“Power system configuration of a typical smart town planning- A case Study in Dholera”

Major Project Report

Submitted in Partial Fulfillment of the Requirements

for the Degree of

MASTER OF TECHNOLOGY

IN

ELECTRICAL ENGINEERING

(Electrical Power Systems)

By

Pawan Kumar Singh

(13MEEE17)

Department of Electrical Engineering

INSTITUTE OF TECHNOLOGY

NIRMA UNIVERSITY

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Undertaking For Originality of the Work

I, **Pawan Kumar Singh** Roll. No. **13MEEE17**, give undertaking that the Major Project entitled **Power system configuration of a typical smart town planning- A case study in Dholera** submitted by me, towards the partial fulfillment of the requirements for the degree of Master of Technology in Electrical Power Systems of Nirma University, Ahmedabad, is the original work carried out by me and I give assurance that no attempt of plagiarism has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere, it will result in severe disciplinary action.

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

Signature of Student

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Industrial Guide

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Managing Director
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CERTIFICATE

This is to certify that the Major Project Report entitled **Power system configuration of a typical smart town planning- A case study in Dholera** submitted by **Mr. Pawan Kumar Singh** (**13MEEE17**) towards the partial fulfillment of the requirements for the award of degree in Master of Technology (Electrical Engineering) in the field of Electrical Power Systems of Nirma University is the record of work carried out by him under our supervision and guidance. The work submitted has in our opinion reached a level required for being accepted for examination. The results embodied in this major project work to the best of our knowledge have not been submitted to any other University or Institution for award of any degree or diploma.

Date:

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With enormous contentment I would like to present this report on the dissertation work related to **Power system configuration of a typical smart town planning- A case study in Dholera** Learning concepts in classroom and doing practicals in lab are different experiences. Project work constitutes the both using the knowledge gained in classrooms and real time practicals. It creates a real picture of the subject. I feel obliged to everyone who has helped me to complete my project work and provided me with their priceless suggestions. I would like to thank my project guide **Er. S.M. Takalkar, Managing director, TPEC** for his support, valuable inputs and priceless time from his busy schedule. I would also like to show my gratitude towards my internal guide **Prof. Gaurang Buch** who always encourages me throughout my completion of my dissertation work. I would like to thank all the technical staff member of TPEC Pvt. Ltd. Specially, **Er. Keval Velani, Er. Gaurang Patel, Er. P.M. shah sir, Er Alpesh Mohite, Er. Sumit Lingerchani, Er. Parth Desai, Er. Swati Pimplekar** for their time to time support during my entire study.

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Pawa

mar Singh

Abstract

To realize the draft development plan of Dholera special investment region (DSIR), Gujarat government and Gujarat infrastructure development board (GIDB) have decided to adopt the concept and technique of prevailing model of town planning scheme in the Gujarat state. The widespread model of town planning scheme is a coherent chain to put into practice the development plan. The entire area of about 920 sq.km. of DSIR out of which 277 sq.km. which is to be developed will be divided into various sectors. Each sector will be treated as independent unit for the implementation of town planning scheme. In this project title, we have to analyse the power distribution of town planning-2 west (TP2W) which is to be fed from a reliable source. Area of TP2W is 44sq.km. approx. In this distribution we have to predict the number of substations, length of transmission lines, sub transmission lines, distribution feeders, ring main units (RMUs). Since the city is called smart, the entire power network will be underground (through cables) save, incoming transmission line of 400 kV and its interface with 400 kV underground cables near the boundary of SIR. Smart grid technology will be used for control and operations as well as for data acquisition. Assumption and calculation of various types of loads are required i.e. industrial, commercial and domestic loads. In actual practice the load we consider contains fraction of two or more types of loads. For e.g. if 'x' is a total load then it is possible that '0.4 x' is industrial, '0.3 x' is commercial and '0.3 x' is domestic. Similarly one has to calculate the load equation of each sector individually and convert it in to zones and make a final total. Finally the whole electrical system has been analysed with ETAP software. The results if conform to the assumption of the planned electrical power system, the same shall be considered for thesis presentation. This has been done till the desired output gained.

Abbreviation

DSIR	Dholera Special Investment Region
GIDB	Gujarat Infrastructure Development Board
TP2E	Town Planning-2 East
TP2W	Town Planning-2 West
RMU	Ring Main Units
ETAP	Electrical Transient Analyzer Program
DMICDC	Delhi Mumbai Industrial Corridor Development Corporation
SPV	Special Purpose Vehicle
IEEMA	Indian Electrical Electronics Manufacturers Association
SPE:	Society of Power Engineers
CEA	Central Electricity Authority
SAIDI	System Average Interruption frequency Index
CAIDI	Consumer Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
ASAI	Average Service Availability Index
MAIFI	Momentary Average Interruption Frequency Index

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Chapter 1

Introduction

1.1 Brief Overview

- Delhi Mumbai industrial corridor development corporation (DMICDC) is a special purpose vehicle (SPV) of government of India (GOI). DMICDC area passes across the states of Haryana, Rajasthan, Gujarat and Maharashtra. Delhi Mumbai industrial corridor (DMIC) is a mammoth infrastructure scheme covering a band of 150 km on both sides of Delhi-Mumbai Rail Freight corridor, which has an overall length of 1483 km amid Delhi and Mumbai. DMICDC is to form a potential hub of financial activities in the western region. This will also endorse local trade and handicrafts. It will also catch the attention of lot of foreign investment in industry and Real estate. This is bound to accomplish sustainable progress in the state as well as in the nation.

- Dholera, one of the special investment regions (DSIR) is a part of DMIC venture in the state of Gujarat. DSIR will have high class communications, transport, buildings and road and rail set-up and amenities comparable to any elegant city on the globe. It will have a most excellent class of life with state of art facilities like water, electricity, gas, transportation, recreation, holiday resort, business centres etc.

- Electrical energy is modern society's most suitable and helpful form of energy. Without it, the present social infra-structure would not at all be practicable. It is unique versatile energy.

- The increasing per capita consumption of electricity throughout the world reflects a growing standard of living of the people.

- Dholera is situated in Ahmedabad District on the Gulf of Khambhat, about 100 km away from Ahmedabad. Dholera Special Investment Region covers about 920 Sq. km area comprising 22 villages of Ahmedabad district. For implementation of this project, DSIR development authority was formed.

- Plan for development of DSIR was published on 5th January 2011 for 30 years starting from year 2010. Complete project plan has been divided into three phases of 10 years. Under the Dholera SIR, 6 Town planning areas are TP1, TP2, TP3, TP4, TP5 and TP6. Out of these 6 areas, it is planned to develop the TP2 area in the first phase of development. TP2 will have total area of 101 Sq. Km. Further, TP2 is sub divided into Town Planning 2 East (TP2E) and Town Planning 2 West (TP2W). TP2E will be developed in two phases. The First 22 km2 of area is to be developed immediately and balance 35 km2. of area is planned to be developed subsequently. The existing Ahmedabad-Bhavnagar State Highway road which is passing through DSIR north – south is a reference for the division of TP2 in TP2E & TP2W. Most sources agree that smart grids must be implemented in places where they add value to the electric system via productivity gains and improvements in energy efficiency. One of the main gains must be in the area of operational efficiency, which includes improvements in the control of life possessions, facilitating the identification of faults or defects, avoiding unnecessary offsets and the lower loading of the system, among others. In the area of energy efficiency, the reduction of technical and non-technical losses will permit a more effective distribution of energy because the generation is up to the final consumer.

- The practices involved in the operation of smart grid architecture and the results that will be achieved are tactical and of concern to various organizations, including but not limited to electrical power utilities, regulators, consumers, public authorities, suppliers, research institutions, funders and development agents.

- As Dholera city is going to be only one of its kind in this country for the first time therefore to plan a world class city which has all the amenities such as access of wi-fi, road connectivity, rail connectivity, natural gas connection, linked with major cities, theft proof, reliable and uninterrupted Power Supply which is necessary for all the facilities and industries going to be setup in the city. To make Gujarat a ideal place to live in and to do business in accelerated, unprejudiced, comprehensive and sustainable growth driven by vigorous, societal, industrialized and physical infrastructure. All these are done without compromising the free offerings of nature.

1.2 Objective

- The objective of this project is to calculate and analyse the whole load requirement and power usage for a typical smart city and then draw power system network for the same keeping standard regulations described in GERC and CEA transmission planning to be developed in Dholera special investment region bearing in mind the load requirements of present as well as future. It is necessary to keep eyes on regular technology innovation happening in the world. In my project work I have tried to find out answers to these questions

1. Type of loads present or will be present?
2. How supply will be given by sub transmission to these loads?
3. Capacities of the feeders and transformers?
4. How much power is to be obtained?
5. How much space is required and how much of it is available for a particular installation?
6. How reliable should the system be?

- I have performed load flow studies and reliability studies of the power system setup prepared on the basis of calculation.

1.3 Methodology

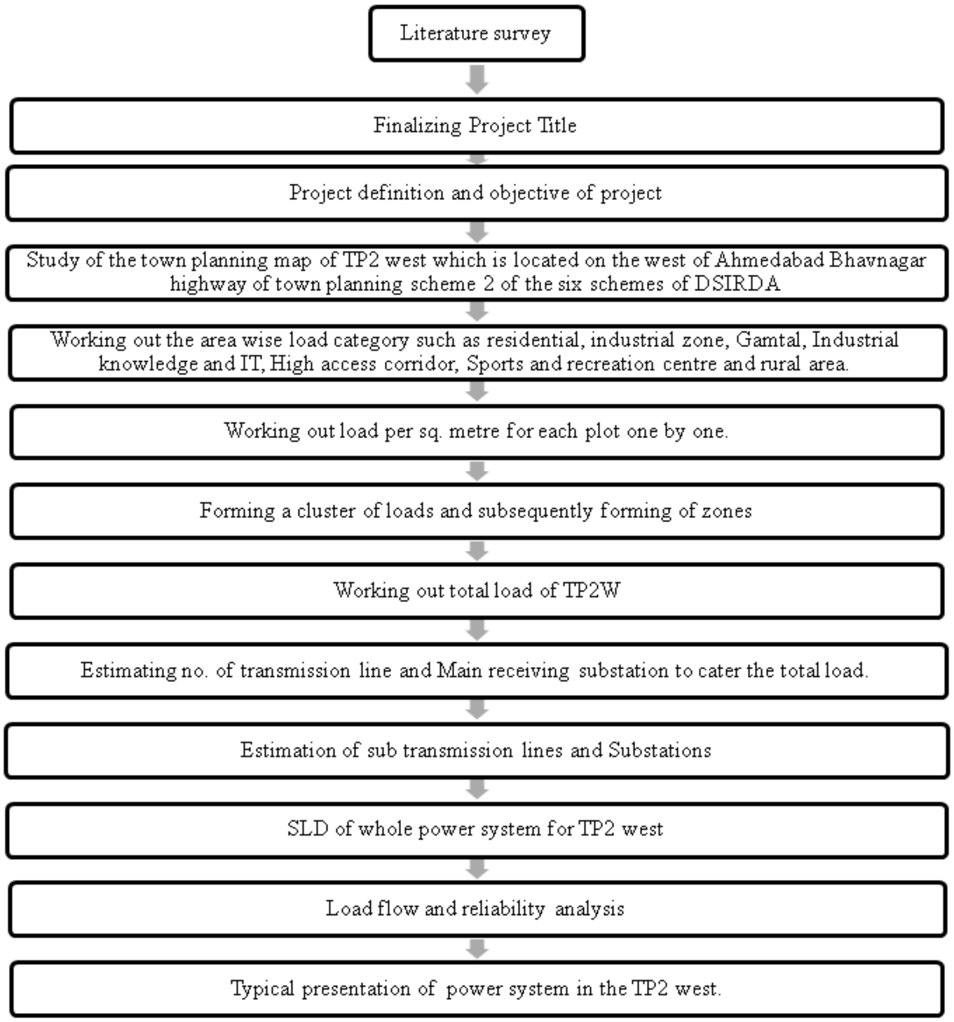

Figure 1.1: Methodology Flow Chart

1.4 Scope of Work

- Building a power system network with greater reliability and reducing technical issues.
- Keeping the Population growth in mind the Power System network should be built in such a way so that it runs smoothly for several years to come.
- The main objective of electricity power supply system in any nation is to maintain a continuous and sufficient power supply to its customers at a reasonable rate of return. In India, this objective is far from being met. However Gujarat is a surplus state but still many of the states are suffering from power crisis.

1.5 Literature Survey

- For the better understanding of project literature survey plays a very important role. Literature Survey consists of papers referred and Monthly and Quarterly Newsletter which gives fundamental knowledge of Power System Distribution.

- **Paper [1]** International Colloquium on Ultra High Voltage in association with Central Board of Irrigation and Power and Indian Electrical & Electronics manufacturers Association (IEEMA) organised by Power Grid Corporation of India Limited: This publication describes Designing issues related with Transmission lines, Transformers and substation. This book creates a clear and concise approach in a practical way about power system.

- **Paper [2]** DSIRDA Report on final development plan sanctioned by Apex authority (GIDB): It discusses about the commencement of this mega Project which started in 2010. Environmental Clearances and other issues about this project. Also it tells about the classification of the whole Town Planning Scheme and its preferential order. It discusses about the whole history behind this and its importance.

- **Paper [3]** Society of Power Engineers (SPE) News Letter: A Quarterly magazine which generally presents the updated techniques used in installation of transmission lines and substations etc. It also discusses basic concepts which are very important to know during practical experiments.

- **Paper [4]**1-s2.0-S037879614002132-main development and implementation of Portuguese smart distribution system: It deals with the Smart distribution network which was installed in Holland. It saves electricity as well as provides maintenance free and good quality power. Paper [5] Criteria for smart grid deployment in Brazil by applying the Delphi technique: It discusses about the saving of the power at peak load. It may be unfair saving or everlasting saving depending on the situations existing. It was a product of the Rand firm think tank and utilizes a cluster approach to provide widespread forecasts. It works on the principle of "many minds are better than one" but avoids the pitfalls into which communities can fall usually. It is most useful technique in those areas which are too new to have accumulated enough historical data to permit the use of other mathematical models.

- **Paper [5]** Scenario Technique: It is a basically a method for viewing the future in a quantitative fashion. Events may be simultaneously occurred or sequentially. All possible outcomes are investigated. It is key in uncertainty. These are important in the present fast changing world and globalisation. It is form of modelling the future. Main inputs are key parameters, foresight, insight, and ideas. Good scenarios are: Plausible, internally consistent, both relevant and challenging, scenario implementation requires action plan with appropriate decisions.

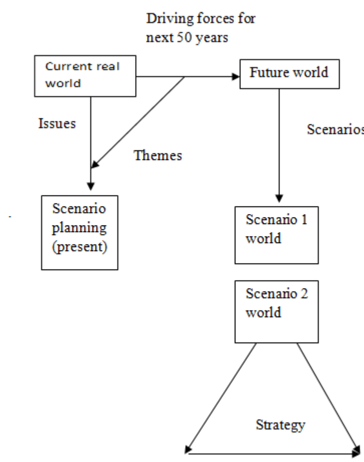

Figure 1.2: General View of Scenario Planning

Figure 1.3: TP2 West Plotwise Distribution

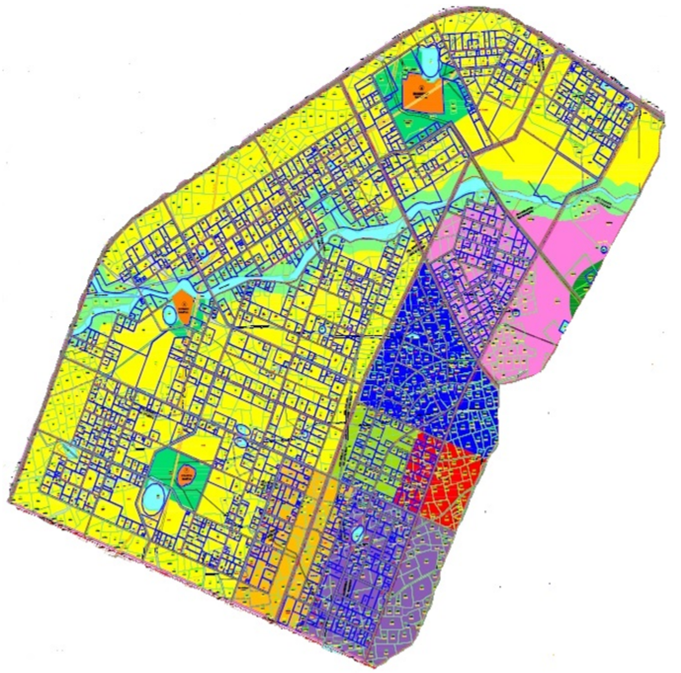

Figure 1.4: TP2 West Plotwise Distribution

Table 1.1: Out comes after studying the Dholera Map

CATEGORY	RESIDENTIAL POPULATION	OCCUPANT POPULATION	AREA IN SQM	AREA IN HECT	PERCENTAGE OF TOTAL BUA
Residential	295772	281804	7451531	2121	57.32
CBD City Centre	32252	73814	1041643	104.6	8.01
Gamtal	12401	10228.97	387922	38.7922	2.98
High Access Corridor	26513	43855	787668	78.7688	6.05
Industrial Knowledge & It	16795	55485	902730	902730	6.94
Industrial Zone	0	19204	1128799	112.78	8.68
Public Facility Zone	0	12989	52000	5.2	0.4
Recreation,Sports & Entertainment	0	494480	402804	40.28	3.09
Tourism Resorts	0	398	4253	0.4253	0.03
Village Buffer	15730	12963	493128	49.3128	3.79

Chapter 2

Load forecasting

- Load requirement of an area depends upon its topography, its residents and their living standards, its present and future development plans, cost of power, etc. In India, Annually, power survey committees under the support of the central electricity authority (CEA) are given the task of preparing the national eventual demand for power.
- Based on the category wise forecast, the 17th Electric survey of India has approximated the sample of electrical energy in the country [3].

Table 2.1: Connected Loads in Respective Area

Categoryl	2003-2004 (Actual)	2011-2012 (Estimated)
Domestic	24.81	29.20
Commercia	8.16	8.70
Agriculture	24	20.25
Industry	35.11	34.45
Others	7.88	7.40
Total	100	100

2.1 Load Characteristics

- Earlier the era was lighting load, motive load era, 3rd is digital load such as internet, communication etc.

(a) **Nature of loads:** It is necessary to know general nature of load which is characterized by the load factor, demand factor, power factor, utilization factor and diversity factor.

(b) As per the development Plan (DP) report and town planning of TP2W,

The total plots in TP2W are divided in following categories/ usage.

1. **Residential**: It consists of mainly fans, lights, domestic appliances such as refrigerators, air conditioners, mixers, heaters, ovens, heating ranges and small motors for pumping, various other household items. Various factors are: demand factor 70-100 %, diversity factor 3 and load factor 10-25 %.

2. **High access corridor:** This consists mainly of lighting for complexes, shops, malls, market places and advertisements, fans, air conditioning, heating etc. The demand factor is usually 90-100 %, diversity factor is 2 and load factor is 25-30 %.

3. **Industrial:** These type of loads may be of the following typical power range:[8]

Table 2.2: Usage of various industries

Cottage industries	$<$ 5 kW
Small-scale industries	5-25 kW
Medium-scale industries	25-100 kW
Large- scale industries	100-500 kW
Heavy industries	Above 500 kW

Large-scale industries and heavy industries need power over a longer duration throughout the whole day. The demand factor for the same would be taken as 70-80 % and the load factor 60-65 % and for heavy industries may be taken as 85-90 % with a load factor of 70-80 %. iv. Recreation, Sports and entertainment: Stadiums and theatres etc.

v. Strategic Infrastructure: Bulk supplies, special industries such as bulk papers,

vi. Roads: This type of load mainly consists of street lighting and remains nearly constant during the night. For this the demand factor is 100% while the diversity factor can be taken as 1. It is required at night mostly although in day time it is used for traffic signals mostly. The load factor for this type of load varies between 25-30 %. Also water supply and drainage system comes under it. vii. Public facility zone: Parks, lawns and community halls come under it.

viii. Tourism and resorts: It is found mostly near sea shore, river banks, waterfalls and historical monuments.

ix. Village buffer: In this type of load power is required to supply water for irrigation by means of suitable pumps driven by electric motors. Demand factor lies between 90-100 %, diversity factor as 1-1.5 and load factor lies between 20-15 %.

x. Gamtal (original inhabited village) xi. River/Water body

xii. Coastal region zone (CRZ): sea harbours and ports mostly comes under it. This is an attempt to calculate the Residential loading in an area which comprises apartments (1bhk, 2bhk, 3bhk, 4bhk, individual villas).

(c) System Power factor: All electrical equipment, except resistance, synchronous motors and incandescent lamps consumes power at lagging power factors. Some devices are given under with their average power factor.[8]

Table 2.3: Power Factor of Various Electrical Items

Flourescent lamps	0.6-0.8
Neons signs	0.4-0.5
Arc lamp	0.3-0.7
Fans	0.5-0.8
Induction heater	~ 0.85
Resistance heaters	0.6-0.9
Arc furnace	0.75-0.85
Induction furnaces	0.3-0.5

(d) System Load diversity: It is important to analyze statistically the summer and winter load ununiformity in an area.

(e) Feeder load characteristics: It is important for a feeder at each bus in terms of electrical load characteristics and load composition. The separation of category demand on the feeder can be done by measure such as: Knowledge of the connected load of each category of consumer. The product of connected load and appropriate demand factor of each load will give demand for each category.

(f) Connected load: Installed load is the sum of the rated inputs of electrical device installed at the end user site. It is that part of the customer's installed load as compared by the power supply utility.

Table 2.4: Connected load in India as on 31.3.2010 [5]

Category	Average connected load/consumer (kW)
Domestic	0.94
Commercial	1.64
Industrial	9.67(LV and MV) 364.49 (HV)
Agriculture	4.04
Misc.	2.05
Traction	4.04

2.2 Calculation of Residential loads per square metre and presented in tabular way

2.2.1 Load estimation

- Circuit design is based on major load estimates of the installations. The circuit demand is calculated by multiplying the load estimate with suitable demand factor and divided by suitable diversity factor. The typical primary load estimates as per NEC are:

Table 2.5: Power Usage of Various House Hold Units

Domestic dwellings	Wattage
Ceiling fans/ table fan	60 W
6 A socket	100 W
Incandescent lamp	60 W
Fluorescent tube 600 mm	25 W
1200 mm	90 W
Socket outlet 16 A	1000 W

2.2.2 Typical schedule for points for dwelling units

- The two contact arms in this type of contacts are positioned parallel to each other. the blow-apart contact design helps to open the contacts faster than the straight-through arrangement. As shown in above two IT characteristic i.e. Fig 2.4 and 2.6 in straight through contact time taken for opening the contact mechanism is more and in blow apart contact system time taken for opening contacts is approx half as compare to straight through contact. Hence it is more preferable to use two parallel connected conductor or contact arm for fast acting circuit breaker.[3]

Table 2.7: Commericial Loads

Commercial complex	% total load	Diversity factor
Ventilation AC	45	1
Power plants	5	1.5
Lighting loads	30	1.05
Lifts	20	1.00
Hospitals lighting	20	1.1
Hospitals AC	15	1.0
Kitchen	10	1.6
Sterilizer	10	1.6
Laundry	10	1.6
Lifts	15	1.6
Electromechanical loads	20	1.6

Table 2.6: Calculation of individual type residential load

(i) Unit wise	Area of units m^2				
	33	45	55	85	140
Light points	7	8	10	12	17
Ceiling fans	2	2	3	4	5
6 A sockets	2	3	4	5	7
Call bells	_	_	1	1	1

Table 2: Calculation of individual type residential load

(ii) Room wise	Sockets 6 A	Power sockets 16 A
Bed room	2-3	1
Lobby/ Lounge room	2-3	2
Kitchen	1	2
Drawing room	2	1
Garage	1	1
Bathroom	1	1

Residential	1bhk	2bhk	3bhk	Villa	Average load (Watts/ m^2)
Net area (ft^2)	525-550	600-650	700-800	1500-1750	
Gross area (ft^2)	600	700	850	2000	
Gross area (m^2)	55.2	64.4	78.2	184	
Max load	2700	3700	5000	8000	
Average load	2572	3536	4796.78	13185	58.3
Min load	2300	3400	4600	11000	
Load (W/m^2)	46.60	54.91	61.34	71.66	

2.2.3 Multi Storey Building

- The loads which are generally required in commercial uses load category are provided with their percentage of total load and diversity factor. These are typical values which are

2.2.4 General loads by occupancy

Table 2.8: Loads with their Occupant Area

Type of Occupancy	W/m2
Auditoriums/ gurudwaras/ temples	10
Banks	35
Barber	30
shops	10
Churches	20
Court rooms	20
Dwelling units	10
Hospitals Restaurants	5
Warehouses	2.5
Storage Space	2.5

Table 2.9: Table Calculation of individual type of load

Residential Industry	58.3
CBD city centre/ HAC	133.4
Recreation sports & entertainment	64.8
Industry	32.3
Industrial knowledge & IT	164.2
Public facility zone	63.5
Local public open space	25.3
Recreation, sports and entertainment	36.5

2.3 Mixed type usage

- Each plot may be of any of the major 7 category would consists of various sub categories two or more and therefore with the weighted arithmetic mean the load demand would be calculated. The classifications of sub categories are provided below with their pie charts. For example: Residential Plot consists of 80 %, 3 % commercial offices, 4 % leisure and hospitality, 5 % public community facility, 2 % local public open space, 5 % local roads and 1 % utilities.

- Similarly for other type of load category mixed type of load would be calculated with the help of weighted arithmetic mean.

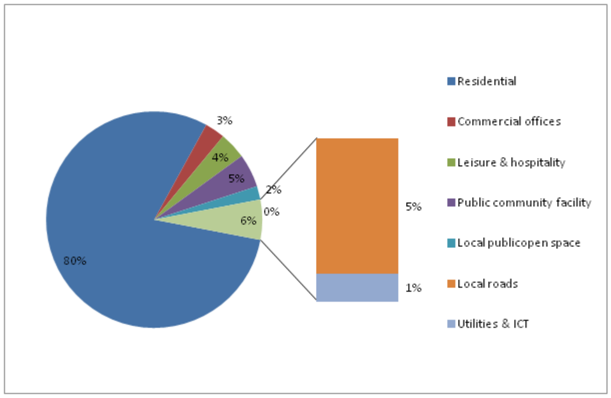

Figure 2.1: Percentage of sub category in residential type of load

Calculation of load for mixed plot Residential:

$$\frac{(80\% * Y * 58.3 + 3\% * Y * 133.4 + 4\% * Y * 64.8 + 5\% * Y * 25.3 + 2\% * Y * 1.1 + 5\% * Y * 1.1 + 1\% * Y}{Y}$$

"Y" is the total m2 under residential is 57.32 % of total build up area.

$$= 57.32$$

$$= 25.2208\, m^2$$

Adopting the WAM technique method the wattage per square meter for mixed type of plot usage is calculated:

$$= 54.58\, watts/m^2$$

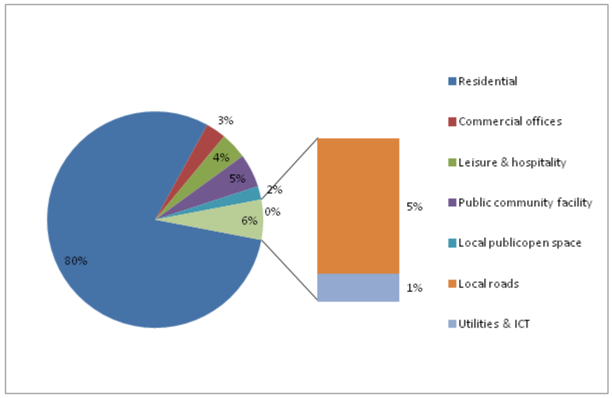

Figure 2.2: Percentage classification of High access corridor into their sub categories

Calculation of load for mixed plot high access corridor:

$$\frac{(2\% * Y * 58.3 + 60\% * Y * 133.4 + 10\% * Y * 64.8 + 8\% * Y * 25.3 + 7\% * Y * 1.1 + 8\% * Y * 1.1 + 5\% * Y}{Y}$$

“Y” is the total m2 under high access corridor is 6.05 % of total build up area.

$$= 6.05\%$$

$$= 2.662m^2$$

Adopting the WAM technique method the wattage per square meter for mixed type of plot usage is calculated:

$$= 89.93watts/m^2$$

Again, industries plots consist of Industrial, Public/community facility, local public open space, local roads and information communication technology devices usage.

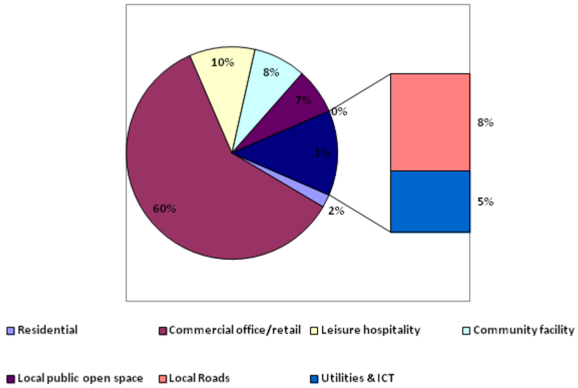

Figure 2.3: Various types of Industrial loads

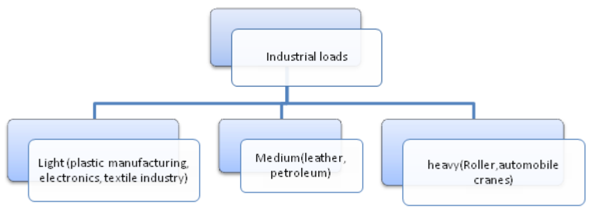

Figure 2.4: % Plot of Area

2.4 Demand Factor

- The ratio of the maximum demand to connected load (rated capacity) of an end user is called the demand factor. The maximum demand or peak load of an installation or system is generally articulated as the largest value of level of the 30-minute demand during a given period, such as a month or year.

Table 2.10: Variation of demand factor for each type of load for a particular span

Types of loads	Morning	Afternoon	evening	Night
	(6:00am - 9:00am)	(9:00am- 6:00pm)	(6:00pm- 11:00pm)	(11:00pm- 6:00pm)
A) Residential	0.75	0.9	0.95	0.6
B) HAC	0.78	0.95	0.98	0.9
C)Industrial	0.8	0.98	0.98	0.95
D) Recreation Sports & Entertainment	0.5	0.65	0.7	0.4
E) Strategic Infrastructure	0.7	0.85	0.85	0.7
F) Roads	0.09	0.01	0.3	0.3
G) Public Facility Zone	0.75	0.98	1	0.95
H) Tourism & Resorts	0.75	0.98	1	0.95
I) Village Buffer	0.09	0.2	0.5	0.5
J) Gamtal	0.25	0.45	0.57	0.8

Overall demand factor can be calculated as with the formula given below here :

Table 2.11: Load per square metre for mixed type of loads

Serial no.	Type of loads(Mixed type)	Demand Factor	Area under category(m^2)	Load (W/m^2)
1	Residential	0.8	7451531	54.58
2	High access corridor	0.85	787668	89.93
3	Industrial	0.95	1128799	136.68
4	Recreation sports and entertainment	0.7	402804	25.65
5	Strategic infrastructure	0.8	902730	54.25
6	Roads	0.2	0	1
7	Public facility zone	0.9	52000	3.25
8	Tourist & resorts	0.9	4253	26.32
9	Gamtal	0.7	387922	0.09
10	Village buffer	0.5	493128	30.14
11	Coastal region zone/ water body	0.6	0	0.08

$$D = \frac{(d_1 t_1 + d_1 t_2 - - - - - - - - - + d_n t_n)}{(t_1 + t_2 + t_3 - - - - - - - - - - - + t_n)}$$

Where $d1$ is demand factor for t_1, d_1 is demand factor for t_1, d_1 is demand factor for t_1 and so on till t_n.

Adopting the weighted arithmetic mean (WAM) method the wattage per square metre for mixed type of plot usage.

Total wattage could be calculated with the formula:

= (Load required in W/m2 * Demand factor for that type of load * Total area comes under that type of load + for all types)

= 519.29 MW

Other consumption such as metro and other facilities would becomes 35 MW approx.

The total load would become approx. 550 MW.

2.5 Land Use Factor

- It is portion the land which is actually requires electric power except it can be consider as spare portion of build up area. Total demand load is calculated with considering future growth of 10 %. On taking account of future growth of 10 % we come to conclusion that we have to made power system network to feed 550 MW. and 650 MVA considering 0.85 pf.

2.6 Formation of blocks

Load is calculated for each plot (area of that plot * load required for that plot) so that the whole TP2 W can be divided into groups so that the placement of substation can be done considering load density. There are 1300 plots in this whole TP2 region.

The entire region has been divided into 44 blocks and eventually combination of blocks will result into 16 clusters. For each cluster a 66 kV substation has been planned following the GERC criteria.

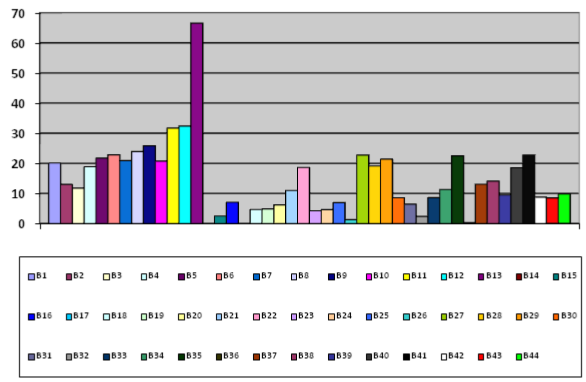

Figure 2.5: block wise load demand

2.7 Formation of Clusters

blocks are grouped so that for each cluster the load requirement will come nearer to each other as much as possible. There are 16 clusters divided in the plot.

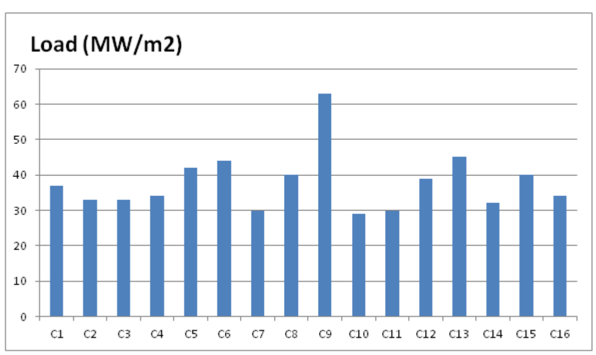

Figure 2.6: cluster wise Loads

2.8 Formation of zones

The electrical power zones have been created in TP2W area by grouping various clusters, so that each zone represents fairly good amount of power distribution. Thus total 3 number of zones have been made. The zones are formed by mixing clusters together so that all zones require nearly same power requirement.

The table showing zones are depicted below:

Table 2.12: Various Zones formed including name of clusters within

Name of zones	Clusters considered in zones	Load Requirement
Z1	1,2,3,4,15,16	177.74
Z2	5,6,7,8,9	185.261
Z3	10,11,12,13,14	148.416

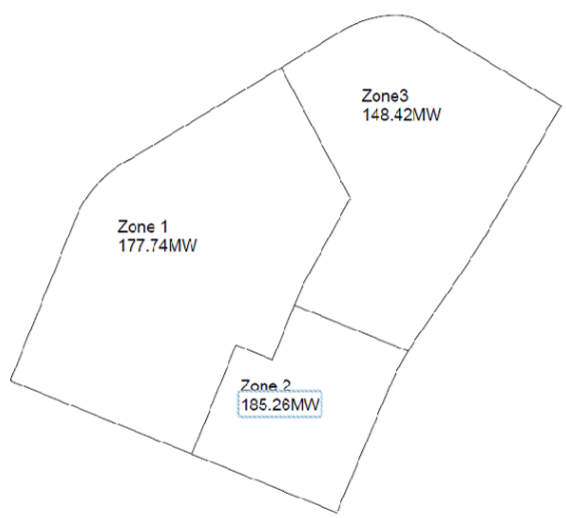

Figure 2.7: Clusterwise wise load layout

Requirement of land/ area for a substation:

The site should have sufficient area to properly accommodate the substation buildings, equipments, structures etc. and it should have the adequate area for future expansion of the buildings/ switchyard.

The requirement of land for erection of substation together with staff colony is listed below:

Following points to be considered in the selection of site for construction of a grid substation are given below:-

a) The load centre should be nearer as achievable.

b) The plot should be as rectangular or square in shape for ease of proper orientation of feeders and bus bars as far as possible

c) It should be far away from obstructions, to permit easy and safe approach/ termination of high voltage overhead transmission lines.

d) It should be free from master plans/layouts or future development activities to have free line corridors for the present and in future.

e) It should be easily reachable to the public road to facilitate transport of material.

f) The substation should be as far as possible near to town and away from public dumping grounds, tanneries and other loathsome areas.

g) The ground selected for substation site should be fairly levelled ground. It helps in lessening in levelling expenses.

h) The site should be above highest flood level (HFL) so that there is no water logging. i) The site should be away from areas where police and military rifle practices are held.

j) The site of the projected substation should not be in the locality of an aerodrome. The distance of a substation from an aerodrome be supposed to be maintained as per policy of the aerodrome authority.

Table 2.13: Voltage levels classification:

Sr.No.	Voltage class of substation	Required area
1	400 kV	20 hectare
2	220 kV	6.0 hectare
3	132 kV	3.5 hectare

Table 2.14: Voltage level Classification

S. No.	Voltage level	Connected load
1	415/230 Volts,	10 kW to 50 kW
2	3 phase four wire 11 KV	$<$ 3.4 MW
3	66 kV	3.4MW to 50 MW
4	220 kV	Above 50 MW

Keeping these things in mind the loads could be divided into feeders 11 kV would supply not more than 4 MVA load demand. Plots could be segregated to be supplied from a feeder if less than 4 or supplied from a individual feeder if

$$demandload >= 4MVA.$$

At every feeder there will be ring main units. In this system there will be 82 such ring main units.

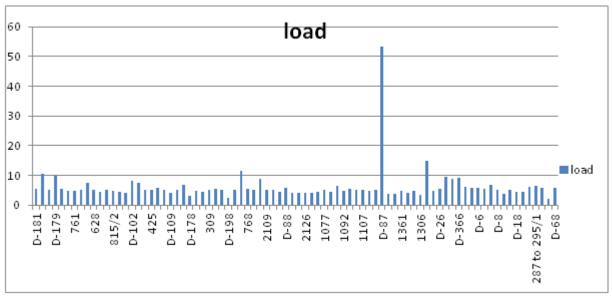

Figure 2.8: 66/11 kV S/S load

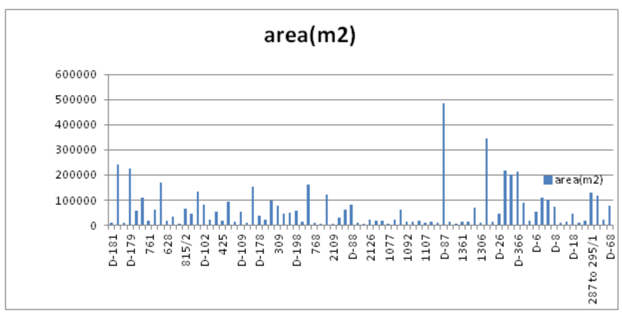

Figure 2.9: 15 Area of plot at 66/11 kV

Location -1, 400kV/220 kV/66kV Main receiving substation Main receiving substation (MRSS) 400/220/66 kV substation is located in the activation zone and in the government land in plot no D-87.The location also affords minimum length of 400 cables. The location also affords minimum length of 400 kV cables. The location is adjoining the proposed 250 metre road. This location has a combination of loads which needs establishment of 1 number of 66/11 kV substation for LV distribution (400/230 V) and others for Industrial loads (66 kV). The locations of other 220 kV substation as well as 66 kV substations are predicted based on load density.

In Zone 1 D-180 is for 220 kV substation and Zone 3 D-46.

System performance under normal condition (static security): The power system should be controlled so that it remain stable especially under normal condition As the system is meant for the n-1 contingency more than 50 % of the load must be fulfilled. Quality and reliability of the system shall affect the risk of the customer from the overloading transmission equipment problem.

The performance standard should be evaluated by including a (N-0) and single contingency system.

Steady state: The measurement index for the system such as voltage, amplitude and phase angle, power frequency variation should not vary with time i.e. dX/dt=0.

Normal contingency system or N-0: The system which operates without any tripping electrical equipment.

Single Contingency condition or N-1: It is the loss of any power system element that has only one of the transmission equipment tripped but it does not include the bus bar or radial line.

As the power transformer would be loaded 80 % for maximum efficiency and distribution transformer would be loaded 50 % for max. efficiency.

The power transformer operates with less than 150 % of the rated value in 30 minutes. It should be not operated beyond 200 % to protect the transformer from spoil. The overloading of the transformer will affect the insulation and lifetime of the transformer.

For Zone 1 i.e. 178 MW load demand and with 0.85 pf it would be 210 MVA. If we are using 100 MVA transformers then in Normal operation: (100*210)/300= 70 % of 100 MVA During (N-1) contingency (100*210)/200=105 % 0f 100 MVA transformers will be used It will fulfill 95 % of the load in (N-1) contingency. Similarly, for each zone and cluster number of transformers and ratings are decided. In this setup ratings for a substation are kept of same ratings as far as possible.

Table 2.15: Clusters

Cluster	Load	No. Of 20 MVA transformers	No. Of 25 MVA	No. Of 30 MVA transformers	No. Of 35 MVA transformers	No. Of 40 MVA transformers
C1	37		2			
C2	33		2			
C3	33		2			
C4	34		2			
C5	42			2		
C6	44			2		
C7	30	2				
C8	40			2		
C9	63					2
C10	29	2				
C11	30	2				
C12	39			2		
C13	45			2		
C14	32		2			
C15	40			2		
C16	34		2			

Chapter 3

Cables

3.1 Selection of cables

The factors to be considered for evaluating the power cables are listed below:

- Load
- System voltage
- Cable insulation
- Short circuit rating
- Safety
- Environmental condition
- Sheath and protective coverings
- Heat dissipation losses
- Economic consideration It means that the selection of a cable depends on many concerns i.e. cost of losses to environmental issues. Underground distribution costs are between 2 to 10 times that of the overhead system. Although it has various merits over the overhead lines such as elimination of outages caused by abnormal weather conditions such as snow, rain, storms, lightening, fires, trees, accidents etc. It is environment friendly almost.

- Improved cable technology has reduced the cost of the underground system compared to the overhead.
- The improvement in materials and manufacturing process allows higher voltage stress in the design of modern cable

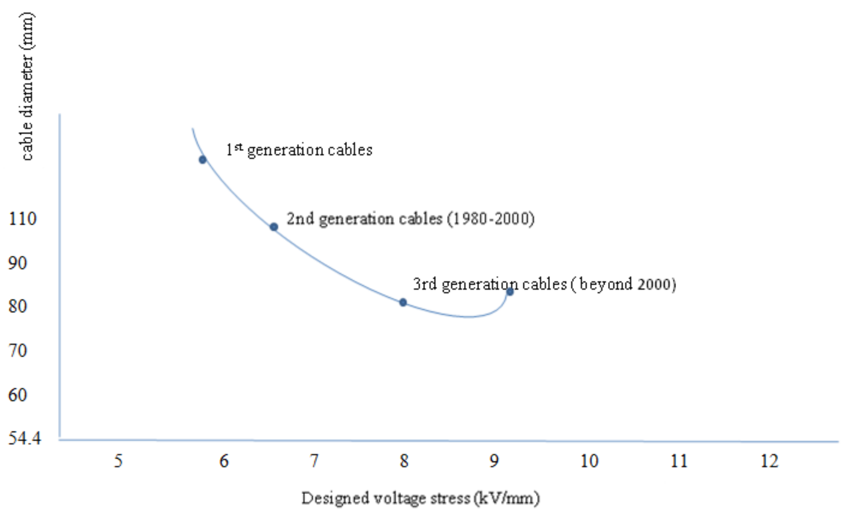

Figure 3.1: Graph of Design Voltage Stress

- Typical variation in the diameter of 66 kV XLPE cable with increase in insulation design voltage stress. [8]

3.2 Circuit configuration

- Circuit configuration for underground systems has a great influence on reliability. It describes the way in which circuit elements are connected and is particularly concerned with the location and type of switching equipment. The emphasis in underground system design is to provide necessary circuit redundancy and switching facilities to isolate the faulted system components and to restore service. There are three basic circuit configurations used in the primary system: radial, open-loop and dual.
- There are many variations in circuit design but generally they are of three types:
- Radial circuit configuration is the simplest to install and operate and expense is lowest in this case. But because of it has no redundancy and no sectionalizing, it has limited application in underground systems.

- The open loop configuration for a circuit supplied from an overhead line is the predominant configuration used in underground distribution, especially in urban centres. It provides facilities to isolate any faulted components, without affecting services to the unfaulted portion of the system.

3.2.1 Effect of Underground Table

- Maximum continuous current expected: while we are choosing cable all the factors should be taken care of in real installation condition.

1. System voltage: It depends on the type of the system whether it is earthed or unearthed. If the system is unearthed then it will require full insulation from the core to the ground and the cable will be costly compared to the earthed system.

2. Voltage drop: At full load, the voltage drop should be within permissible limits.

3. Conditions of installation: Methods of installation, estimated thermal resistivity of soil, type of covering, type of armouring, additional protection such as protection etc.

4. Expected short –circuit level of the system: On the basis of an expected short circuit current and time of clearance.

5. Void formation and ionization: void formation results from the daily contraction and expansion due to different materials used in the cable formation. These happen due to variable daily load (heating –cooling) cycle. The voids are centers for the discharges in the cables. In extruded cables, voids are formed along the impurities. These events are the reasons for the deterioration of the cable life.

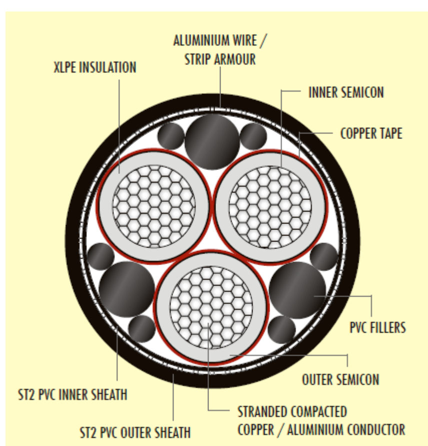

Figure 3.2: cable cross sectional view

Cable ampacity calculation:

For 400 kV I/C line bay load demand is 650 MVA

Therefore, [(load MVA*1000)/$\sqrt{3}$*sys kV]

$$\frac{(load\,MVA * 1000)}{\sqrt{3} * sys\,KV}$$

Hence, it will be =938.19 amp

Similarly for each cable laying ampacity has been calculated.

Also, cable size would be decided with the help of cable catalogues provided by cable manufacturers. Catalogue of Poly cab, Isxlpe, Tropothen-S EHV cables are used.

Various electrical parameters of power cable: The various parameters of cable are calculated with these formulae:

Inductance :

$$L = K + 0.2\log(\frac{2s}{d})$$

Where K= constant for different stranded conductor

S= axial spacing between cables and conduct

d= conductor diameter

here K is taken as 0.05 typically if no. of wires in conductor 1(solid)

Reactance :

$$X = 2 * \pi * L * 10^{-3}$$

Where f = frequency

L = inductance

Impedance :

$$Z = (R_2 + X_2) * 0.5$$

Where, R= A.C. resistance at operating temperature

X= Reactance

Charging current :

$$A = U_0 * 2\pi * f * C * 10^{-6}$$

C= cable capacitance

Voltage drop:

For 3 Core Cables

$$\sqrt{3} * Z \, mV/A/m$$

For 1 Core Cables

$$2 * Z \, mV/A/m$$

where Z= impedance

Capacitance :

$$C = \frac{E_r}{18 \log(\frac{D}{d})}$$

Cable Addition: in ETAP library has been added for 400 KV, 220 kV and 66 kV for the purpose of load flow. Cable sheets and catalogues have been taken from Manufacture's manual which has been added in appendix no. Also the lengths of cables have been calculated with the help of dwg file provided by DSIRDA in AutoCAD.

Chapter 4

Reliability Analysis

4.1 Reliability

Reliability is defined as the probability of a system to perform its function satisfactorily for the period of time and operation intended. The period may be the lifetime of device or any permissible period during maintenance.

4.2 Failure

When a device is put in operation there are many premature failures which decrease with time. For a mature device there will be few failures that are generally constant. It is termed as average failure rate.

Failure rate is defined as,

$$\lambda = \frac{Total number of failure}{Total no. of unit test or operating times}$$

The reciprocal ofλ i.e. $\frac{1}{\lambda}$is defined as the mean time m between failures, i.e. $m = \frac{1}{\lambda}$. The power distribution system comprises equipment which is identified with a specific consumer or group of consumers, and the effect of consumer habits on the equipment failure of system.

In case of large industrial plants, where a dual –feed arrangement is supplied, the reliability analysis becomes complicated but can be evaluated with computer programmes.

$$MTBF = \frac{1}{\lambda} = \frac{2T}{x(DF)(CONF)}$$

Where λ is the failure rate, T is the operating time, χ^2 (chi square) is a value obtained from statistical tables, DF is the degree of freedom (typically equal to the no. of failures + 1) and $CONF$ is the confidence level (typically about 90 %)

The reliability of a system is limited by the weakest element which fails first. Generally, the failure rate of a component depends on the four main factors:

- Quality
- Temperature
- Stress
- Environment It is desirable to obtain the values of MTBF and MTTR estimates for the system which is based on field experience.

These will facilitate the calculating the reliability of the system.

- **Maintainability** is a measure of the Mean time to repair rate and is given by formula

$$\frac{\Sigma(\lambda R_t)}{\Sigma\lambda}$$

Where R_t is repair time.

- **Availability** is a measure of the design availability for equipment comparison and tradeoffs and is given by:

$$\frac{MTBF}{(MTBF + MTTR)}$$

When designing a power system two questions come in the mind i.e.

a) What degree of reliability does the system has?

b) What do the varying degrees of reliability cost?

Objectives of performing reliability test:

a) Gathering & evaluation of considerable data to achieve compatibility b/w degree of reliability & economic cost.

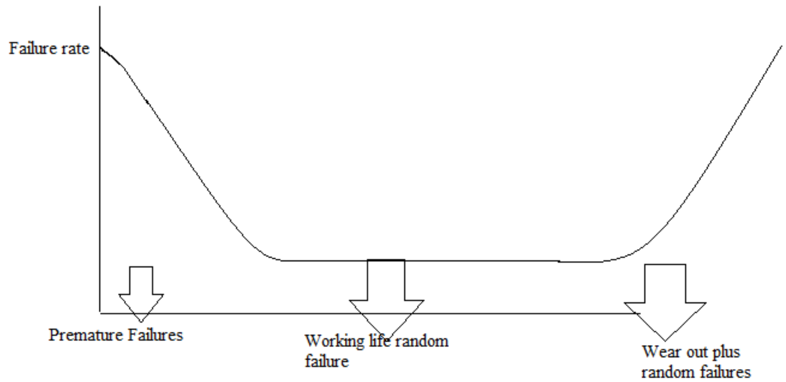

Figure 4.1: General nature curve showing constant failure

b) It involves gathering outage data & evaluating outage design. To increase the reliability it is important to know a. Causes of outages b. Types of equipment failures.

Typical causes of outages are:

a. Power utility of equipment failure

b. Consumer's equipment failure

c. Trees d. Lack of consumer care

e. Accident

f. Lightening

g. Wear and tear

h. Dig in for cables

Outage data:-

a. To determine the average failure rate of each component

b. Down time or repair /maintenance is based on data collected & averaged over many years.

If the failure rate is constant then it can be expressed by exponential or poison distribution.

Probability:- If there are n devices, then the probability that 'x' out of them have failed for mutually events is given by Bernoulli's equation i.e. Binomial distribution can be given by the following equation:[8]

The binomial distribution can have discrete distribution only and have points only where x is an integer. The standard deviation σ and μ of a binomial distribution are given by:

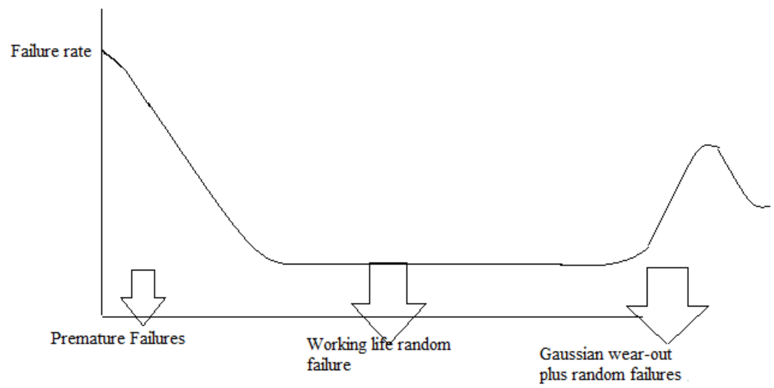

Figure 4.2: General nature curve showing Gaussian distribution of wear out and constant failure rate

$$\sigma = \sqrt{npq}\, and\, \mu = np$$

If p is very small and np is very greter than p, binomial distribution can be given by:

$$f(x) = \frac{(e^{-np})(np)^x)}{x!}$$

$$= \frac{(e^{-\mu}\mu^x)}{x!}$$

Above equation is Poisson distribution for which standard deviation

$$\sigma = \sqrt{(np)} = \sqrt{\mu}$$

$$\mu = \mu p$$

If a device fails with an average rate of λ then the mean number of devices failures in time, t is λ. Probability for x failures in time t is given by Poisson's distribution:

$$= \frac{(e^{-\lambda t}\lambda t^x)}{x!}$$

Probability for x =0 i.e. when no failure occurs, $f(0) = e^{-\lambda t}$

For x = n no. of failures with a frequency $\frac{\lambda}{t}$.

$$f(n) = e^{-\lambda}[1 + \lambda + \frac{\lambda^2}{2!} + \frac{\lambda^3}{3!} + - - - - - - - - + \frac{\lambda^n}{n!}$$

Reliability function can be achieved with this formula:

$$R(t) = e^{-\lambda t} = e^{-t}$$

The probability that the estimated probability is equal to the true probability is given by the term:-

$$f(np) = n!/[(np)!(n - np)!] * p^n pq^{(n-np)})$$

It is desirable to mention the MTBF & availability figures for the major electric transmission and distribution equipments.

The purchase should be based on the lowest life cycle cost.

(Lowest initial cost + present cost of future annual cost & outages of system.

Reliability Measurement:-IEEE standard 1366-2003 provides definition of most of the reliability indices.

Few reliability indices are given below:-[8]

SAIDI: - System average interruption frequency index. It is the average total duration of interruptions of power supply that a consumer experiences annually.

CAIDI: - Consumer average interruption duration index. It is the average duration of an interruption of power supply faced by consumer annually.

SAIFI: - System average interruption frequency index. It is the average number of the interruptions faced by a consumer.

ASAI: - Average service availability index. It is given by the formula by

$$= \frac{(Consumer hours service reliability)}{(Consumer service demand in hours)}$$

MAIFI: - Momentary average interruption frequency index. It is useful for tracking the momentary outages which cannot be defined by other indices such as CAIDI and SAIFI.

The momentary outages are caused by lightning strikes and any shrub comes in contact with power line. It should be in the duration of 3 seconds to 5 minutes as per IEEE 1366-2000. **Assessment of System Reliability:** - For assessing system reliability we follow following steps: -

Draw the model diagram of the power system, i.e. series, parallel or combination of both.

Here system redundancy is an important factor for the reliability assessment. For each configuration the total reliability would be given below.

Series System: -Here two components in series are having rate of failures as λ_1, λ_2 and r_1, r_2 are average outage duration for the elements component 1 and component 2 respectively.

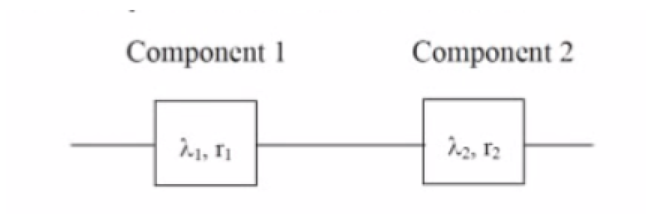

Figure 4.3: Power system elements in series

The overall failure rate for the system will be $\lambda_1 + \lambda_2$ For n components we have,

For n components we have

$$\lambda_{net} = \lambda_1 + \lambda_2 - +$$

Failure duration for two elements will be

$$\lambda_1 r_1 + \lambda_2 r_2)$$

otal failure duration for n elements will be

$$\frac{(\lambda_1 r_1 + \lambda_2 r_2 + - \lambda_n r_n)}{\lambda_s y_s}$$

If the reliability of elements are R1 and R2 Then overall reliability of the system will be R1* R2

Parallel system: - Similarly for the parallel system we may have failure rates,average outage duration, reliability and respectively.

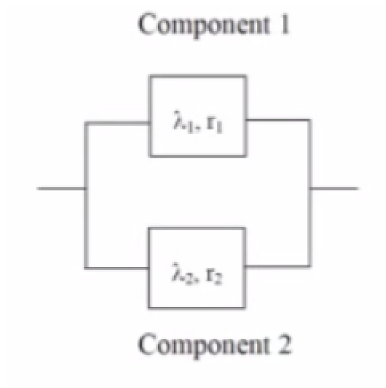

Figure 4.4: Electrical components in parallel

$$\frac{\frac{((\lambda_1\lambda_2(r_1+r_2))}{8760}}{(1+(\lambda_1 r_2+\lambda_2 r_2)}$$

Total average outage duration of two elements in parallel

$$r_{sys} = \frac{r_{1+r_2}}{(r_1+r_2)}$$

Average failure rate at load point (f/year)

$$\lambda = \Sigma\lambda_e, j$$

$$J = N_e$$

Annual outage duration at load point

$$Ui = \Sigma\lambda_e, jr_ij$$

Average outage duration at load

$$ri = \frac{U_i}{\lambda_i}$$

Expected energy not supplied index at load point (MWh/year)

$$EENSi = PiUi$$

Expected Interruption cost index at load point (k\$/year)

$$E_{costi} = \Sigma Pif(rij)\lambda_{(e,j)}$$

$f_{(rij)}$is the sector consumer damage function

Chapter 5

Simulation Results

Reliability analysis has been done on the power system model. Also for each type of load i.e. Residential, commercial, industrial, government buildings and agricultural loads average failure rate , outage duration, expected energy not supplied and expected interruption cost index at load point have been found with the simulation in ETAP.

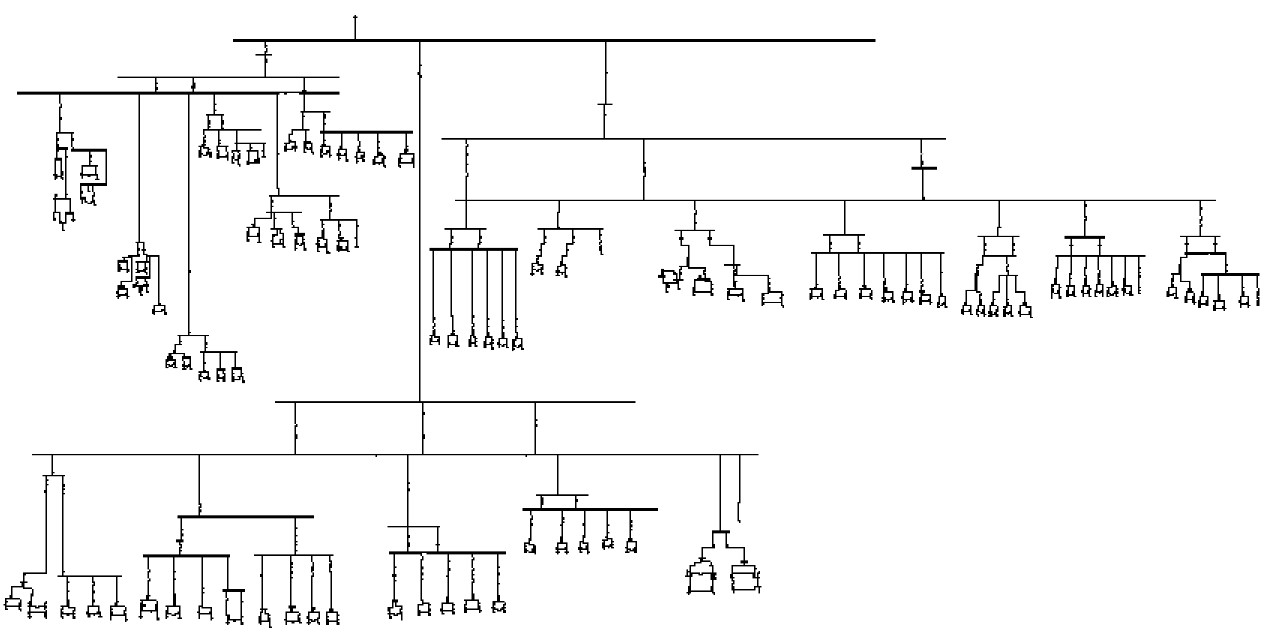

Figure 5.1: Complete power system network model for the system

The Cluster 1 has been circled and zoomed view has been shown in fig.

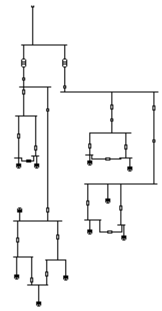

Figure 5.2: Cluster 1

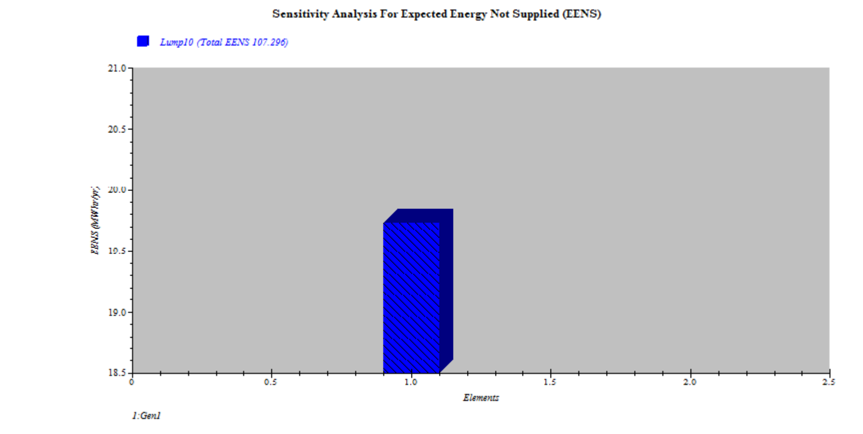

Figure 5.4: Expected energy not supplied for agricultural load

In the next figure agricultural load which has failure rate of 0.02 and MTTR i.e. average outage duration is 15 hours has been shown in fig

Net failure rate at load 10 has been found to be 0.3550 and the net outage duration will be 40.72 hours per year

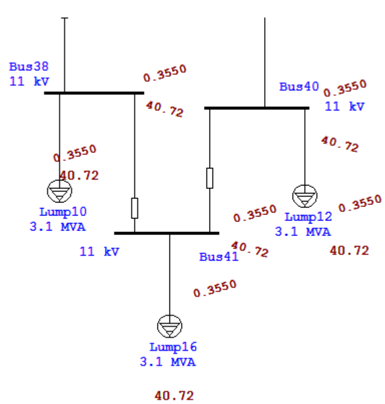

Figure 5.3: Cluster 1

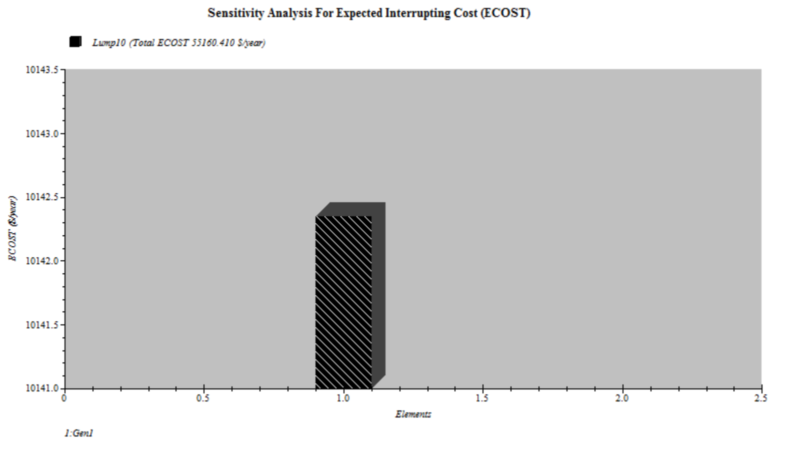

Figure 5.5: Expected interrupting cost for lumped agricultural load

In fig expected energy not supplied index have been generated for load 10 i.e. agricultural load comes out be 107 MW. In next fig expected interruption cost index at load point has been provided. i.e. 55160.410 $\frac{\$}{year}$

Similarly for office building load ECOST and EENS have been generated i.e. 91.587 MW and 1166771 $\frac{\$}{year}$

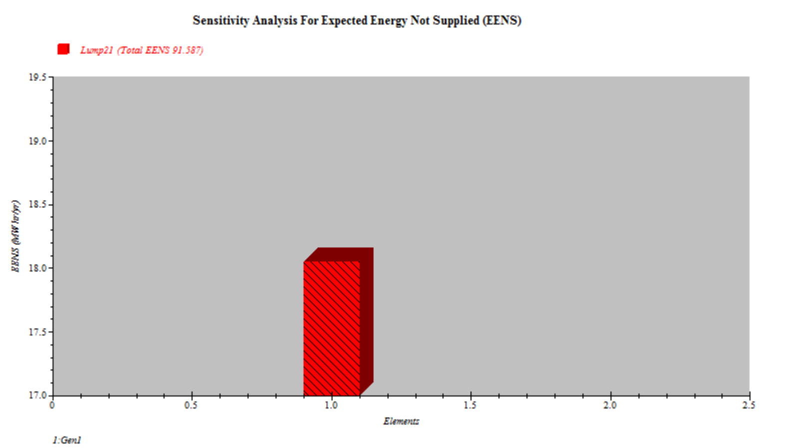

Figure 5.6: Expected energy not supplied for lumped office building load

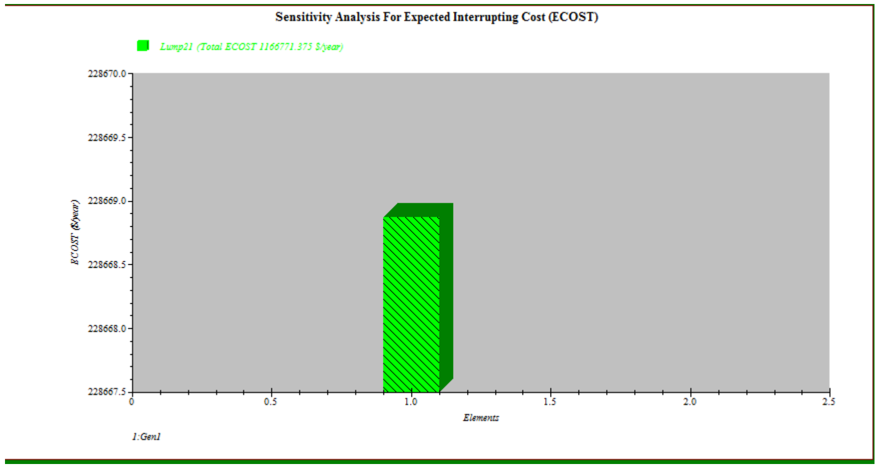

Figure 5.7: Expected interrupting cost for lumped office loads

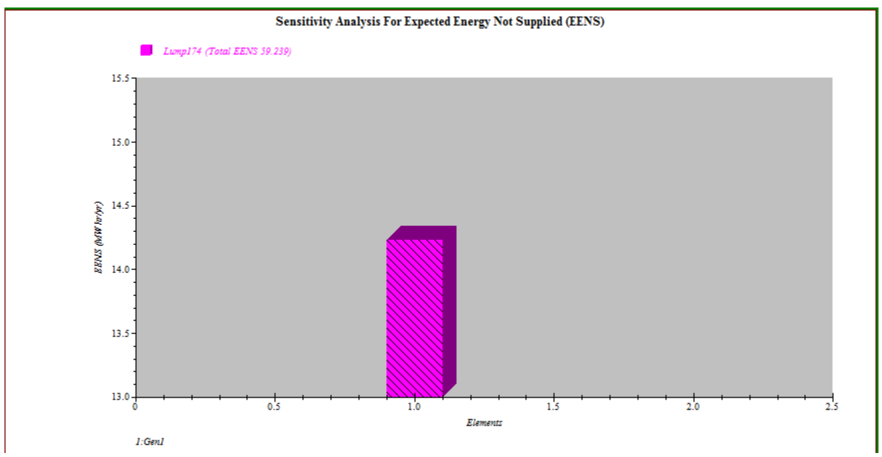

Figure 5.8: Expected energy not supplied for residential load

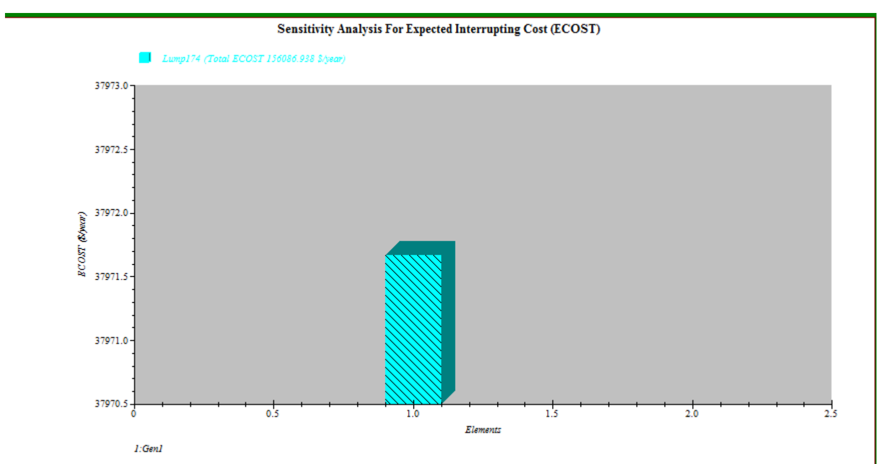

Figure 5.9: Expected interrupting cost for lumped residential load

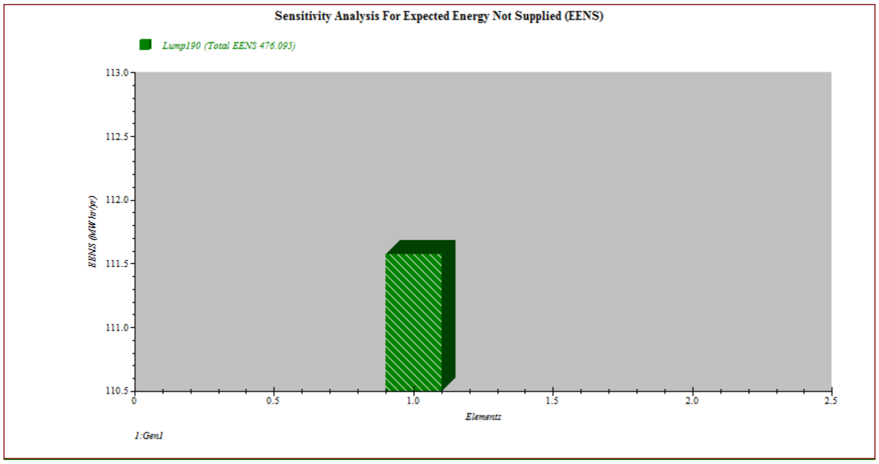

Figure 5.10: Expected energy not supplied for Industrial load

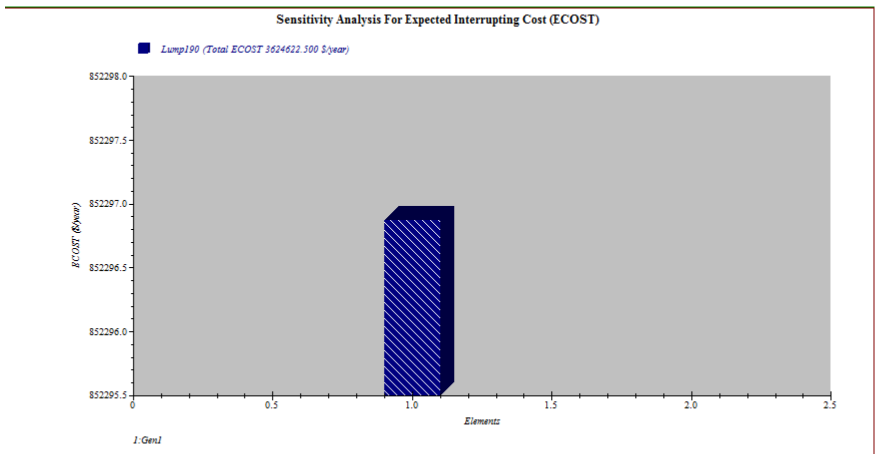

Figure 5.11: Expected interrupting cost for lumped Industrial load

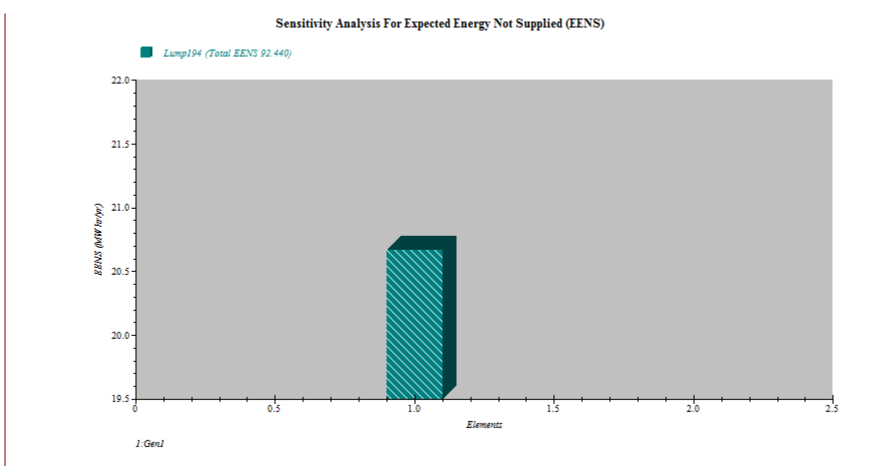

Figure 5.12: Expected energy not supplied for govt. institutes load

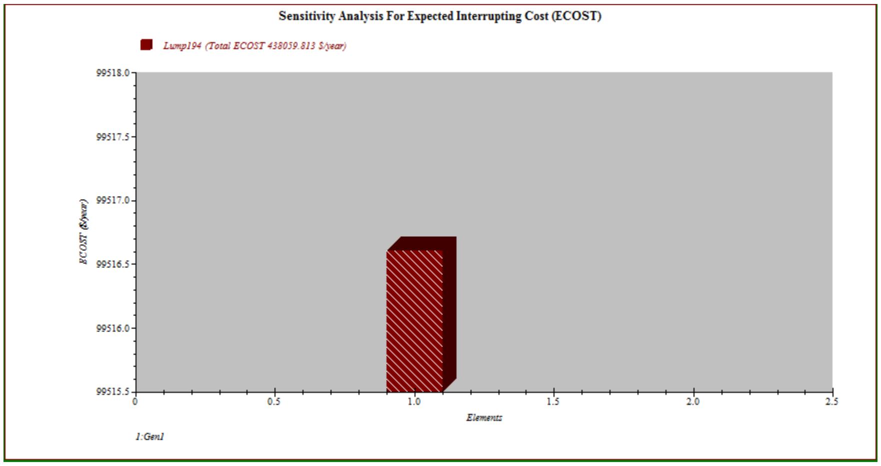

Figure 5.13: Expected energy not supplied for govt. institutes load

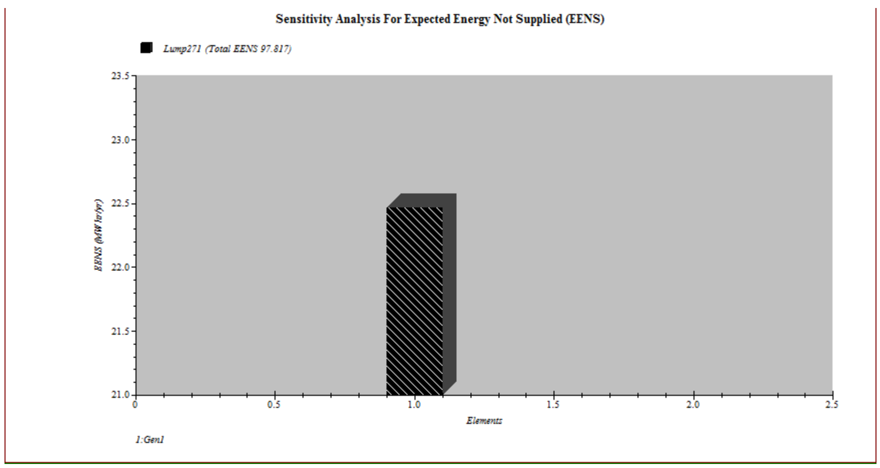

Figure 5.14: Expected Energy not Supplied lumped govt. institutes load

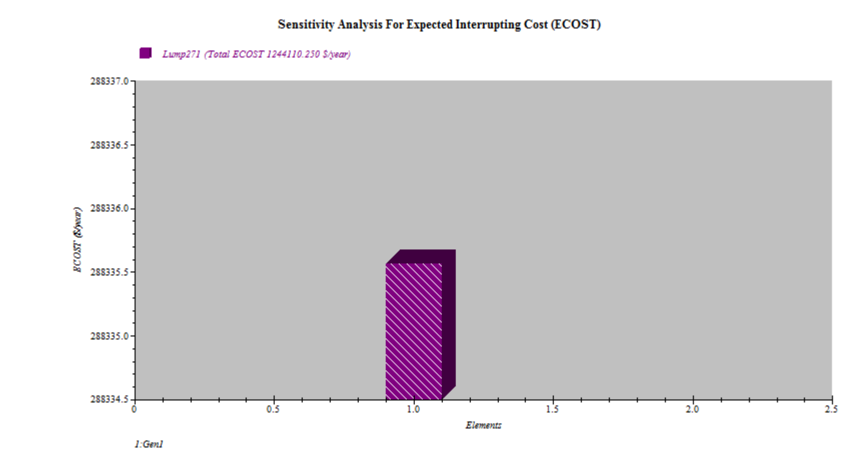

Figure 5.15: Expected interrupting cost for lumped govt. institutes load

Conclusion and Future Work

Conclusion

- In my dissertation project Reliability analysis have been carried out for the power system model designed for the Dholera smart city. Load forecasting and then calculation of ratings of transformers based on the 'N-1' contingency so that the system would remain reliable in case one element goes in outage. Expected Outage duration and net failure rate for the each type of load have been carried out in ETAP. EENS and ECOST have been found in simulation.

Future Work

a. Load flow would be carried out for the system

b. Analysis of Heating of cables due to grouping

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[A]

Appendix A