolution of a time - dependent load flow. This method has been proven in terms of characteristics and usage in power system planning and operation. Hence, the interoperability ofwith smart grid specifications could account for adequate use of current methodology to perform analysis in both usual and alert states.

The implementation algorithm proposed will extend the following capability:

Model input of RER [and load will be changed to account for variability; the input will have to include some power distribution flow so as to advance the congested value of new estimate ofP_f,Q_g, $and\ P_d, Q_d$. These attributes also have a unique load appropriate effectiveness in the performance Study**.**

Scarcity may be affected because the loads of RER may be widely distributed, that is, load and size of RER has to be considered.

Computational challenges in new load flow with RER for smart grid that include the stochastic model may affect the independent computation.

ATC is the maximum amount of additional MW transfer possible between two parts of a power system. Additional means that existing transfers are considered part of the "base case" and are not included in the ATC number. Typically these two parts are control areas or it can be any group of power injections. The term "maximum" refers to cases of either no overloads occurring in the system as the transfer is increased or no overloads occurring in the system during contingencies as the transfer is increased in online real time.

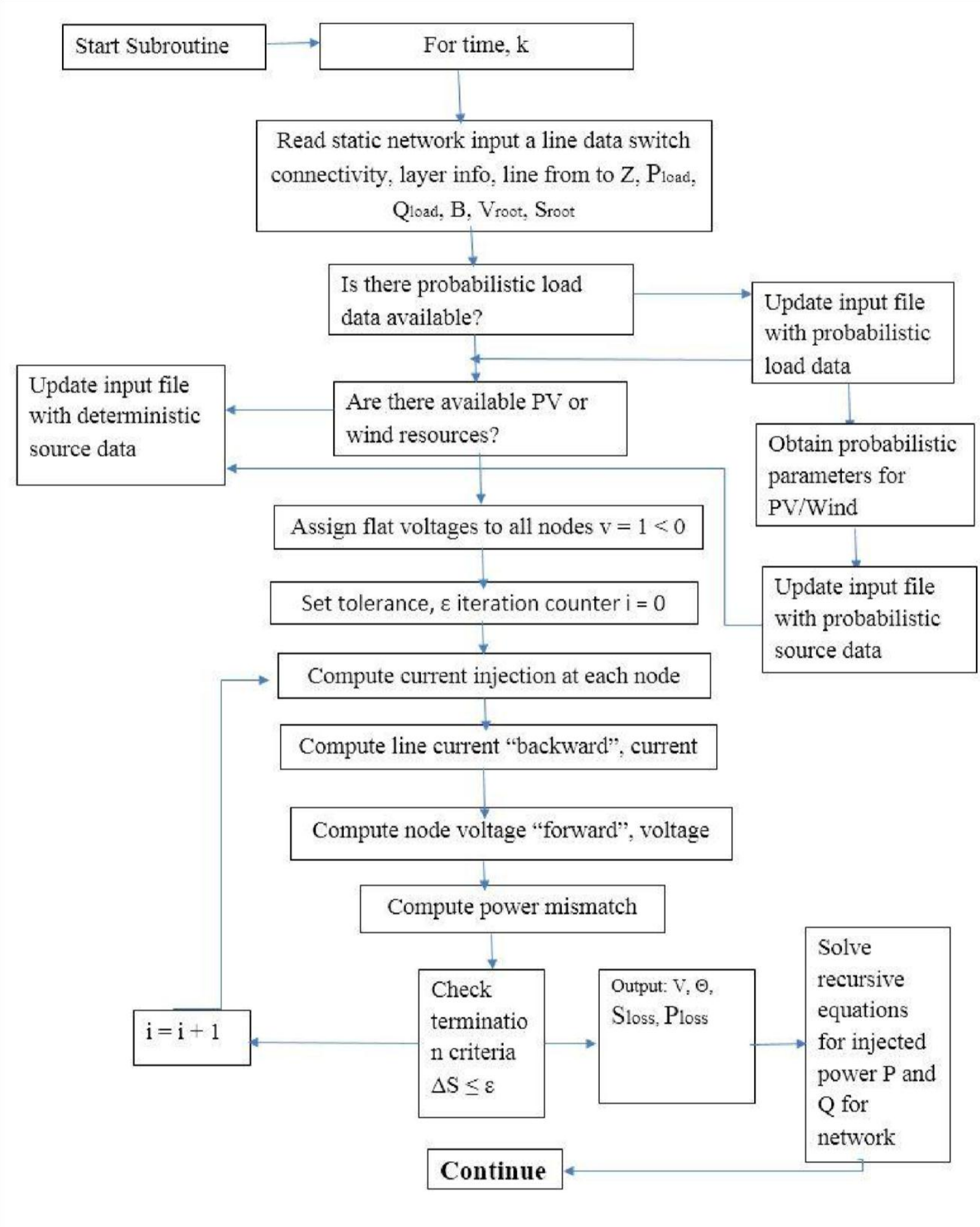
$ATC = TTC - \sum$ (CBM, TRM and existing TC)

Where the components are Total Transfer Capability (TTC), Capacity Benefit Margin (CBM), Transmission Reliability Margin (TRM), and "existing Transmission commitments". ATC is particularly important because it signals the point where power system reliability meets electricity market efficiency. It can have a huge impact on market outcomes and system reliability.

The load flow is solved using the iterate solution on:

$$\begin{bmatrix} \Delta\delta \\ \Delta V \end{bmatrix} = [J]^{-1} \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix}$$

The load flow is also used in distributed networks:



(Figure . 4.2)

CHAPTER 5

SUBSTATIONS SURVEYS

5.1Amin bazar Grid substation

5.1.1 Introduction:

Amin bazar Grid substation receives the power at 230 KV (Tongi & Hasnabadb station) and convert the receiving power to 132 KV (transmission) then distribute the power at 33 KV only for the substation purposes.

Amin bazar Grid substation can be consider as transmission & distribution substation.

It is responsible for supplying the required power through various feeders at two different voltage levels.

Amin bazar Grid substation is buildup of German equipments.

Consumption of the electrical energy is very low compare to the developed countries

Effective policies must be enacted to ensure that management of generated power is made efficient and free pressures from various quarters that affect pricing ,uses and distribution that debilitate the industry today

The use of modern technologies in power system.is advantageous in many ways

power quality problems can affect our productivity and out bottom line .so, we have to have the experience, know-how and technology to identify, solve and oftentimes prevent problems

5.1.2 Purpose and Significance:

Convert the received power at two voltage levels which are 132 KV & 33 KV .

Plays a significant role in delivering power to Kalyanpur , Mirpur line & Savar line.

Works as both transmission and distribution substation .

Plays a major role in both transmission and distribution.

using digital computers (software) we can save our time and get more reliable results and this can provide solution to existing power quality problems that may be looming in power system and provide recommendations to ensure optimal power quality for facilities under construction or renovation.

5.1.3 One & Half Breaker Scheme (Tie Breaker):

Amin bazar grid substation is using one & half breaker scheme for energizing the buses.

Plays a significant role in delivering power from bus 1 (the energized bus) to bus 2

Normally from generation either bus 1 or bus 2 is energized, then from the energized bus power is transferred to the other bus

Process of energizing the second bus from bus one which is already energized from the incoming connections.

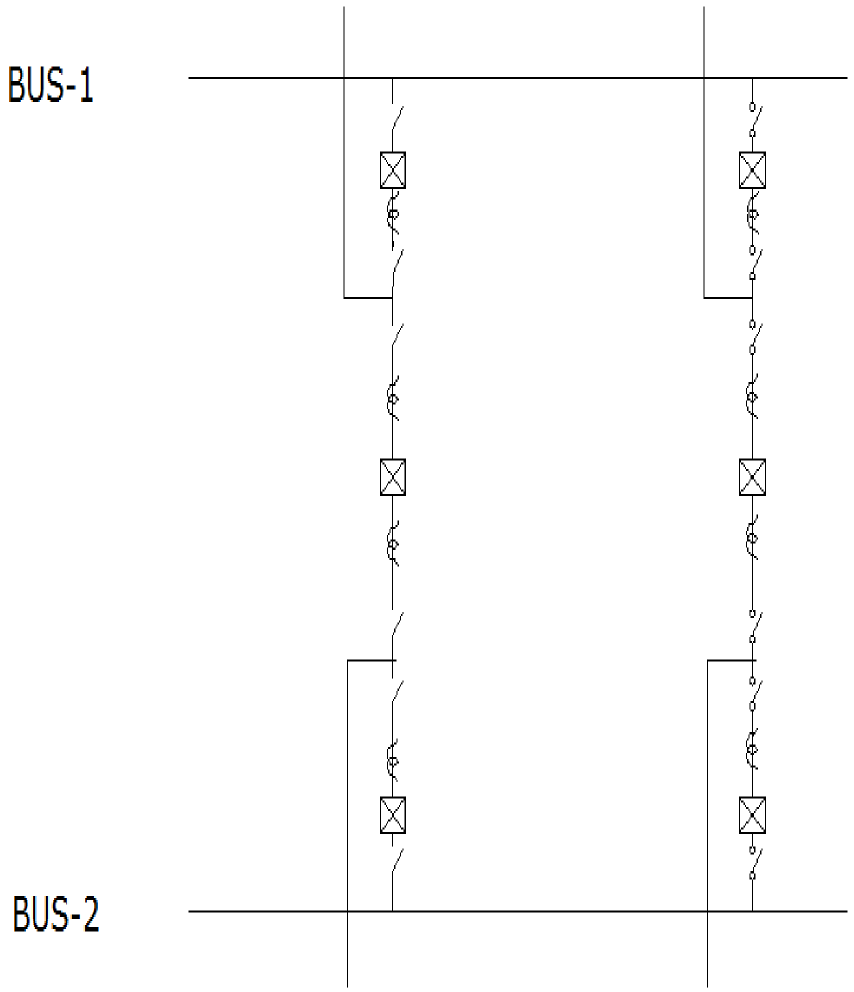


Figure 5.1: one and half Breaker

The incoming connections:

There are 2 incoming connections at 230 KV which consist of Tongi & Hasnabad .

The one line diagram for the 230 KV shows the above mentioned incoming connections.

Tongi & Hasnabad are active connections and Old Airport line is stand by connection.

Starting from the generation side of the diagram.(check the diagram).

5.1.4 Diagrams of Amin bazar Grid substation 230\132KV:

230 KV SINGLE LINE DIAGRAM
OF AMIN BAZAR GRID SUBSTATION

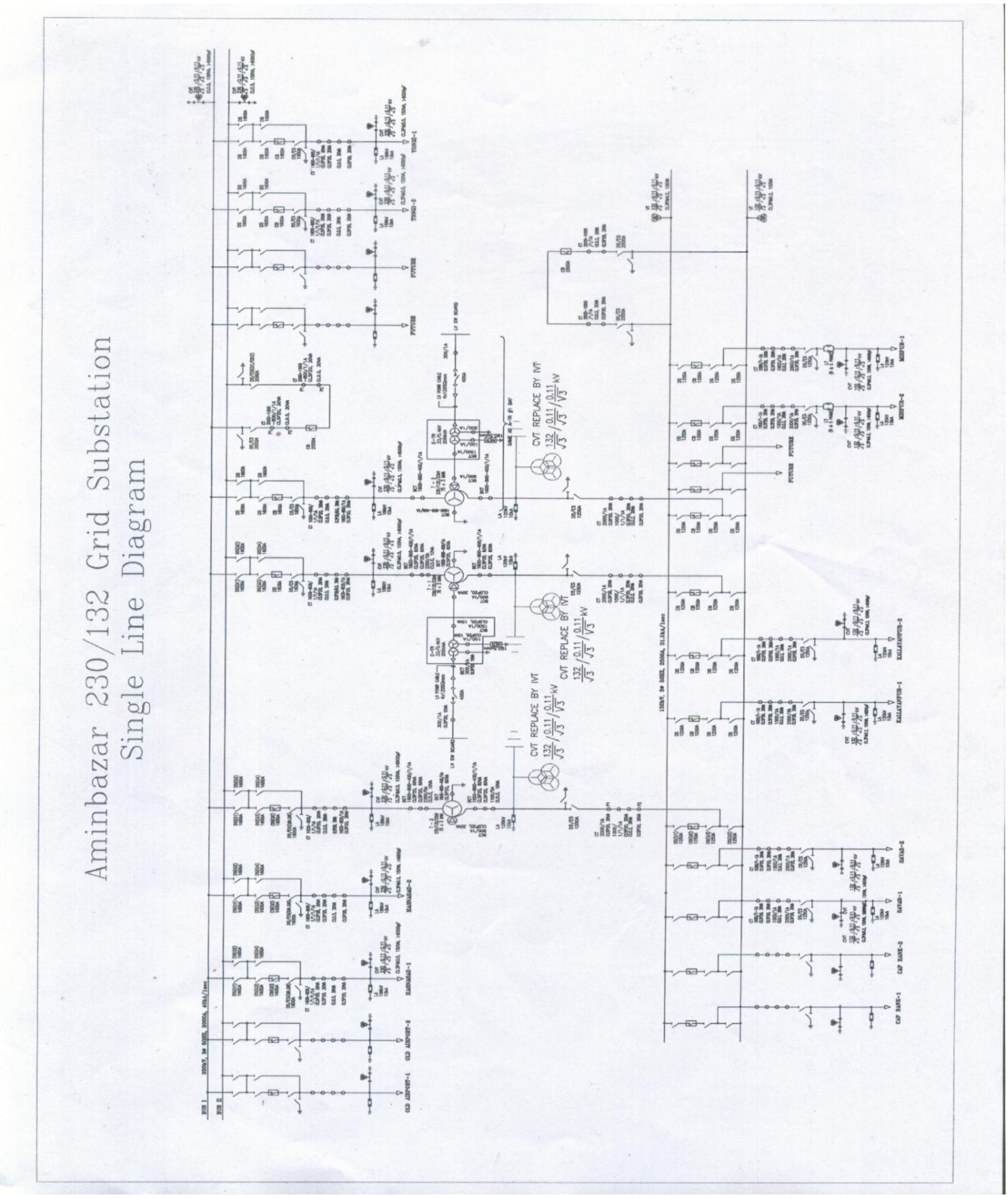


Figure: 5.2

132 KV SINGLE LINE DIAGRAM
OF AMIN BAZAR GRID SUBSTATION

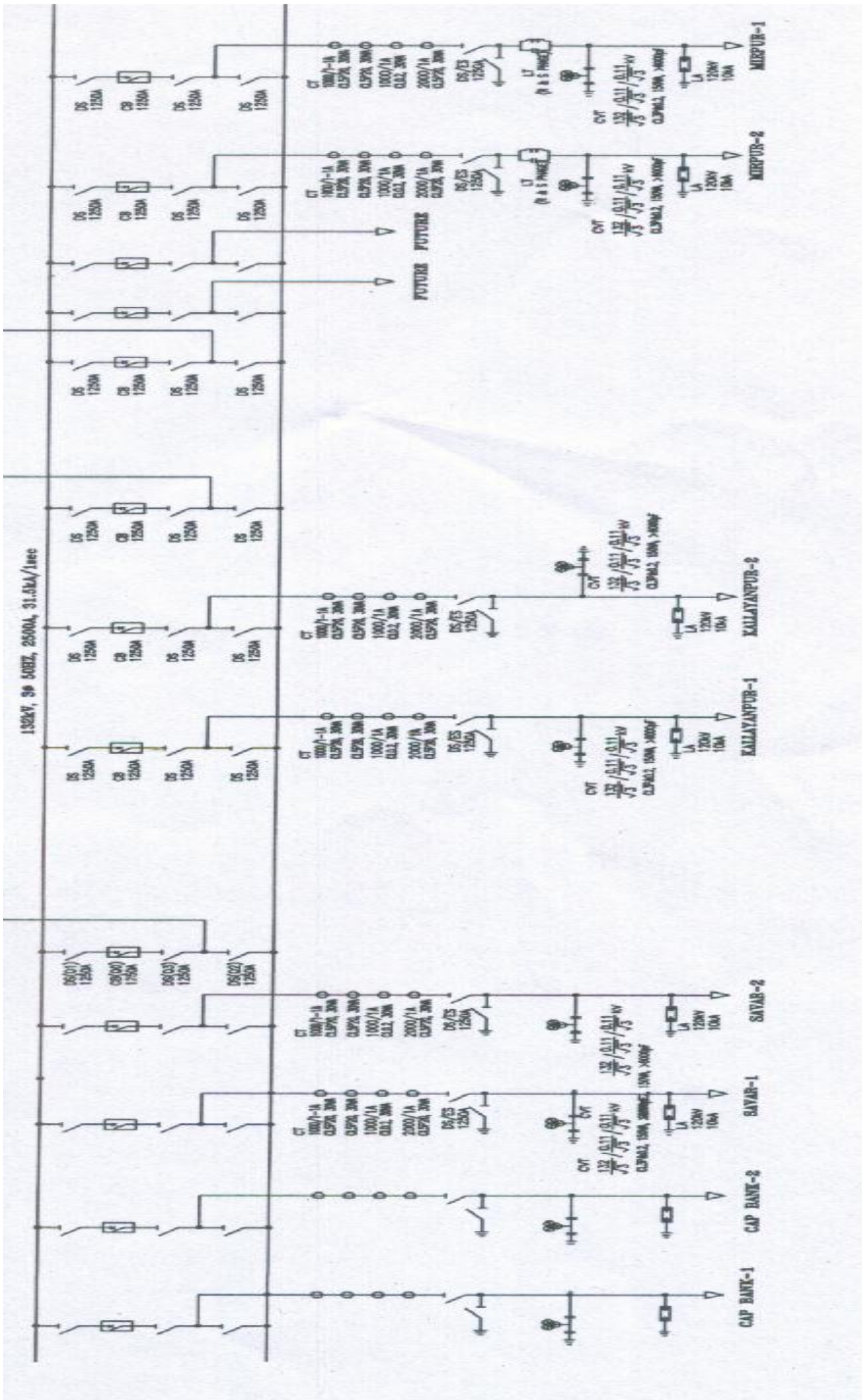


Figure: 5.3

5.2 BOARD BAZAR SUBSTATION

5.2.1introduction:

Board Bazar substation receives the power at 33 KV (Tongi substation) and converts the receiving power to 11 KV using transformer.

Total capacity of Board Bazar substation is 20-28 MVA.

Board Bazar substation is buildup of Chinese equipment.

Board Bazar substation feeds six (11 KV) feeders and IUT is one of them.

5.2.2 Purpose & Significance:

Convert the received power at one voltage level which is 11 KV

Plays a significant role in delivering power to Grameen line, BMTTI line, 4^{th} Feeder line, 5th Feeder line, IUT line, 3th Feeder line.

Works as both transmission and distribution substation.

The incoming connections:
There is one incoming connection at 33 KV which consist of Tongi

5.2.3 Diagrams of Board bazar substation 33\11KV:

33/11 KV SINGLE LINE DIAGRAM
OF BOARD BAZAR GRID SUBSTATION

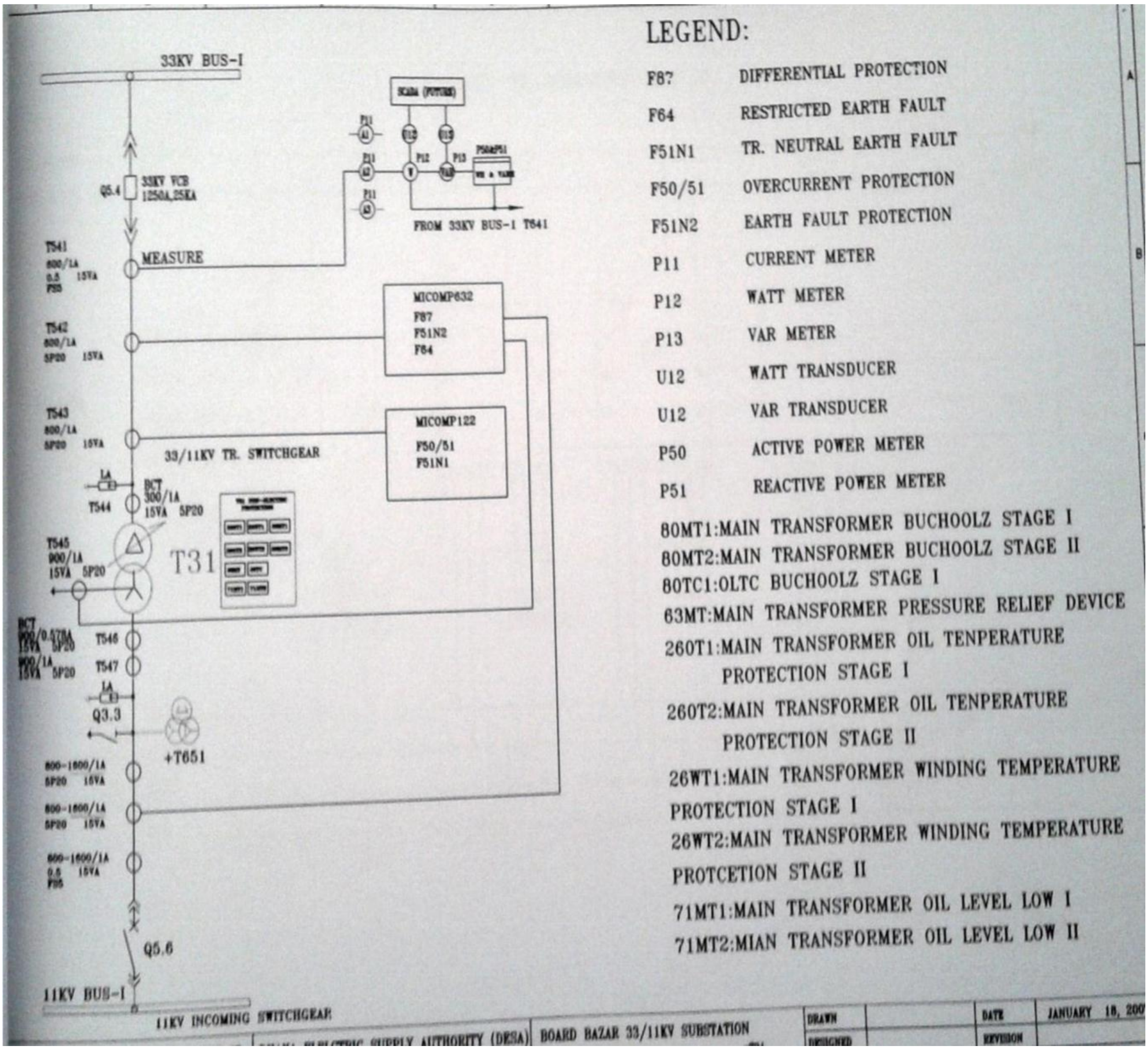


Figure: 5.4

5.3 IUT SUBSTATION

5.3.1 Introduction:

IUT substation receives the power at 11 KV (Board bazar) and convert the receiving power to 0.4 KV using transformer.

5.3.2purpose & Significance:

Convert the received power at one voltage level which is to 0.4KV .

5.3.3 Diagram Iut Substation:

11/0.4 KV SINGLE LINE DIAGRAM
OF IUT SUBSTATION

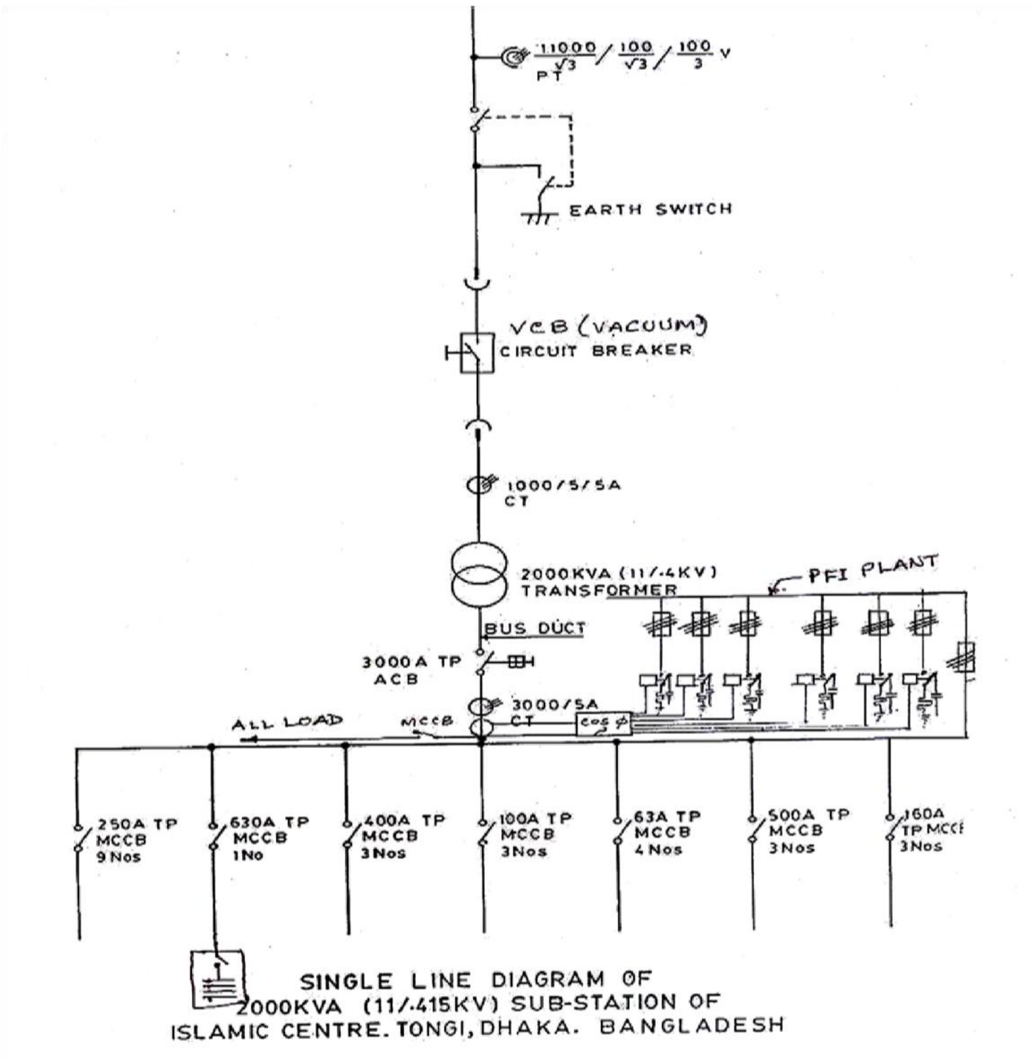


Figure: 5.5

SINGLE LINE DIAGRAM
OF TWO GENERATORS IN IUT SUBSTATION

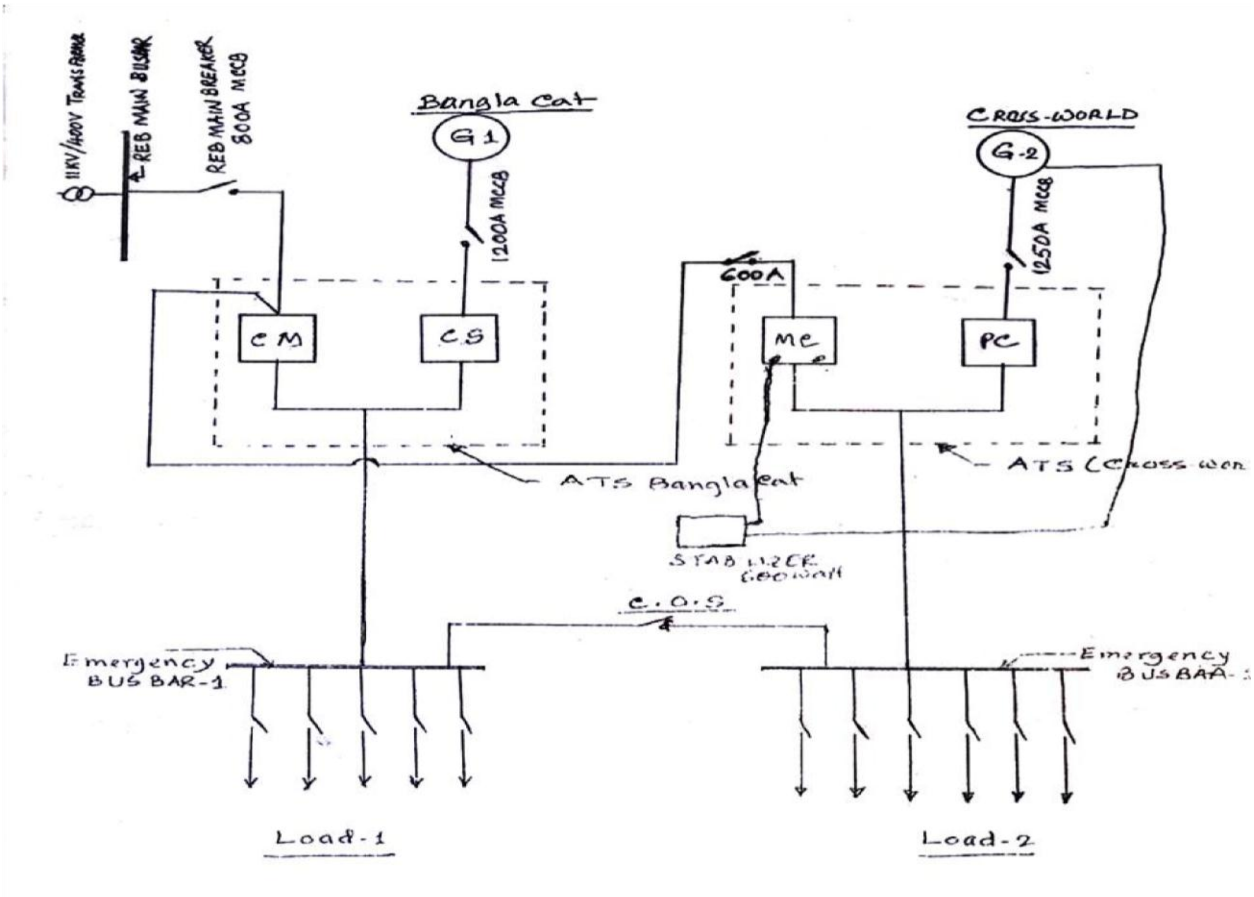


Figure: 5.6

CHAPTER 5

ETAP SOFTWARE

6.1 Introduction:

Enterprise Software, ETAP is the most comprehensive analysis platform for the design, simulation, operation, control, optimization, and automation of generation, transmission, distribution, and industrial power systems.

ETAP is used by engineers in more than 3,000 companies worldwide for industrial and utility power systems. ETAP products and services are used in all stages of the power process, from power generation, to transmission and distribution, to utilization.

Major industries include:

Generation Plants

Transmission & Distribution

Engineering Consulting

Nuclear Generation Plants

Oil & Gas

Data Centers

Renewable Energy

Manufacturing

Metals& Mining

Government & Military Facilities

Transportation

Education – Colleges & Universities

6.2 Power Generation Plants:

ETAP is the leading power system analysis platform for power generation plants of all types and sizes. From basic standby systems to 2417 mission-critical generation, some of the world's most advanced power generation plants count on ETAP to help provide reliable, clean and cost-effective power to their customers.

There has been a steady increase of generation companies turning to ETAP as a solution to optimizing their electric system to meet their demand for clean and efficient energy

.ETAP is being used to help engineers maximize the power output from their plants and lower fuel consumption.

Meeting future electricity demand for clean, efficient energy has never been greater. More and more generation plants are looking for ways of optimizing their electric system to meet this demand. OTI recognizes that generation companies have to produce power economically and designed ETAP for engineers looking at maximizing the power output from their plants and lowering fuel consumption.

ETAP EMS provides real-time intelligent optimization recommendations to the operators and assists in efficient operation of co-generation plants. Renewable energy sources like wind and distributed generation using fuel cells are gaining more importance. OTI foresaw this trend and developed extensive Machine Models and Harmonic Analysis to help engineers design these generation parks.

6.3 Transmission& Distribution:

With ETAP Geographic Information Systems (GIS), Unbalanced Load Flow, Extensive Transmission Line Models, Static Var Compensator (S VC) Models, Capacitor Placement Distribution Reliability Assessment and HVDC Link, we are helping our customers expand the reliability, stability, flexibility, and energy delivery capabilities of their power distribution systems .ETAP is used by the largest number of cities throughout the world.

Energy will never stands till. It has to be transported from where it's created for it to be useful .OTI understands the behavior and significance of miles and miles of distribution networks. With modules like Geographic Information Systems (GIS), Unbalanced Load Flow, Extensive Transmission Line Models, Static Var Compensator (SVC) Models, Capacitor Placement, Distribution Reliability Assessment and HVDC Link, we are helping our customers expand the reliability, stability, flexibility, and energy delivery capabilities of their power distribution systems.

6.4 Electrical Engineering Consulting Firms:

Top Design Firms Have Standardized on ETAP

According to the Top 40 Electrical Design Firms published in EC&M Magazine, 100% of the Top 10 Electrical Design Firms rely on ETAP for their power system design and analysis needs.

In fact, 80% of these top 10 firms have multiple or corporate licenses for ETAP. With over 3,000 companies world-wide using ETAP, this is just a small portion of the many users who have standardized on ETAP.

Consulting companies serve diverse markets and provide the best possible service to their clients. They demand an equally diverse tool that will help them deliver small to large-scale electric power system design, analysis, and construction projects. It is crucial for them to have a tool, which would provide a slew of sophisticated time saving features, integrated database management automated and concise reports.

OTI works with the top design firms worldwide to provide custom Database Conversions, Data Exchange, and Data Synchronization capabilities between ETAP and third party databases.

ETAP provides full spectrum power systems analysis tools and has interfaces with plant life-cycle management tools like e-DPP. Consulting firms use ETAP to provide their clients with one common database and a complete analysis of their electrical system. Project Wizard and Scenario Manager provide yet another time saving tool by automating power system analysis.

6.5 Nuclear Generation plants:

89% of U.S. Nuclear Generation plants have standardized on ETAP

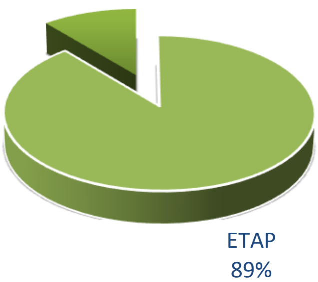


Figure : 6.1

ETAP Nuclear is used throughout the world by nuclear generation plants, research laboratories consulting firms, government agencies, etc. ETAP has established itself as the de facto standard within the United States nuclear generation plants, so much so that 57 out of 64 operating plants (89%) have standardized on

ETAP.

Companies such as Bechtel SAIC (Yucca Mountain Project) and Washington Savanna River trust ETAP for their electrical system analysis. ETAP is also becoming the standard software for international nuclear generation plants. In fact, Framatome ANP GmbH in Germany is currently using ETAP to design the largest grass root nuclear generation plant in Finland.

The electrical system design for Nuclear Utility Plants requires a tool, which complies with the United States Code of Federal Regulation. OTI recognizes the requirements and procedures followed by engineers designing and maintaining these plants.

ETAP has features and modules designed specifically for engineers serving these plants. It provides them unparalleled time saving tools like 3-D Database and Multiple Access Levels for added security. DC Modules like Battery Sizing& Discharge and Control Circuit Diagram provide tools to model details of the electrical system right down to the power drawn by an indicator light on a meter.

6.6 Oil & Gas:

The oil and gas industries depend on ETAP to protect their electrical systems with minimal downtime and have critical load running at all times. Predictive studies have saved these companies thousands of dollars every day.

From cars to paper products, natural gas to everyday gasoline, process and refining plants are always operational and manufacture everyday use products. Engineers designing the electrical systems for these plants have to take all precaution to protect the process and provide a system with minimal down time and have critical load running at all time. OTI has engineers who have tremendous industrial experience and have restructured ETAP to include 'first of its kind' protection and coordination module, ETAP STAR. We have always been active in providing feedback in industry standards and quick to adopt safety related standards like Arc Flash Analysis. Predictive studies can save a plant thousands of dollars every day. ETAP is also a real time energy management system with modules like Advanced Monitoring and Real-Time Simulation for full spectrum power systems analysis with real-time data.

6.7 Data Centers & Mission Critical Facilities:

IT operations are a crucial aspect of most organizational operations. One of the main requirements is ultra-high reliability and availability of the electrical power system that must meet stringent 24/7 operating criteria to maintain continuous functionality and minimize costly unscheduled downtime.

While security and availability come first, energy usage is becoming a focus when considering long-term operations.

Figure: 6.2 Create & Optimize Data Centers with ETAP

ETAP enables designers and engineers to conceptualize the power distribution model for mission critical facilities, simulate / test the integrity and security of the system and analyze the results with accurate reports.

ETAP is utilized in mission critical facility for tracking, managing and reducing energy consumption while maintaining maximum availability of vital operations. Modules such as Underground Raceway System allow you to design and predict the system availability not just for today but also consider the impact of server farm expansion in the future. ETAP enables green data centers to save energy by optimizing power usage which further minimizes the need for expensive infrastructure upgrades.

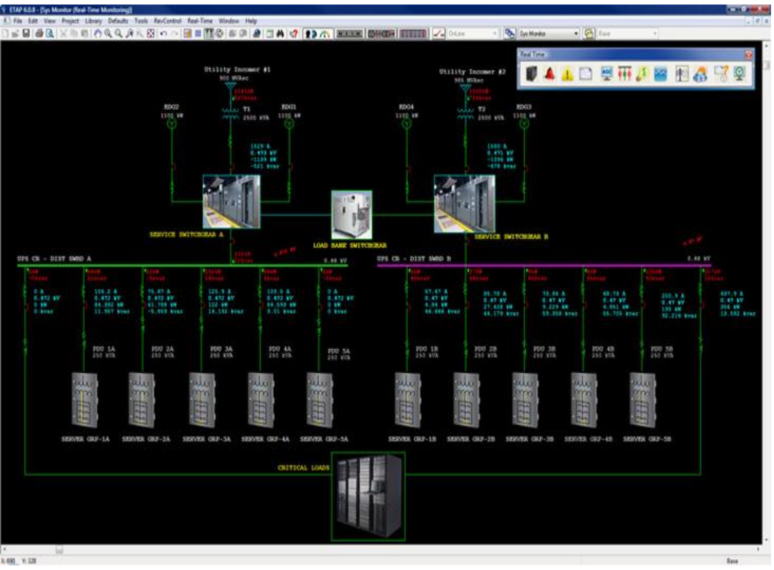


Figure:6.3

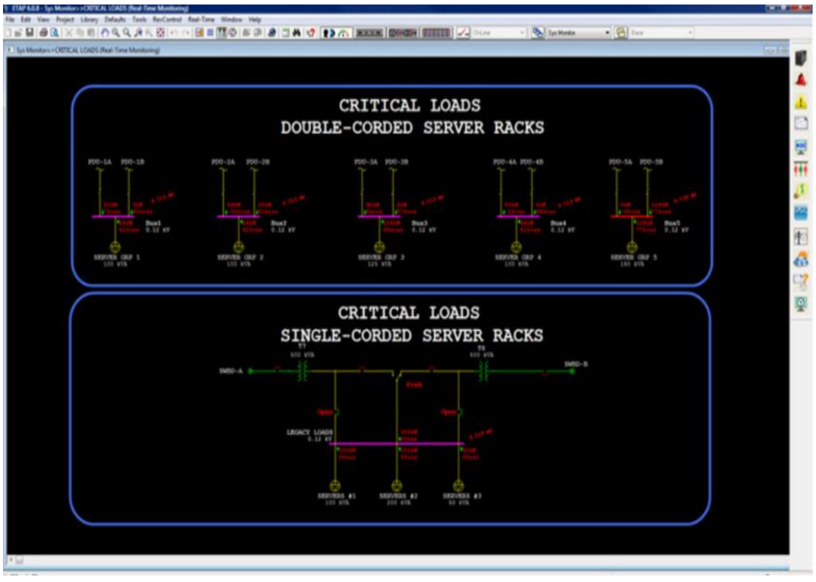


Figure:6.4

Key Features

- Green data center optimization
- Dedicated data center HMI
- Energy management system
- Power monitoring system
- Environment condition monitoring
- Safety system monitoring & evaluation
- Predictive simulation
- Sequence of events
- Protection scheme
- Load preservation & restoration
- Fault tolerant architecture
- UPS system monitoring & control
- Full spectrum electrical distribution design & analysis
- Distributed redundancy & high availability
- Real-time system reliability assessment
- Failure mode assessment

Figure:6.5

Figure:6.6

6.8 Renewable Energy - Wind & Solar Power Systems:

Design, Analyze & Operate Green Energy Power Systems with ETAP

The use of renewable energy is not new. More than 150 years ago, wood, which is one form of biomass, supplied up to 90 percent of our energy needs. As the use of coal, petroleum and natural gas expanded, the United States became less reliant on wood as an energy source. Today, we are looking again at renewable resources such as wind, solar and geothermal and finding new ways to use them to help meet our energy needs.

ETAP enables designers and engineers to conceptualize the collector systems, determine wind penetration and perform grid interconnection studies. ETAP includes comprehensive renewable energy models combined with full spectrum power system analysis calculations for accurate simulation, predictive analysis, equipment sizing, and field verification of wind and solar farms.

ETAP Real-Time allows for a logical and smooth transition of the design model into an operator / dispatcher tool for monitoring, controlling and managing power throughout the generation network.

ETAP puts you in control of your renewable energy generation in order to maximize output and improve efficiency:

- Dedicated generation farm HMI
- Generation management system
- Environment monitoring
- Wind turbine performance monitoring

- Solar panel & inverter performance monitoring
- Prediction of system response to operator actions
- Sequence of events

Full spectrum, electrical network design& analysis for:

- Collector system design
- Wind penetration studies
- Grid interconnection studies

6.9 Manufacturing:

Leading Manufacturers Worldwide Depend on ETAP Top manufacturers around the world depend on ETAP to meet the industry's rigorous operational, quality, and safety requirements for their power systems. ETAP is utilized for design, analysis, operation, and automation of manufacturing facilities.

Manufacturers are not concerned with high power systems but their network has its own complexity. Manufacturing facilities including high-rises, theme parks, warehouses, shopping centers, and large data centers have fluctuating loads and single-phase power distribution. OTI extended the analysis capability of ETAP to cater to the engineers designing power systems having loads like security, heating, air conditioning, and fire control. Panel systems combines a graphical user interface and the intelligence of ETAP to let the engineers easily design and analyze low voltage distribution systems. Combined with Single-Phase Load Flow, makes ETAP a necessary tool for designing and analyzing commercial low voltage power systems.

6.10Metals & Mining:

Many metal and mining operations rely on ETAP to reduce unnecessary load shedding and thereby preserving critical loads directly associated with production. ETAP brings significant energy savings to the industry by diverting non-essential loads during hours of high energy costs and managing the optimal combination of utility and self- generation power.

An Indonesian copper/gold mine operated by PT Newmont is the latest of a number installations that have greatly benefited from deployment of ETAP for absolute system optimization. PT Newmont needed a solution that would not only determine how much load needed to be shed but would also make recommendations on the loads to be shed based on user defined priorities. The answer for PT Newmont was

Production interruptions in the mining industry are associated with substantial losses in revenue. Inadequate load shedding triggered by a disturbance in the onsite power generation often results in loss of critical loads which negatively affect the production process, having a substantial impact on revenue in the tune of millions of dollars per incident. It is essential to have a proactive solution that can shed loads in a fast, optimal, safe, and intelligent manner in order to minimize production losses. ETAP Intelligent Load Shedding (ILS) is one such solution. ETAP ILS is a state-of-the-art, load preservation solution designed for the mining industry.

This mining specific load preservation system has been proven to reduce unnecessary load shedding and thereby preserving critical loads directly associated with production. In addition, ILS will bring significant energy savings by diverting non-essential loads during hours of high energy costs and managing the optimal combination of utility and self-generation power.

6.11Government & Military Facilities:

ETAP has been deployed at many government institutions and armed forces facilities. ETAP is utilized in research and development for government and military projects.

This contract allows OTI to be listed on an approved GSA schedule and sell ETAP products directly to government agencies. The inclusion of OTI as a GSA Schedule vendor allows government customers to obtain special and approved pricing and license terms from a trusted vendor. To see ETAP products available under the GSA Schedule.

ETAP enables designers and engineers to conceptualize their model, simulate the integrity and security of the system, analyze the results with accurate reports, and manage the electrical system with added real-time capability.

6.12 Transportation:

ETAP provides unique and efficient solutions for all segments of transportation. Transportation engineers use ETAP to design and maintain the electrical system for a number of critical mass transit networks such as railways, canals, etc. as well as terminals such as airports and seaports.

In fact, only two automobile manufacturers made it to the Top 5 of the Fortune 500 list and both utilize ETAP for the safe and reliable operation of their production line.

An urban transportation company recently added ETAP ARTTS in order to bridge the gap between relay-testing hardware and power system simulation technology. With knowledge of the actual response of their protective relaying, they are now making informed decisions and providing commuters a more dependable and faster service.

When rail transit was introduced over a century ago, it looked like the transport of the future. It still does. Sprawling cities, crawling highways, and chronic pollution all stress the importance of sustainable rail systems in the years to come. Rail design is very complex and the electrical system uses very high power electrical and electronic devices to serve endless miles of railroad.

OTI understands the importance of transit system analysis and works with key transportation companies to enhance ETAP with DC modules like Rapid Transit System and DC Load Flow designed specifically for transit system modeling and analysis. ETAP also has a unique Underground Raceway System design tool allowing engineers to design and analyze the thermal integrity of raceways especially for urban subway systems.

6.13 Education - Colleges & Universities:

Colleges and universities use ETAP to teach students in electrical engineering to design, model, and analyze electrical power systems.

ETAP offers an educational software package for instructors, university computer labs, and students.

Instructors use ETAP in a power system lab setting to solve engineering queries and provide the hands-on experience to better prepare students to enter the workforce. OTI has always been a strong supporter of educational programs for power systems. ETAP offers an educational software package for instructors, university computer labs, and students. The Educational Edition of ETAP provides universities with access to the latest technology for the design, modeling and analysis of electrical power systems. Using ETAP in a power system lab setting allows students the opportunity to do real-world practical problems utilizing the most sophisticated electrical engineering software package available. Students not only learn how to use ETAP to solve engineering queries, but also have the opportunity to be better prepared to enter the workforce upon graduation.

CHAPTER 7

USING ETAP FOR SIMULATION

7.1 Load Flow Study for Our Visited Substation:

Existing load flow performance tools capable of determining voltage, angle, flows, MW/Mvar, and scheduling dispatch are mostly offline although a few can give real - time results. Most of the existing substations don’t have the performance analysis tool for the real time data collection. However, for data collection and analysis we used the following two types of tools:

7.2 Data Collection Using Clamp Tester:

Clamp Tester is normally used for taking data from bus connection. When it is connected to any bus bar it can show the current values, temperature and resistance also. We used Clam Tester for collecting the current values different bus in IUT substation**.**

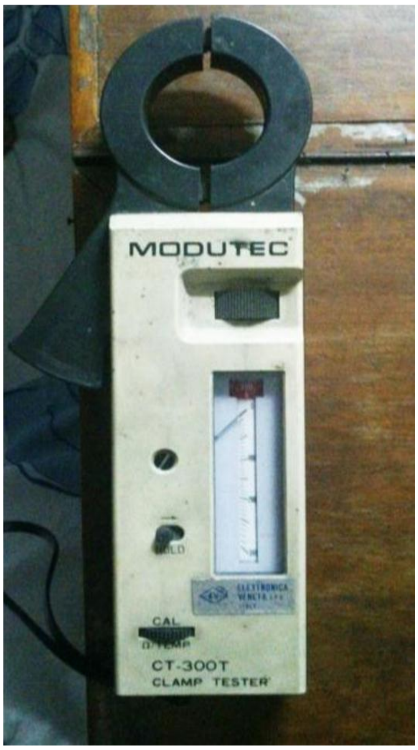


Figure 7.1: Clamp Tester

7.2.1 Load Flow Simulation Using Etap Software:

ETAP offers a suite of fully integrated Electrical Engineering software solutions including arc flash, load flow, short circuit, transient stability, relay coordination, optimal power flow and more. ETAP Load Flow software performs power flow analysis and voltage drop calculations with accurate and reliable results. Its calculation program calculates bus voltages, branch power factors, currents, and power flows throughout the electrical system. ETAP allows for swing, voltage regulated, and unregulated power sources with unlimited power grids and generator connections. For details: http://etap.com/index.htm.

Figure **7.2: Etap Software Logo**

7.2.2 Load Flow Simulation for Board Bazar Substation:

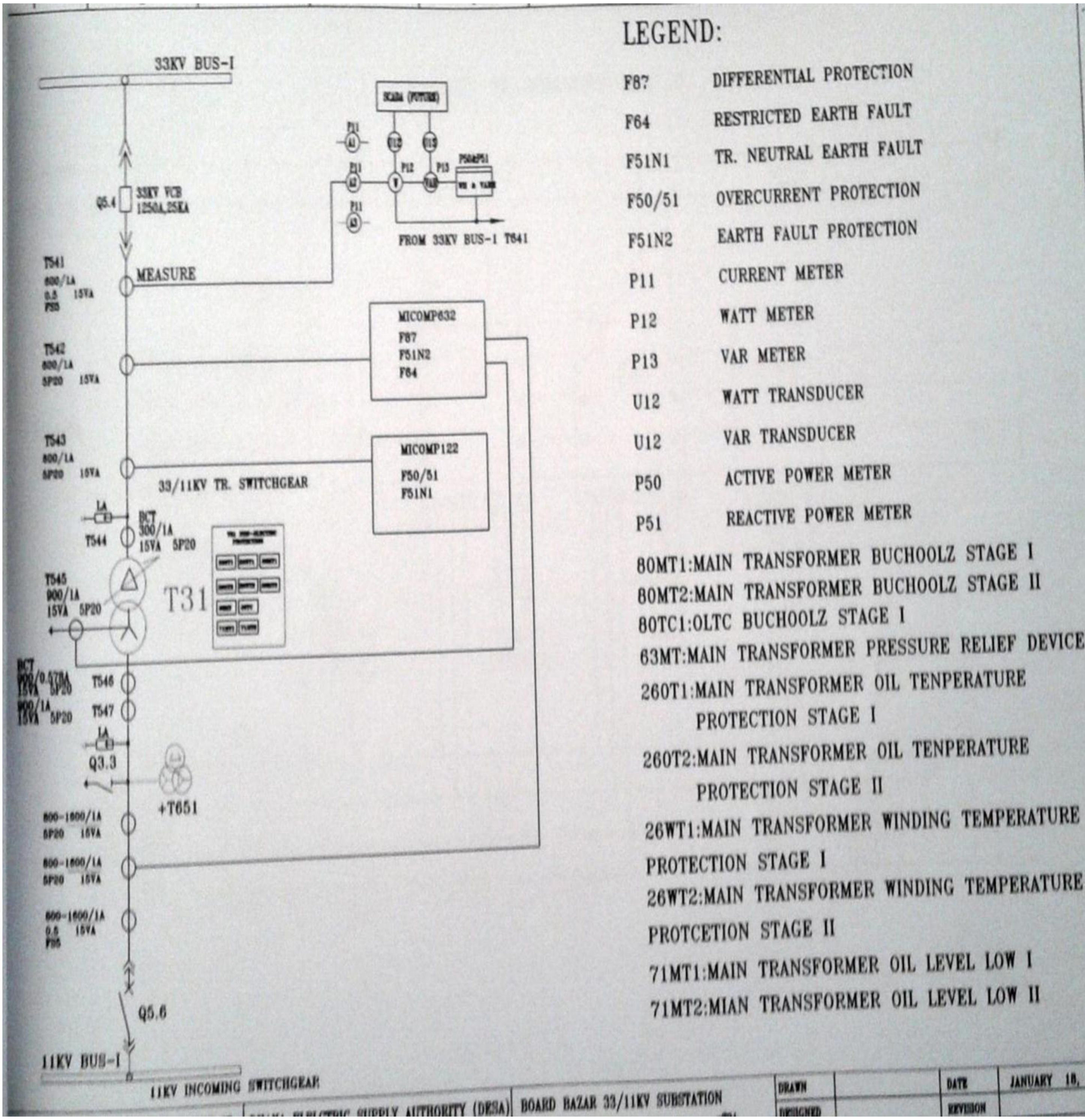


Figure 7.3: One Line Diagram of Board Bazar Substation

Board Bazar substation can be considered as distribution substation.

The above one line diagram along with all data is simulated in *Etap Software* for Load flow calculation at the peak demand.

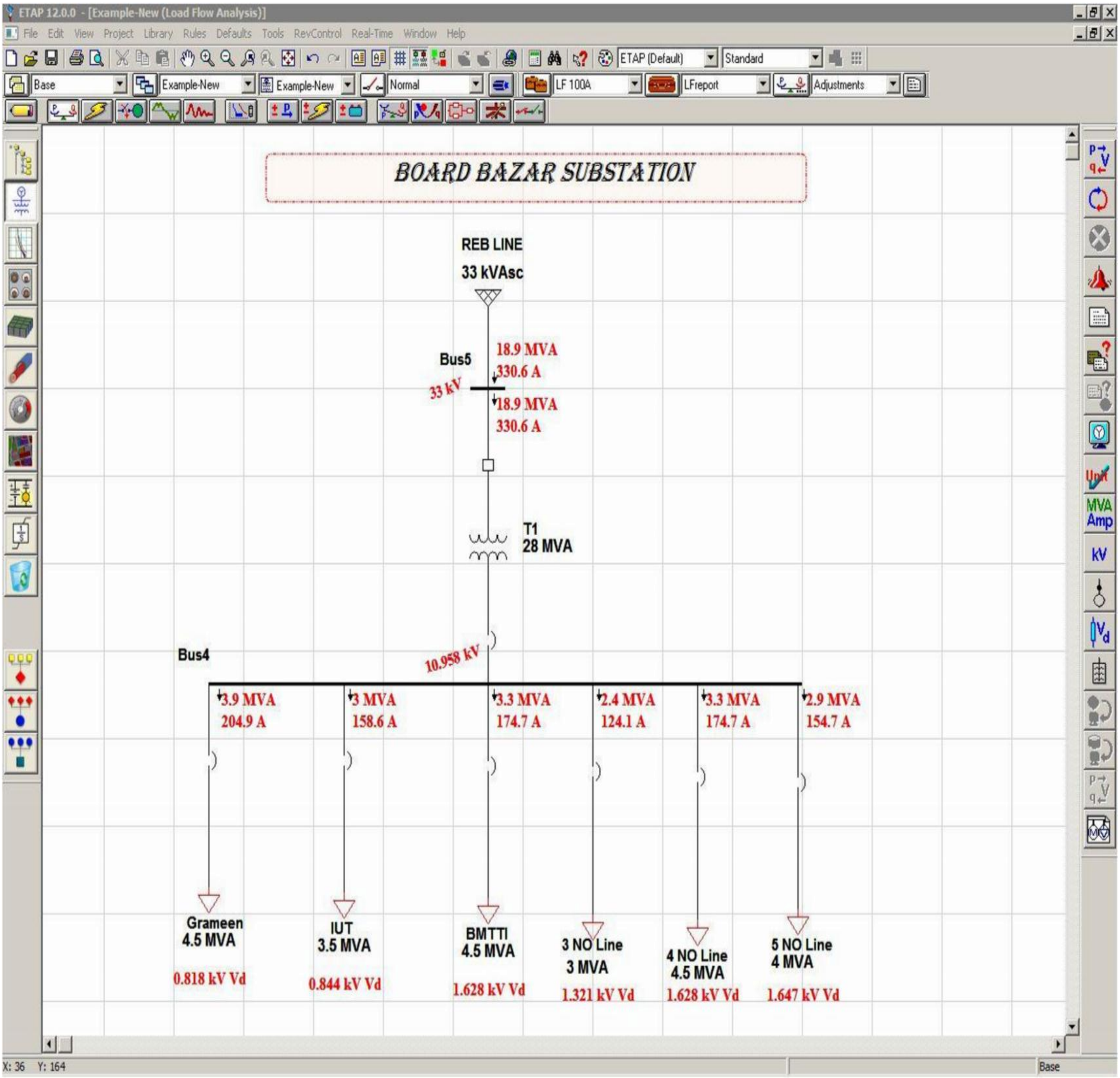


Figure 7.4: Load Flow Calculation for Board Bazar Substation.

7.2.3 Load Flow Simulation for IUT Substation:

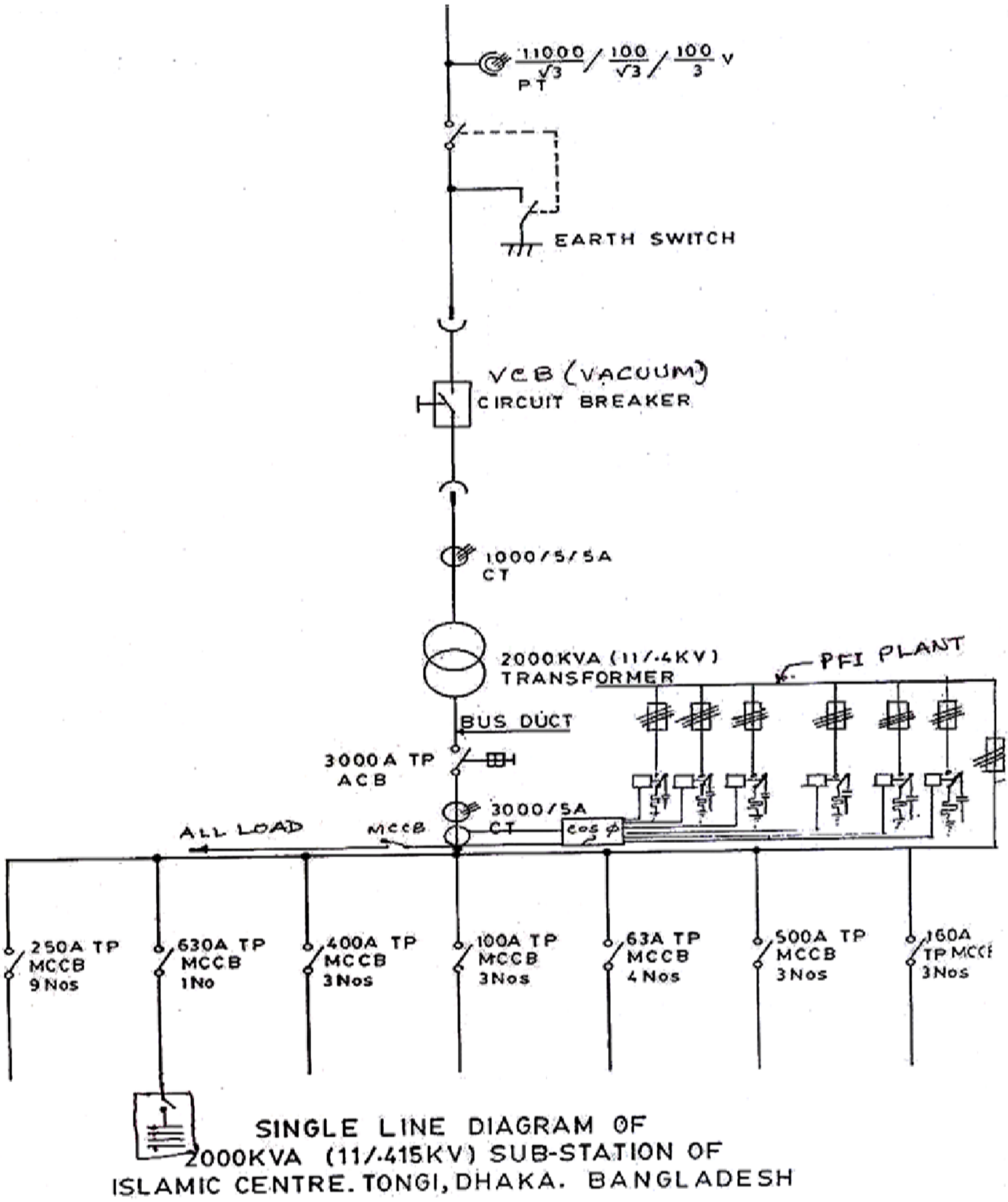


Figure 7.5: One Line Diagram IUT Substation.

There are **two generators** in IUT substation.

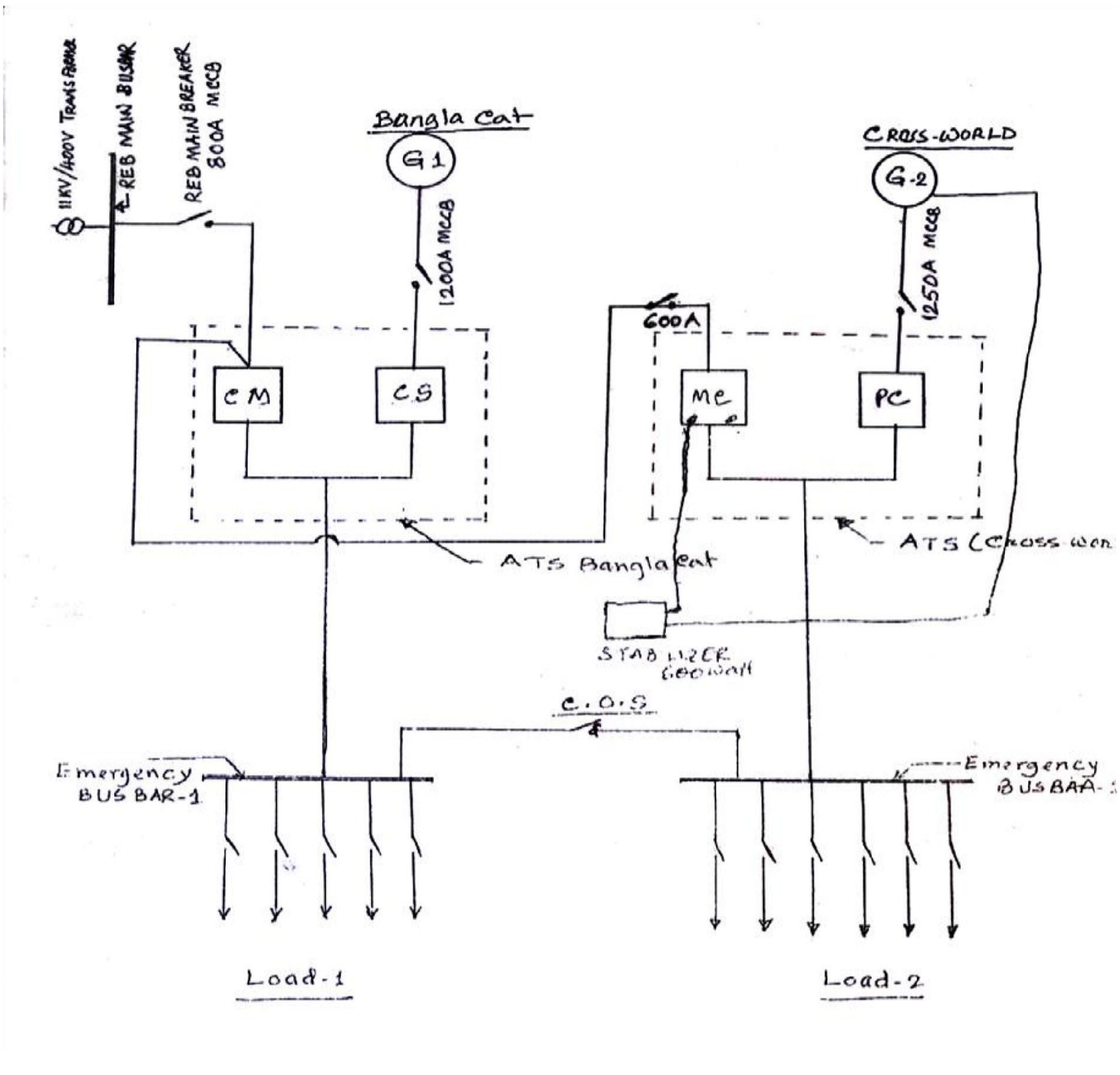


Figure 7.6: One Line Diagram of Generator Connection in IUT Substation.

From the Figure **7.6** Load 1 & Load 2 are actually the line connection for different buildings inside IUT which are receiving power from IUT substation.

During load shedding this two generators supply the required power for all buildings. Both of them are Diesel Generators.

Name of these buildings along with their demands in Kilo Watt (KW) is given below :

Islamic University of Technology (IUT)
Board Bazar, Gazipur
Total Electrical Load (Connected)

Sl. No.	Name of the Building / Installation	Load (Kilo Watt)
1	Administrative Building	66.15
2	Academic Building (Old)	274.39
3	Cafeteria+ Library	43.28
4	Auditorium	30.32
5	Mosque	14.73
6	North Workshop	42.00
7	Middle Workshop	62.55
8	South Workshop	38.40
9	North Halls of Residence (East Block)	40.50
10	North Halls of Residence (Middle Block)	40.50
11	North Halls of Residence (West Block) (Converted Academic Building)	40.50
12	South Halls of Residence (East Block)	33.46
13	South Halls of Residence (Middle Block)	33.46
14	South Halls of Residence (West Block)	33.46
15	Common Facilities Building	43.49
16	Student Center + Gate House	10.70
17	Gymnasium + Tennis Court	28.12
18	Medical Center	6.46
19	Laundry Building	10.44
20	"D"- Type Housing	20.48
21	"E"-Type Bungalow (2Unit × 8.33 kw)	16.66
22	"F"-Type Guest House	19.45
23	Water Supply Plant (Pump House)	49.00
24	Street Lights + Garden Lights+ Central Plaza Lights	10.60
25	Academic Building (New) (Under Construction)	545.71
26	Central Air Cooler of Library (50 Ton)	100.00
27	Central Air cooler of Auditorium (50 Ton)	70.00
	Total connected Load=	1724.81

Figure 7.7: Name of the Buildings with Their Demands in Kilo Watt (KW)

At this stage we took practical data for different buildings from their bus bar connection using *Clamp Tester* and then finally we simulated the one line diagram in *Etap Software* for further analysis.

As the current consumption rate changes in every second the following data are collected using *Clamp Tester* may also vary from the real time calculation.

Feeders name	First Reading (2:35) PM 17/6/2013 REB Line ON Voltage = 395 V Total Load=700A	Second Reading (12:30) PM 18/6/2013 GEN. 1 ON Voltage = 392 V Total Load=600A	Third Reading (12:00) PM 20/6/2013 REB Line ON Voltage = 392 V Total Load=650A
Administrative Building	70A	80 A	60 A
Auditorium	2A	10 A	10 A
'D' Type Building	10 A	22 A	12 A
Guest House	10 A	0 A	5 A
Academic Building	72 A	100 A	80 A
Dormitories / Pump House/ Student Center/ Common Facilities Building/ Level-5(A.B)	250 A	200 A	300 A
New Academic Building	412 A	350A	150A
Cafeteria/ Library	40 A	52 A	42 A
Mosque	6 A	10 A	5 A
North Work-shop	20 A	5 A	0 A
Middle Work-shop	15 A	0 A	5 A
Welding Work-shop	0 A	0 A	20 A
South Work-shop	25 A	20 A	5 A
Street Light	0 A	0 A	0 A

Table 7.1: Name of the Feeders & Current Consumption in Ampere (A).

The above one line diagram along with all data is simulated in *Etap Software* for Load flow calculation at the peak demand.

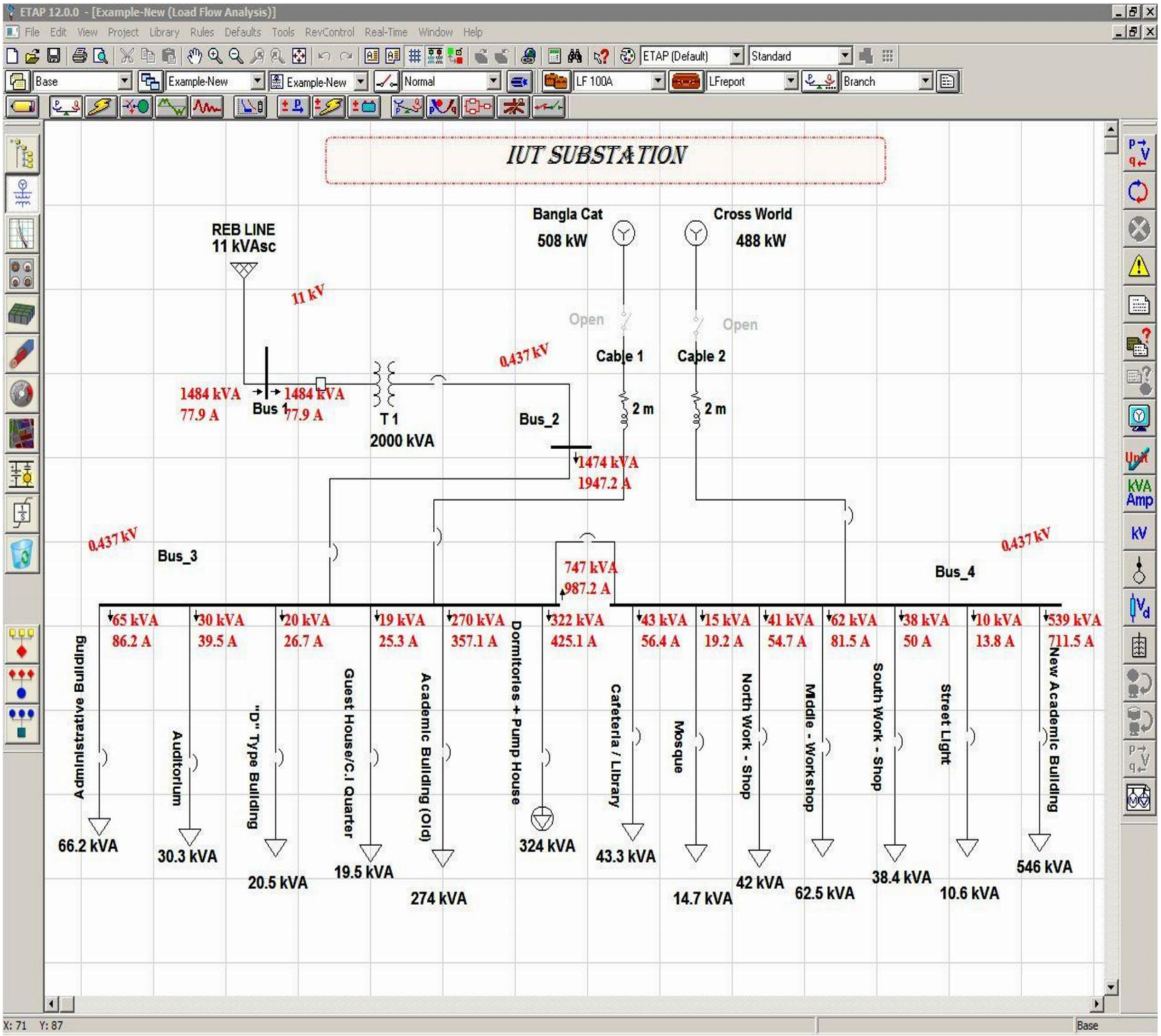


Figure 7.8: **Load Flow Calculation for IUT Substation.**

The above load flow calculation is done for ‘REB Line ON’ condition which means that IUT substation is receiving power from Board Bazar substation and there is no load shedding going on.

7.2.4 Comparison of Data Analysis:

We can compare our practical data collected from *Clamp Tester* and the data we obtained from the *Etap Software* simulation as given below:

Load Type	**Data in (Amp) from *Clamp Tester***	**Data in (Amp) from *Etap Software***
Dormitories + Pump House + Student Centre	300	425
Administrative Building	80	86
Staff Home	22	26
Cafe + Library	52	56
Mosque	10	19
Auditorium	10	39

Table 7.2: Comparison of Data Analysis in Load Flow Study

As the current consumption rate changes in every second it is not really acceptable to have the same data in both case.

Though we got some similar type of data in both case which implies that the one line diagram that we have designed in *Etap Software* is accurate enough for further analysis.

7.2.5 Load Flow for Combined Network (Board Bazar and IUT):

The load flow analysis for combined one line diagram of Board Bazar & IUT substation is given below:

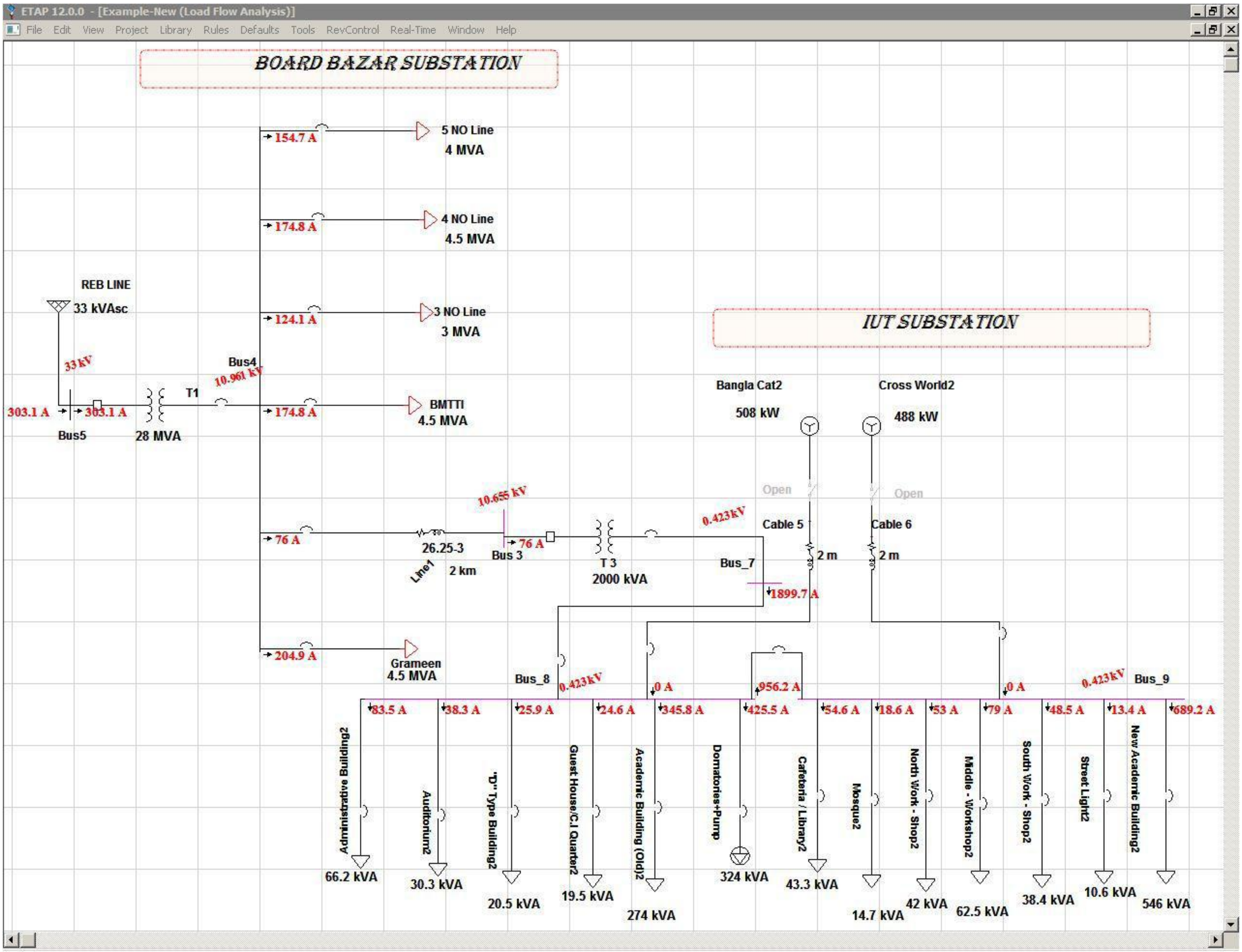


Figure 7.9: Load Flow Calculation for Combined Network.

The above load flow calculation is done for 'REB Line ON' condition which means that IUT substation is receiving power from Board Bazar substation and there is no load shedding going on.

In reality during peak time when the demand is high it often causes outage problem as a result power failure occurs frequently.

As uninterrupted power supply is the prerequisite for smart grid implementation, therefore outage problem should be minimized as much as possible.

The load flow analysis for combined one line diagram of Board Bazar & IUT substation during **load shedding** is given below.

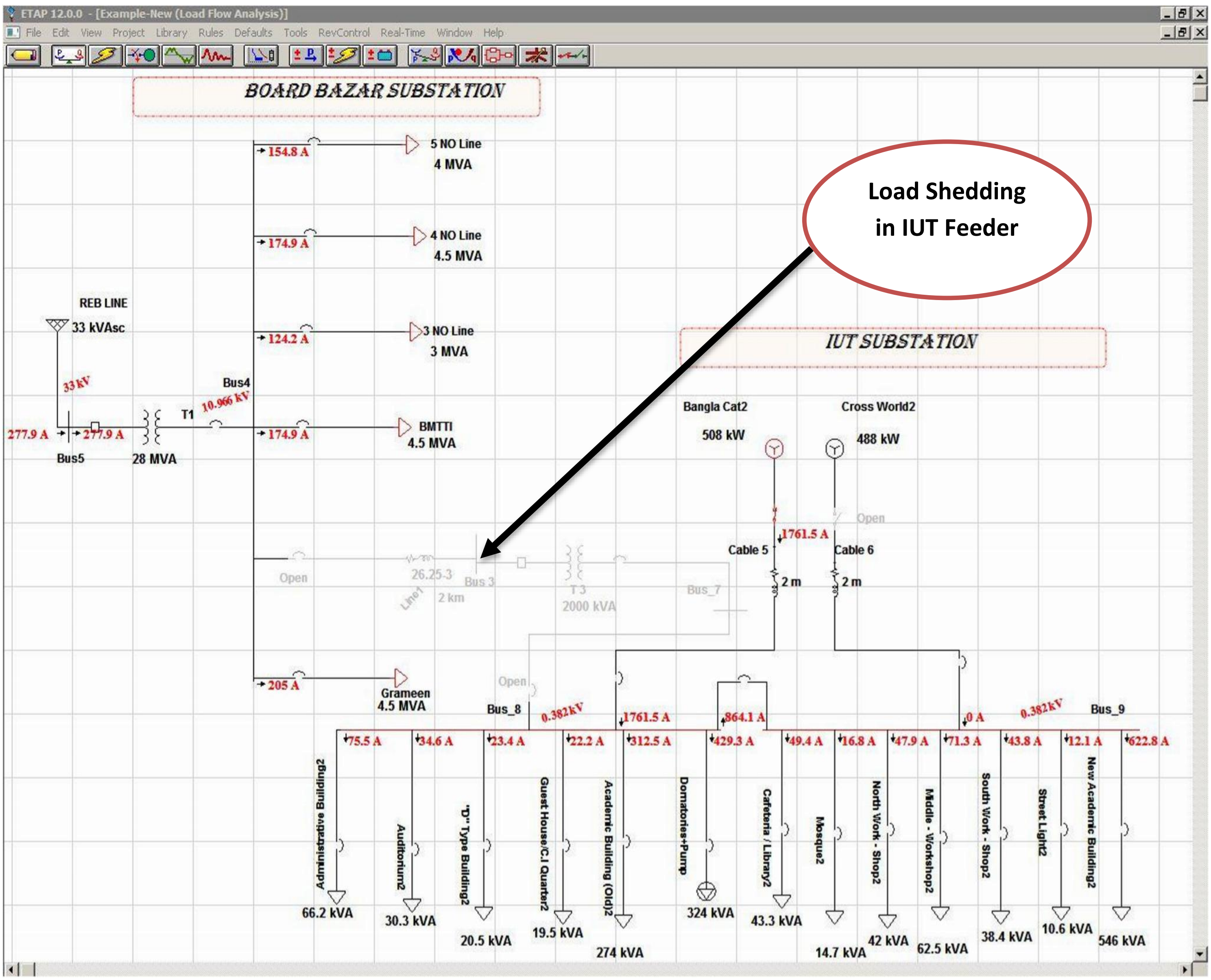


Figure 7.10: Load Flow Calculation during Power Outage.

The above figure shows the outage problem in IUT feeder whereas, same scenario may happen in other feeders also.

Though because of generator we are getting power, more robust & reliable system is required for uninterrupted power supply with extensive monitoring.

7.3 Reliability Analysis:

The reliability associated with an electric utility system is a measure of the ability of the system to provide an adequate supply of electrical energy consistently.

Reliability of a power system is generally addressed by considering two basic aspects of the utility power system: Adequacy and Security.

Adequacy relates to the existence of sufficient generation, transmission and distribution facilities to supply the total electric power and energy requirements of the customers at all times, taking into consideration planned and random outages of system components.

Security, on the other hand, relates to the ability of the electric utility power system to withstand both local and widespread disturbances and unanticipated loss of generation and transmission equipment.

The basic reliability indices normally used to predict or assess the reliability of a distribution system consist of two reliability indices:

- Load point average failure rate (l) in fault per year (f/yr)
- Average outage duration (r) in hours per year (hr/yr)

The following reliability studies is based on this two indices.

7.3.1 Reliability Analysis for IUT Substation:

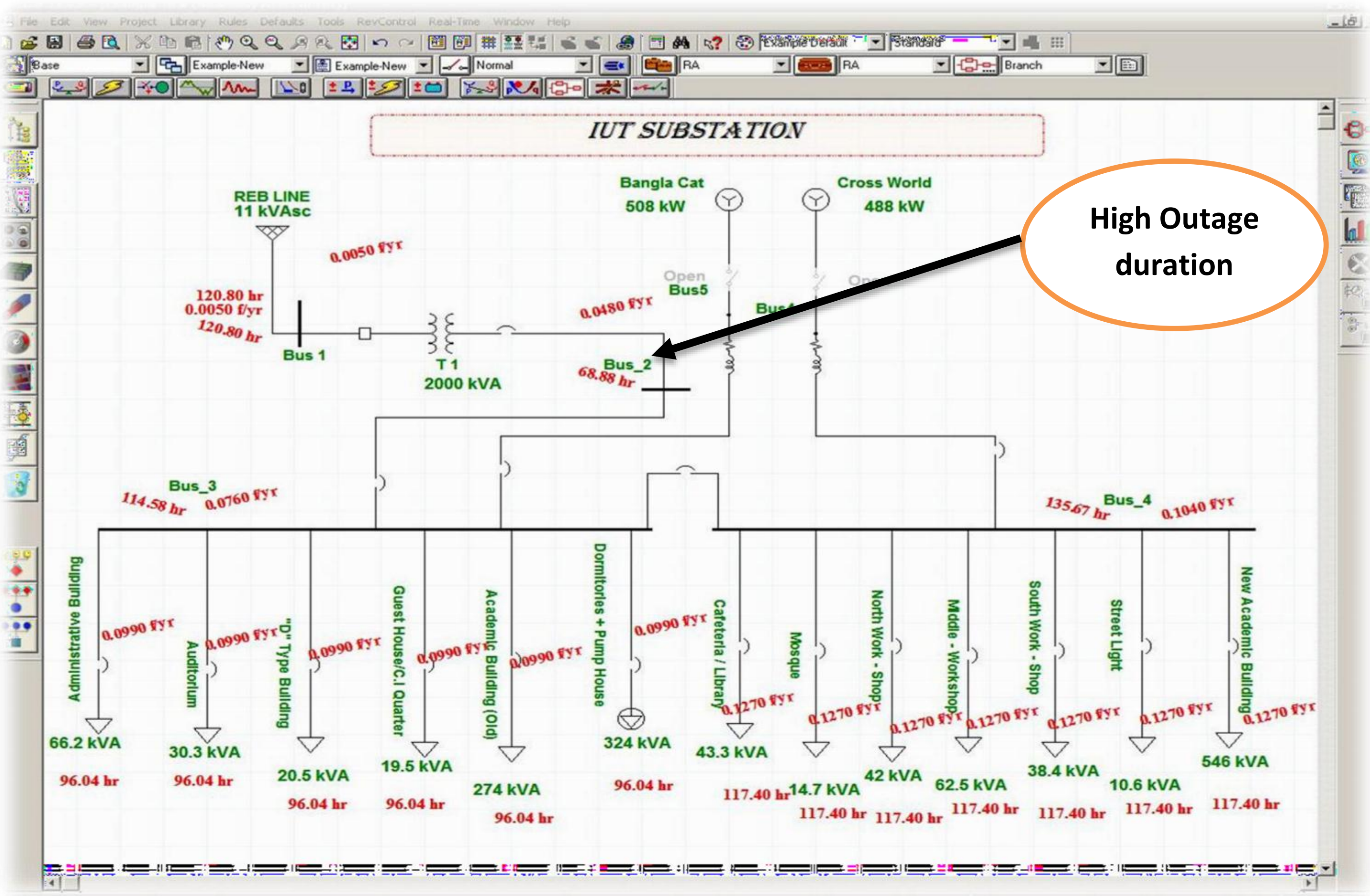


Figure 7.11: **Reliability Analysis for IUT Substation**

From the above reliability analysis for IUT substation we obtained High load point average failure rate (l) = 0.140 times fault per year* & High average outage duration (r) = 68.88 hours*

Further analysis of combined network will give us appropriate results to propose our model to mitigate this problems.

*This results are software simulated based on random probabilistic function which may vary with real time operation.

7.3.2 Reliability Analysis for Combined Network (Board Bazar and IUT):

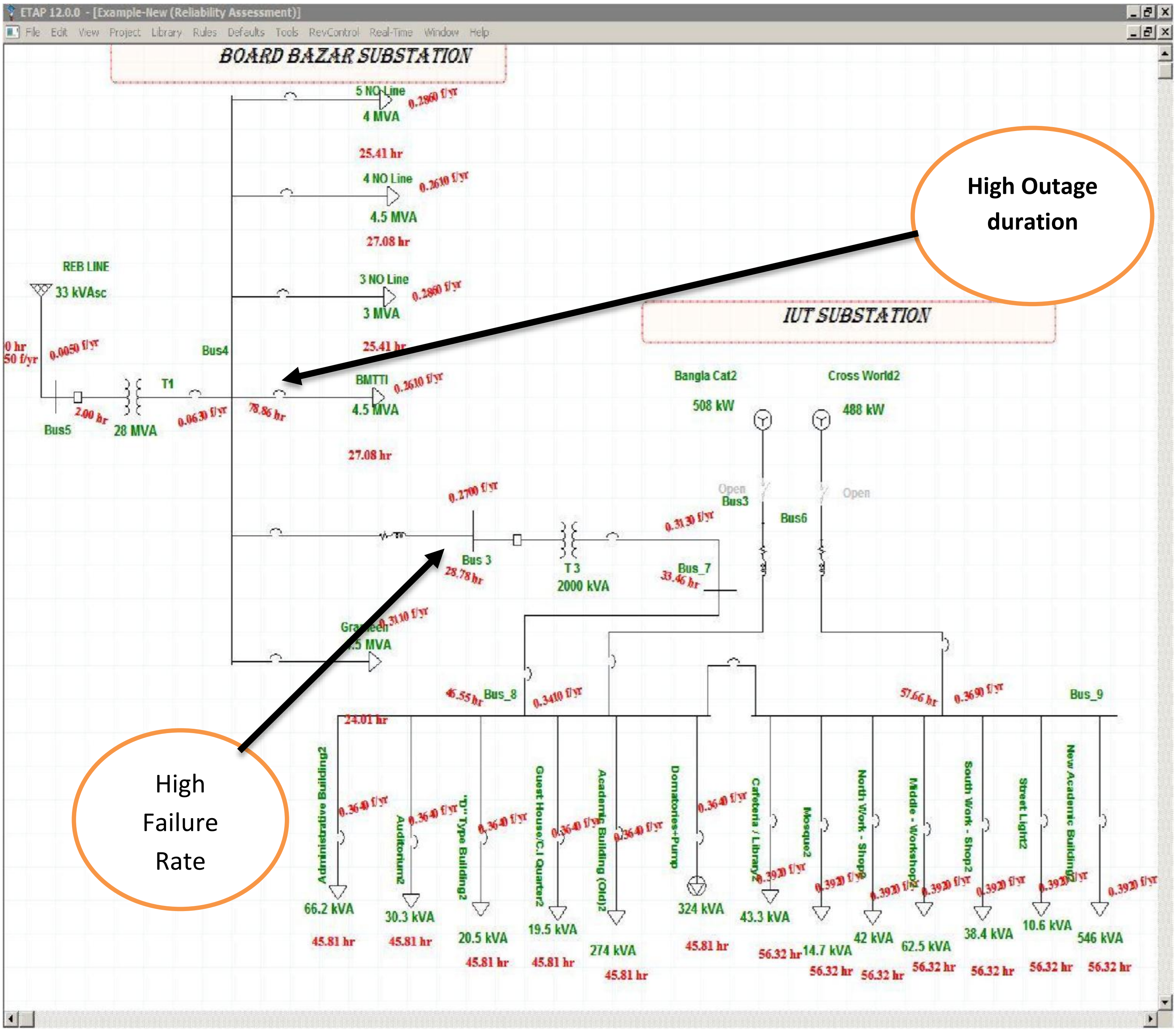


Figure 7.12: Reliability Analysis for Combined Network.

From the above reliability analysis for Combined Network we obtained High average outage duration (r) = 78.86 hours at 11 KV feeder line as well as high load point average failure rate (l) at different load points.

So from the above load flow & reliability analysis we acknowledged that the present grid system has so many problems that are summarized in next topic.

7.3 Problems with the Existing Grid System:

The following problems are listed below from the above analysis of present grid system:

- **Lack of two way Power flow system**
- **Integration of renewable energy is absent**
- **No system for storage facility**
- **High outage rate**
- **High average failure rate**

Actually the above problems are the main reason of implementing Grid technology to ensure a healthy and self-healing power system.

So, we will try to mitigate this problems by adopting some basic characteristic technology of Grid in our proposed model in following chapter.

CHAPTER 8

OUR PROPOSALS

8.1 Finding Solution through Smart Grid Technology:

The problems that we faced in case of present grid can be mitigated by adopting some key technologies which are actually define the Smart Grid.

For this we have to keep in mind the above problems and to ensure the healthy and uninterrupted power system which is the prime concern of Standard Grid Substation, the following steps should be noted while designing an interconnected grid system:

- **Ensuring two way Power flow**
- **Integration of renewable energy in grid**
- **System for storage facility**
- **Reducing the outage rate**
- **Reducing the average failure rate**

In this chapter we will design an interconnected system for Board Bazar & IUT substation using Etap software and also analysis the load flow and reliability for our designed grid system to ensure the above criteria.

First we will represent our proposed model in a block diagram to make it easier to understand and then we will go for the load flow & reliability analysis to compare our results with the present system.

8.2 Block Diagram Representation of Our Proposed Model:

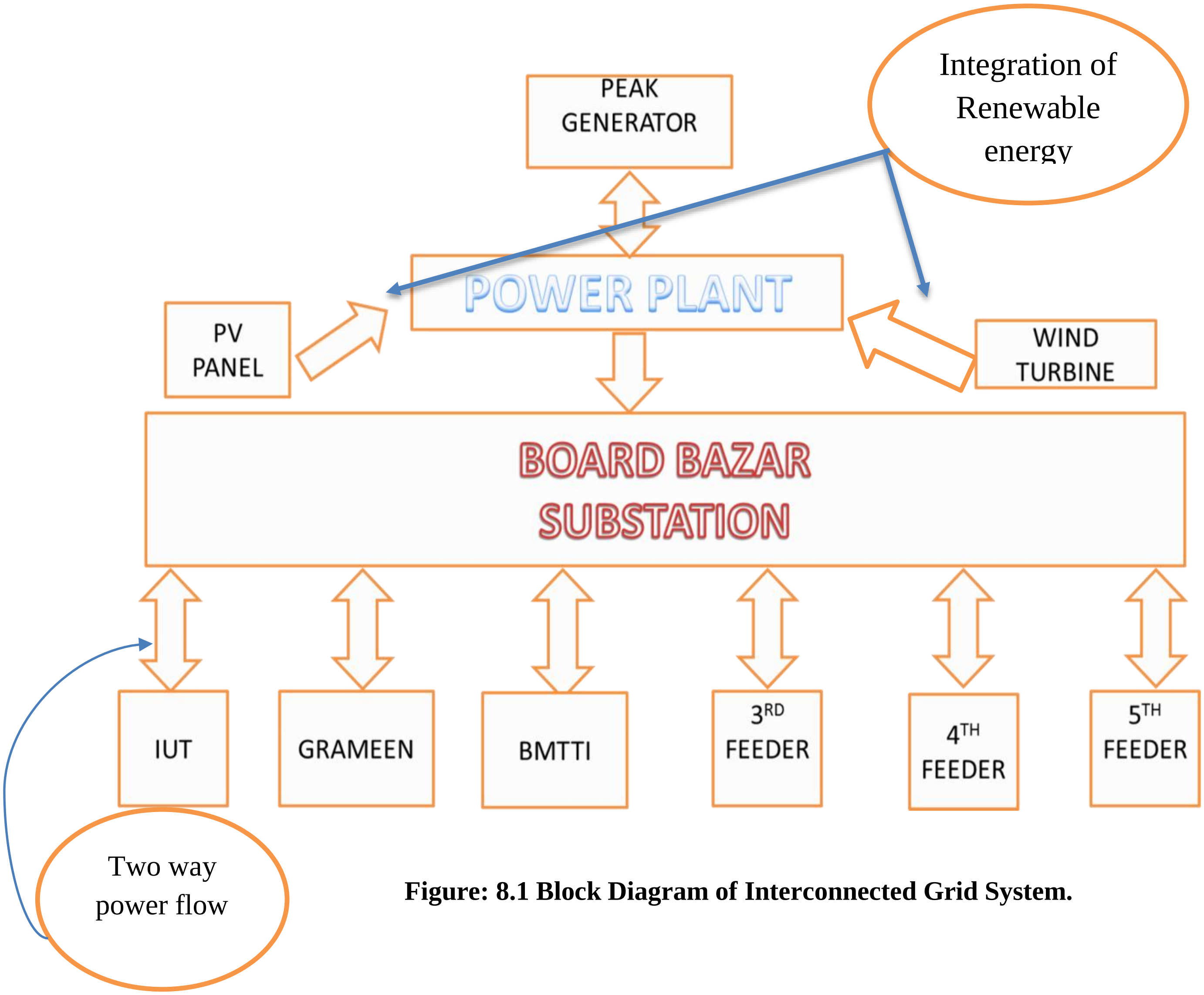


Figure: 8.1 Block Diagram of Interconnected Grid System.

The above figure is shown for Board Bazar substation & its six feeders where:

- Two way of power flow is considered &
- Integration renewable energy is also ensured.

Two way power flow is required during peak time to feedback the power from consumer to utility and integration of renewable sources ensure the pollution free electricity production which is the major concern in case of reducing greenhouse gases (CO2).

The following figure is shown for only the IUT substation and its interconnected system:

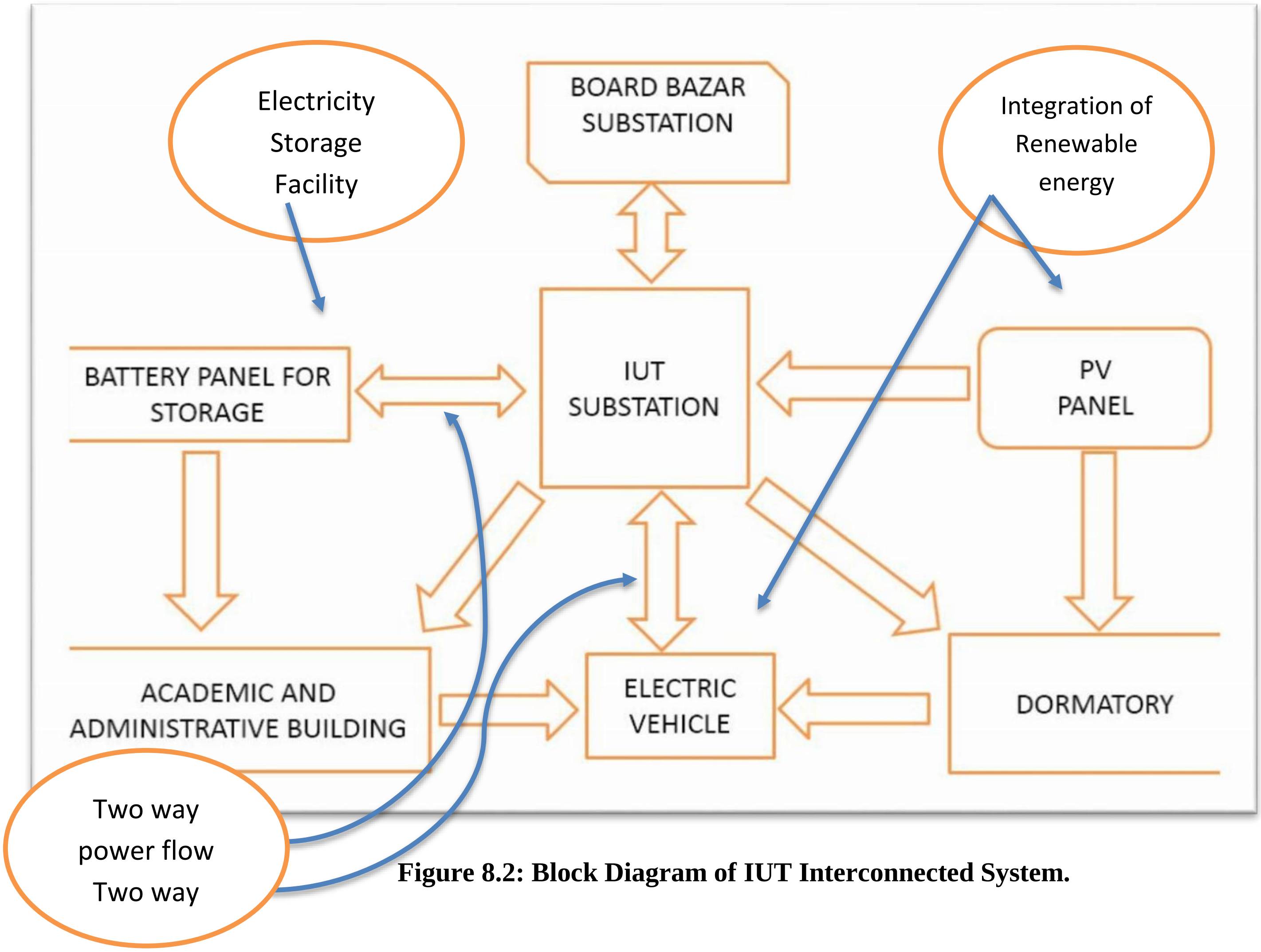


Figure 8.2: Block Diagram of IUT Interconnected System.

From the above figure it is acceptable to have the two way power flow, integration of renewable energy and electricity storage system for IUT substation which will be self-healing as well as capable of feeding back power to Board Bazar substation during peak demand via two way power flow system keeping the record that amount of power in smart meter for billing purpose.

8.3 One Line Diagram of Our Proposed Model:

Here we will step forward to design the one line diagram of IUT & Board Bazar interconnected grid system in Etap software keeping those criteria in mind for further analysis.

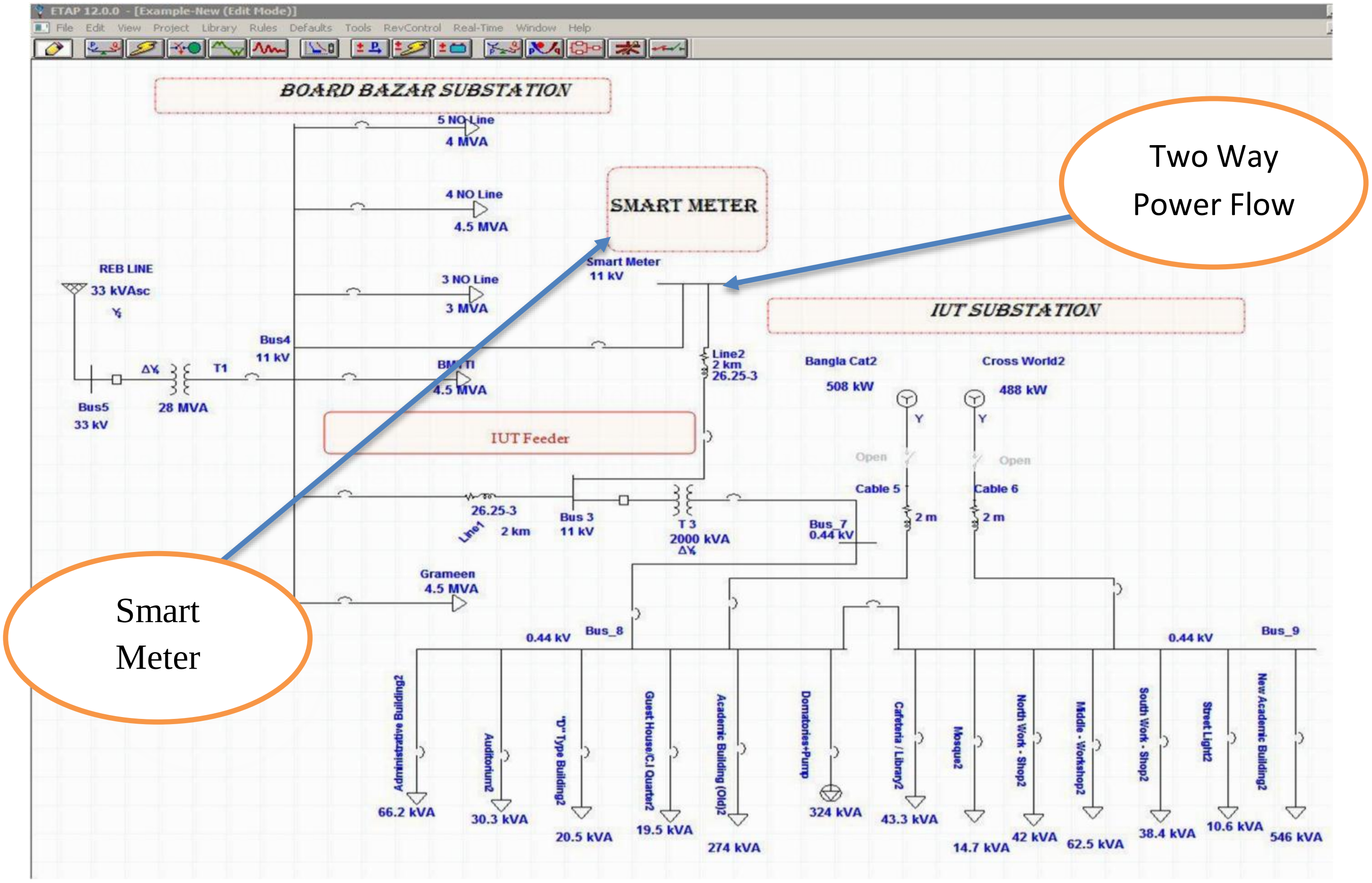


Figure 8.3: One Line Diagram of Interconnected Grid System.

The two way power flow path via smart meter is shown in the above figure from IUT to Board Bazar substation which ensures the power feeding back system in peak demand when IUT substation will have adequate power generation.

The load flow simulation for this one line diagrams given below:

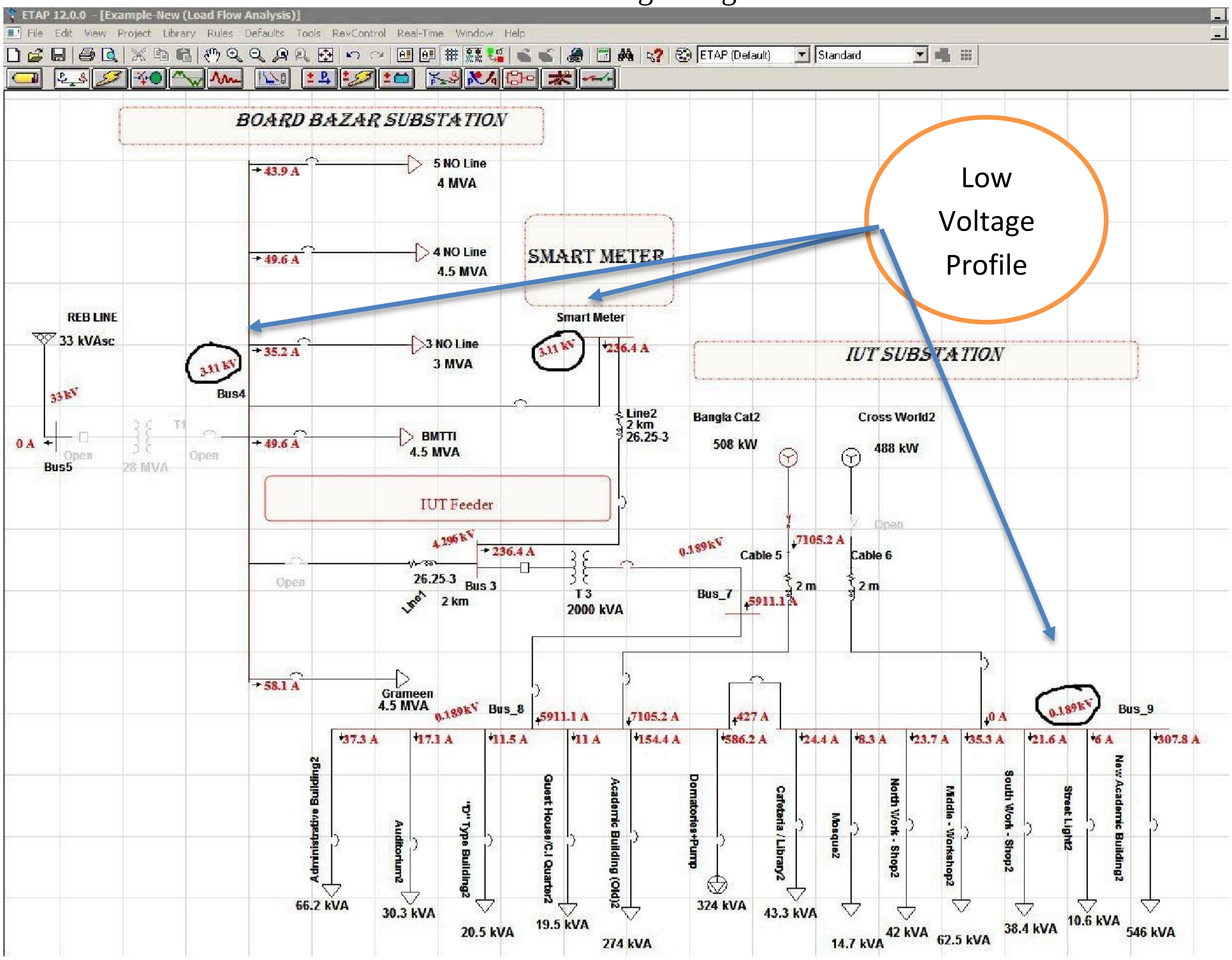


Figure 8.4: Load flow of One Line Diagram of Interconnected Grid System.

The above load flow is done when the IUT substation is getting power from its generator and the REB line is off.

As the load shedding is going on the other feeders of Board Bazar substation will not get power but here because of two way power flow system they are also getting power from IUT substation.

Here the smart meter is keeping the record of how much power is going back from IUT substation. Thus one criterion is fulfilled for adopting smart grid technology.

It is not really practical to feed all the feeders with only one generator of IUT substation and that's why the low voltage profile is shown here.

This low voltage profile reminds us that we have lack of renewable sources integration in our model and there is no storage system which is also another reason of this problem as well as another prerequisite for smart grid.

So we need to modify our system with adding renewable source for electricity production and with storage facility to meet the peak demand.

In the above figure all the basic criteria of smart grid is ensured by adding two way power flow, renewable sources(Wind turbine, PV array) and storage system(adequate battery panel).

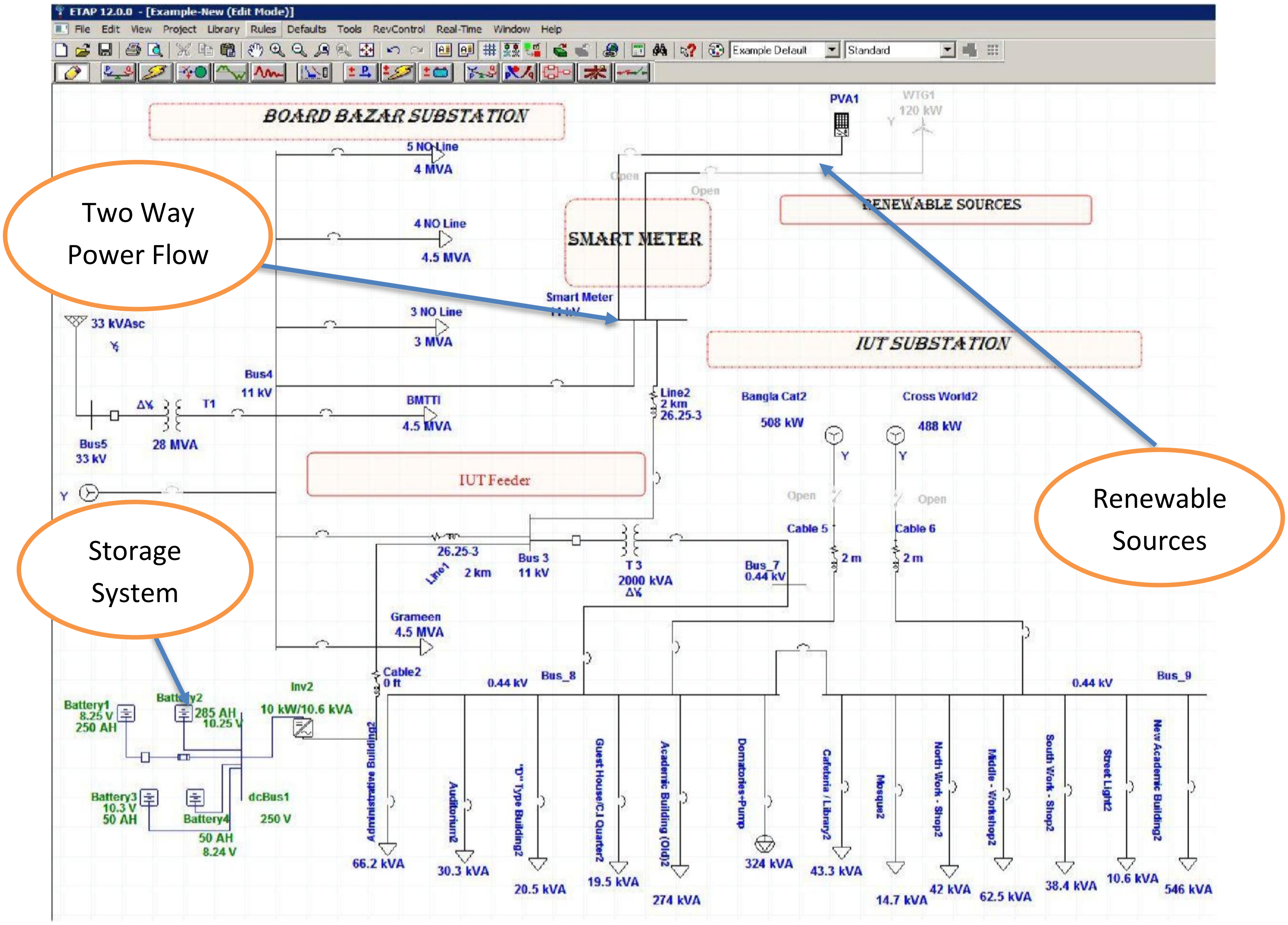


Figure 8.5: One Line Diagram of Our Proposed Interconnected Grid System.

In the above figure all the basic criteria of smart grid is ensured by adding two way power flow, renewable sources(Wind turbine, PV array) and storage system(adequate battery panel).

Now, the load flow analysis & reliability analysis of the above model can give us better solution by mitigating the above problems.

8.4 Reliability Analysis of Our Proposed Model:

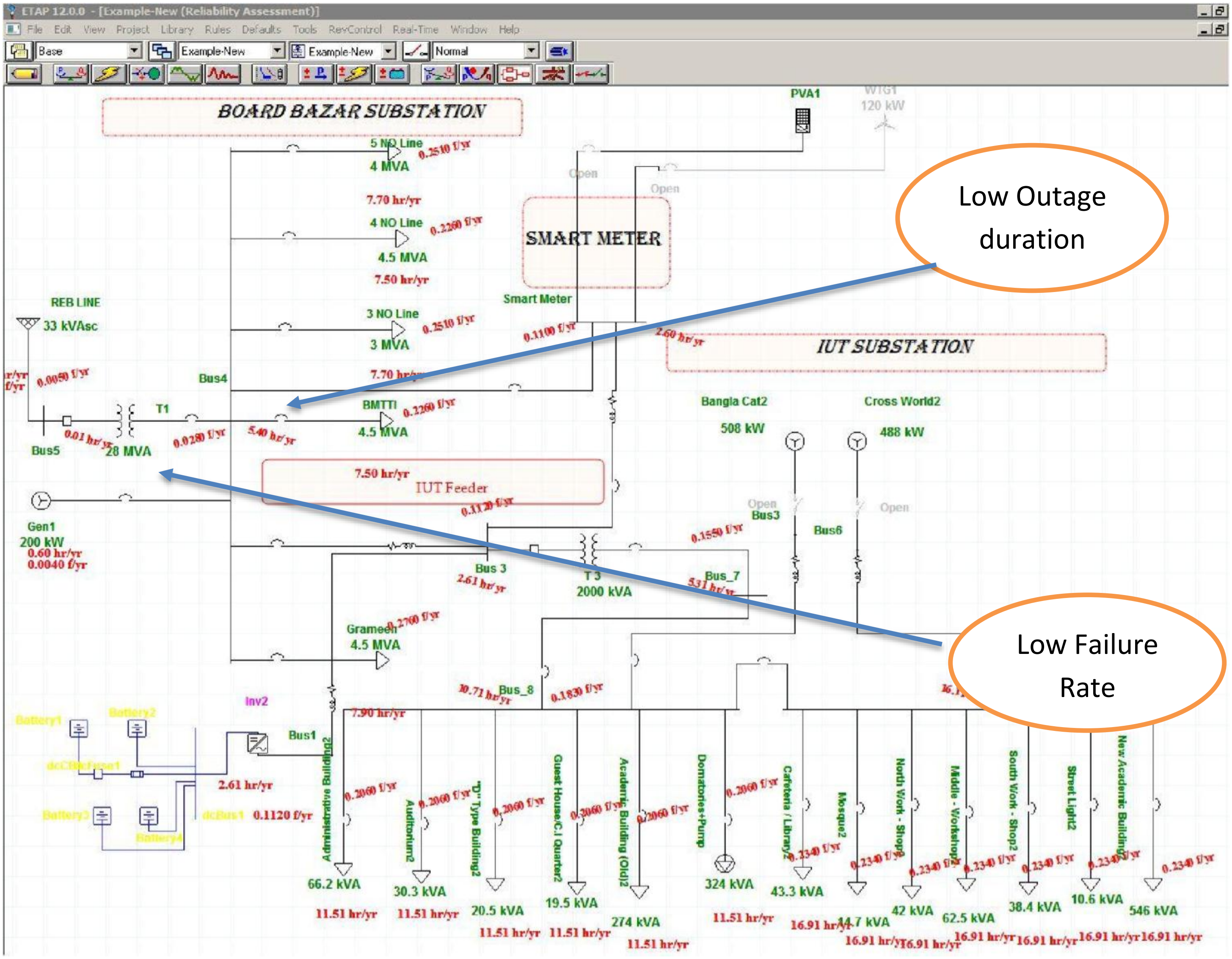


Figure 8.6 : Reliability Analysis of Our Proposed Interconnected Grid System.

Reliability analysis of our proposed model shows better results compared to the present grid reliability analysis.

8.5 Comparison of Data Analysis:

The comparison of data analysis between our proposed model and the present grid system is given below:

Types of Faults	Current Grid System	Proposed "Smart Grid" System
Average Failure Rate	**0.0630**	**0.028**
So, Average Failure Rate is improved by 55%		
Average load Shedding	**78.86**	**5.40**
So, Average Load Shedding Rate is decreased by 93 %		

Table 8.1: Comparison of Data Analysis.

The above data is taken from the 11 KV feeder of Board Bazar substation from the proposed model.

Due to the integration of renewable sources, capacity of storage facility and two way of power flow system in the grid, the average outage rate and failure rate is improved dramatically which is the prime concern of smart grid technology.

So the modified model consisting all basic criteria of smart grid technology shows better result with less failure rate and decreased load shedding rate.

8.6 Overall Pictorial View of Our Proposed Model:

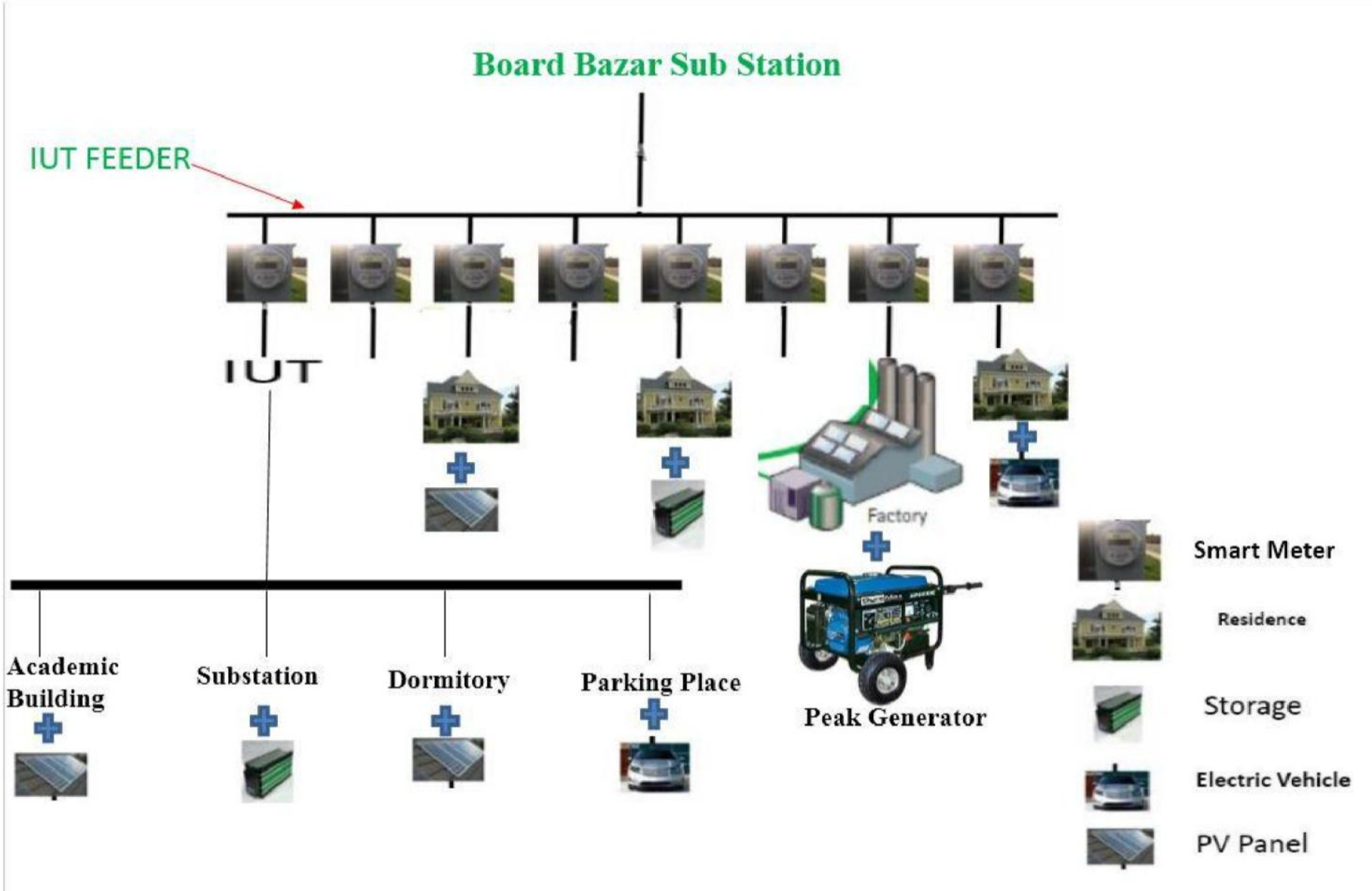


Figure 8.7: Overall Pictorial View of Our Proposed Model Grid System.

The overall pictorial view of our proposed model states the following facts:

For areas outside IUT under IUT feeder

Every 11 KV feeders connected to the Board Bazar substation is receiving power and during peak demand they can also feedback the power via smart meter where the meter will keep the record of that power.

Every feeders should have enough renewable integration within their interconnected system so that they can meet their peak demand.

For the large factory situated within the IUT feeder with their own peak generator can also feedback the power via smart meter to the substation.

Residential area under IUT feeder with their solar PV and electric vehicle can also contribute to the power sharing. Enough storage facility for proper application should also be considered for peak demand.

For inside IUT:

- Every building inside IUT should have the solar PV module integration with the substation to increase the electricity production.
- Storage facility with battery panel integrated with the substation can be built for charging during vacation time when the load of dormitory and academic building is reduced and thus the power can be used again.
- As new academic building is taking more power compared to the other building, the load minimizing scheme should be taken for this building to maintain the optimal power flow.
- More digital equipment should be introduced in IUT substation to make it a smart substation as stated
- The communication system between different buildings about load status should be introduced with a center control system through wired or wireless technology.
- Sufficient system should be built to charge up the electric vehicle in parking place and to take power from them during peak time via smart meter and many more initiative can be taken to transform the present electric system for IUT substation into a smart grid system.

CHAPTER 9

Conclusion

Electrical power system is a vital sector for every country. To maintain its quality, every country must give emphasis on this field & most of the country already giving. To ensure the ultimate quality every sector within the system should maintain a minimum quality. The cumulative effort from every sector can only make the system well qualified. Some of the countries are fighting with the shortage of generation; they can't give proper attention to other sectors: like transmission, distribution etc. To ensure maximum use of the generated power it is must to ensure minimum loss in the transmission & distribution. Transmission & distribution sectors are affected by several problems .The identification of these problems should problems should have the priority. In Bangladesh most of the electrical power distribution industries are facing some common problems. Their systems are not studied in a recommended time interval or even not at all. So they fail to supply quality power. The use of software for fault current calculation is a necessary productivity tool. The fault current for all possible configuration of the network can be instantaneously calculated by the software. Any attempt to manually calculate by hand will be time consuming and may be prone to error.

The objective of our project was to use the capabilities of study and troubleshoot the problem using the ETAP software for analysis.

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