Analytic Study for 66 kV Sub Transmission System Planning

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Abstract—**The objective of this paper is to know the operation conditions of the system in terms of power flow, power losses and the weak points of the network. After which, solutions were proposed for solving such problems. The strategic and methodology for planning Criteria are chosen in a way that matches the general standards. A seventeen years plan is considered with short and long term planning applied and computed, system model was designed and a simulation for this model was performed using NEPLAN software. A strategic plan for the 17 year next for 66 kV sub-transmission network has been obtained. The targeted network consists of four rings fed from four 220KV feeding points and capable of providing an expected total demand of 253 MW.**

Index Terms: **Sub transmission system planning, loading, voltage drop, NEPLAN, GPS data**.

I. INTRODUCTION

The power sub-transmission system planning problem is defined as an attempt to minimize the cost of sub-transmission, substation, feeders as well as the cost of line losses, subjected to a certain requirements and constraints such as voltage drop, power flow limit and security constraints .

The transmission network expansion is a complicated non-linear mathematical problem due to the multitude of confronted technical and economical constraints, the nature of facility cost, the non-linear nature of the power losses cost and the large number of parameters encountered in solving real power system.

The general form of network expansion problem can be stated as follows:

1. Existing network configuration.
2. Available line types and the corresponding cost
3. All possible routes (Length and right of way).
4. Load generation pattern at target year.

During the last three decades , several sub-transmission system planning models were developed for application [1]. In the early 70S sub-transmission system planning researchers used linear programming models ,especially network programming, to select the most economical feeder routes and substation sites [2,3]. The capability of linear programming methods in handling discrete spaces is an attractive advantage that counterweighs the poor linear approximations required for system modeling**.** furthermore linear programming considerably reduces the size of the planning problem [4].

In the late 80S, simple quadratic programming proved relatively efficient for planning purposes [5]. The quadratic modeling of the planning problem deprived the decision making process from its practical sense of discreteness, but offered a substantial basis to accurate representation in system modeling. In the 90S, the evolutionary progress in computer resources brought heuristics such as the branch exchange and sequential rejection techniques into in the field of power delivery planning [6,7]. In the same decade, and for the same reason mathematical techniques such as genetic methods and simulated annealing became applicable [8].

In the 2001's developed a new sub-transmission system planning model and methodology are developed. The model can determine in a single stage optimum system topology, substation sites, optimum voltage level, and optimum cross section of system feeders. The objective of the proposed methodology is to detect a global optimum through a dynamic search [9].

Due to the demand growth, generation intermittency and network capacity limitation, research interest on Distribution Expansion Planning (DEP) has been growing. In [10], DEP problem is solved for only one planning horizon. In these papers, the location, type, and the capacity of new equipment are evaluated, DEP problem is solved for several stages. In these works, the growth of the demand for a long time is evaluated. The MDEP has been solved using Mixed Integer Linear Programming (MILP) framework in [11,12]. In [13], the evolutionary algorithms are used for the solution of the DEP problem. Solving MDEP problem using Optimal Power Flow (OPF) and Genetic Algorithm (GA) is proposed in [14]. Distribution system planning for peak cutting using GA is used for minimizing investment cost in [15]. a multiobjective decision making procedure is applied to MDEP problem using an efficient heuristic search method to minimize the total cost while the associated technical constraints are satisfied. Reliability indices of a radial distribution network have been improved using multiple fault indicators and optimum DG placement in [16]. Reliability-oriented distribution network reconfiguration considering demand uncertainty has been studied in [17]. In the 2010's investigated the optimal substation capacity expansion problem for distribution system. The monthly energy consumption and the service types of all customers within each fence area have been retrieved from the customer information system in Taipower. The load demand of each fence area is calculated according to the typical load

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patterns and energy consumption of customers, The S curve with different time constant is used to represent the load growth of each customer class for the load forecasting of each fence area. The load flow analysis is performed to find power demand of each fence area for annual system operation over the study period. The objective function is formulated by considering both the cost of power loading loss and investment cost of substations as the equivalent cost of all feasible states of each year [18].

There are some research works which deal with Distribution Feeder Reconfiguration (DFR) problem, For instance, multi-objective adaptive PSO algorithms have been presented in [19,20] to solve stochastic DFR problem for systems with distributed wind power generation and fuel cells. The paper is organized as follows: in section II & III, Factors Affecting System Planning and Methodology is presented. System Model are evaluated in section IV. Future System Expansion and Result of three design included in the paper is mentioned in section V and finally the most important results are elaborated in section VI.

II. FACTORS AFFECTING SYSTEM PLANNING

The basic challenge of any electric power system is to ensure supply of electric energy with good quality at minimum cost. In addition, this can be achieved by:-

- Power System Security .
- Power System Quality (Supply frequency, Voltage profile, Elements loading) [21].

The most important factors influencing the expansion of the distribution system are :

A. *Load Forecasting:*

The forecasting of load increases and system reaction to these increases is essential to the planning process. There are two common time scales of importance to load forecasting:

Long-range, with time horizons on the order of 15 or 20 years away.

Short-range, with time horizons of up to 5 years distant [18].

B. *Substation Expansion:*

There are some factors affecting the substation expansion like, transmission voltage, feeder limitation, power losses, economic factors, existing substation locations, etc., but in the system expansion plan the present system configuration , capacity, and the forecasted loads can play major roles[18].

C. *Substation Site Selection:*

The important factors affecting the substation site selection are, the distance from the load centers and from the existing sub-transmission lines as well as other limitations, such as availability of land, its cost, and land use regulations [23,24].

D. *Other Factors:*

Once the load assignments to the substations are determined, then the remaining factors affecting primary voltage selection, feeder route selection, number of feeders, conductor size selection and total cost [24].

III. SUB TRANSMISSION SYSTEM PLANNING METHODOLOGY

To map out a strategy to develop a network it is necessary to know where the way should lead to. This goal is defined by the long term network which has to be planned first. This long term network will then act as a guideline for all changes in the network implemented during short and medium term action (Figure 1.) [22].

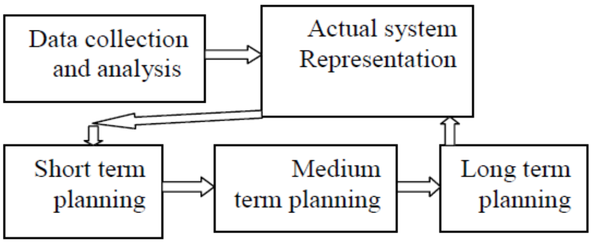


Figure 1. General Planning Procedure

Figure 2. shows a functional block diagram of the Sub transmission system planning techniques process currently followed by most of the utilities. This process is repeated for each year of a long-range (15-20) planning period. In the development of this diagram, no attempt was made to represent the planning procedure of any specific company but rather to provide an outline of a typical planning process.

As the diagram shows, the planning procedure consists of two major activities:

Load forecasting, Sub transmission system configuration design, substation expansion, and substation site selection.

If the resulting decision is to build a new substation, a new placement site must be selected. Further, if the purchase price of the selected site is too high, the expand-or-build decision may need further reevaluation [24].

A. *Planning Criteria*

The main planning criteria regard the following points.

1- (n-1) reliability
2- Standard network structure
3- Standard size of components
4- Voltage level
5- Allowed voltage bands

The main factors which influence the criteria are

1- Reliability of supply
2- Operability of the network
3- Flexibility
4- Economic

A network that is of an extreme simple structure is usually cheap and simple to operate, but reliability and flexibility are low [22, 34].

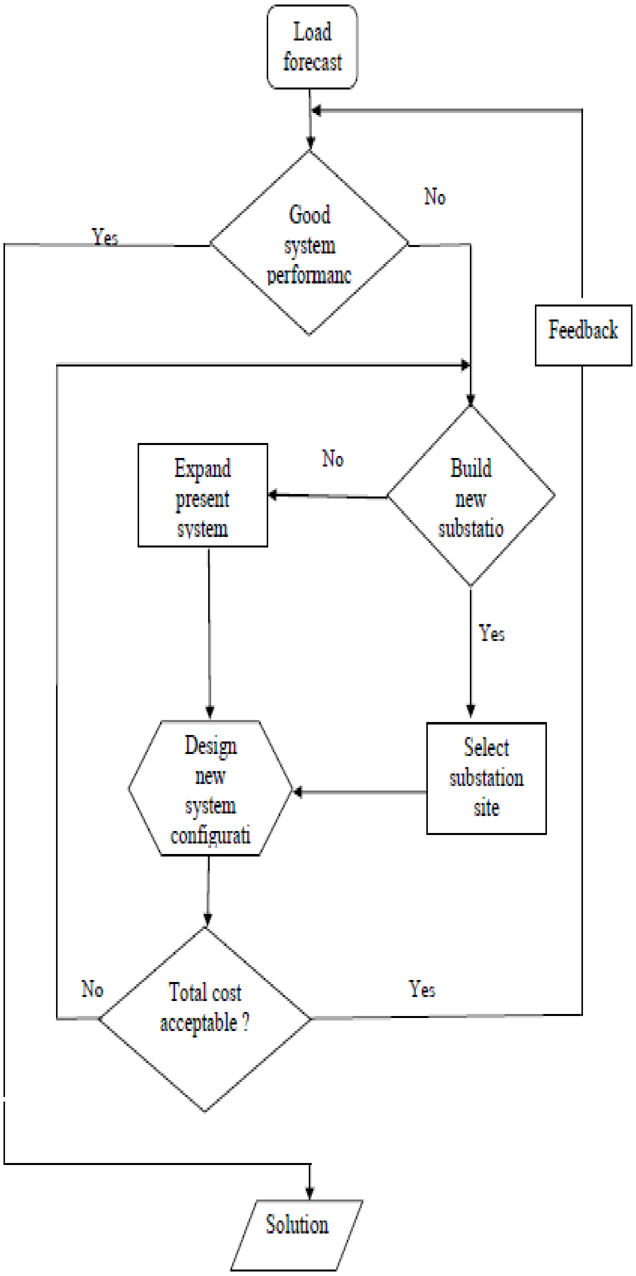


Figure.2 A Block Diagram Of A Typical Sub-Transmission System Planning Process

IV. SYSTEM MODEL

This part introduces single line diagrams of the 66 KV network of the city of Ben Walid in Libya Country . Also presents the results of the load flow study carried out using the NEPLAN software, the method used in this calculation is Newton Raphson method. under actual loading condition for existing network.

The master plan for the sub-transmission system for the 17 year next is presented and the fundamentals upon which it was so developed are also presented and discussed.

Figure 3 shows The structure of the studied system. The system components are given in table 1.

Table 1. The System Components

Type	Slack Bus	Load Bus	Control Bus
Substation	1x (220/66 kV)	11 x (66/11kV)	-----
Transformers	3 x 63 MVA	(7x20), (11x10) , (3x5) MVA	-----

There is another in feed point called city North but it is not connected with the system. Too There are another in feed points called the city North and West connected with the system. It is healthy system but the substation is out of service!.

A. *NEPLAN Analysis Of The Existing Network*

The studies were conducted for two main loading conditions , the peak and minimum loading condition. The total load for ring at the peak was assumed to be 68.4 MW.

Careful examination of the results reflects that the steady state for ring is not satisfactory since there are voltage drop at the nodes as shown in table 2. also there are any overloaded lines as shown in table 3.

Table 2. Voltage Drop At The Nodes

Bus No	V kV	P.U %	δ angle °	P_{Load} MW	Q_{Load} Mvar
1	10.21	92.85	-9.3	4.407	2.731
7	10.37	94.22	-8.6	19.12	11.85
14	10.36	94.18	-8.5	1.469	0.911
16	10.43	94.84	-8..0	22.01	1.363
18	10.42	94.68	-8.1	4.407	2.731
20	10.38	94.34	-8.4	3.671	2.274

Table 3. Overloaded Lines

N	Type	P MW	Q MVar	I kA	Loading %	P_{Loss} MW	Q_{Loss} MVar
28	Line	31.14	20.16	0.32	80.33	0.203	0.632
101	Line	-30.9	-19.5	0.32	80.42	0.203	0.632

B. *Solution For The Analysis Problems*

In this study the following conditions are regarded to be weak points which require urgent actions:

1. Lines (cables and overhead lines) loaded higher than 80 % of their rated current.
2. Nodes with a voltage of less than 95 % or more than 105 %.
3. Transformers (220/66 kV or 66/11 kV) loaded more than 80 % of their rated current.

Various alternatives for correcting the above mentioned problems were tried including changing the transformers tap changes , placing of fixed capacitors and upgrading conductor size.Various studies were conducted using the NEPLAN software the summary of studies is detailed below .

Some problems with overloaded transformers will be solved if the problems with overloaded lines and the voltage drop will be solved. Therefore, it is recommended to install switchable capacitors with a total size as given in table 4. It is assumed that these problems will be solved before the transformer problems will be taken care of.

1. Solution To Overloaded Lines

We add another two lines with the same specifications for existing line.

2 * 6 Km OHTL type A.C.S.R(Bear(326.5mm^2)) [33,34].

2. Solution To Voltage Drop

Some voltage drop will be solved after the problems with overloaded lines will be solved. Additional voltage support is needed at the following stations. As the reactive power requirements of the loads change, the amount of compensation power needed varies through the day.

The next equation is used to estimate the receiving end reactive power [32-34].

$$Q_{\mathcal{R}3\phi} = \frac{|\mathcal{V}_{\mathcal{SLL}}|*|\mathcal{V}_{\mathcal{RLL}}|}{|\mathcal{B}|}\cos\delta - \frac{|\mathcal{V}_{\mathcal{RLL}}|}{|\mathcal{B}|}\cos\beta\mathcal{L} \qquad (1)$$

Thus, The required capacitor Mvar is

$$Q_{\mathcal{C}} = Q_{LOAD} - Q_{\mathcal{R}} \qquad (2)$$

Therefore, it is recommended to install switchable capacitors with a total size as given in table 4.

Table 4. Solution To Voltage Drop

Bus number	capacitor .(MVar)
1	3.5
7	6.0
18	3.0

The steady state performance of the ring can be assured from the examination of the load flow study results there are no voltage drop at the nodes as shown in table 5.

Table 5. Node results of ring after the solution

Bus No	V kV	P.U %	δ angle °	P Load MW	Q Load Mvar
1	10.93	99.36	-8.7	4.407	2.731
7	10.91	99.14	-7.9	19.12	11.85
14	10.97	99.72	-7.9	1.469	0.911
16	11.03	100.3	-7.5	2.21	1.363
18	11.01	100.1	-7.5	4.407	2.731
20	10.97	99.71	-7.8	3.671	2.274

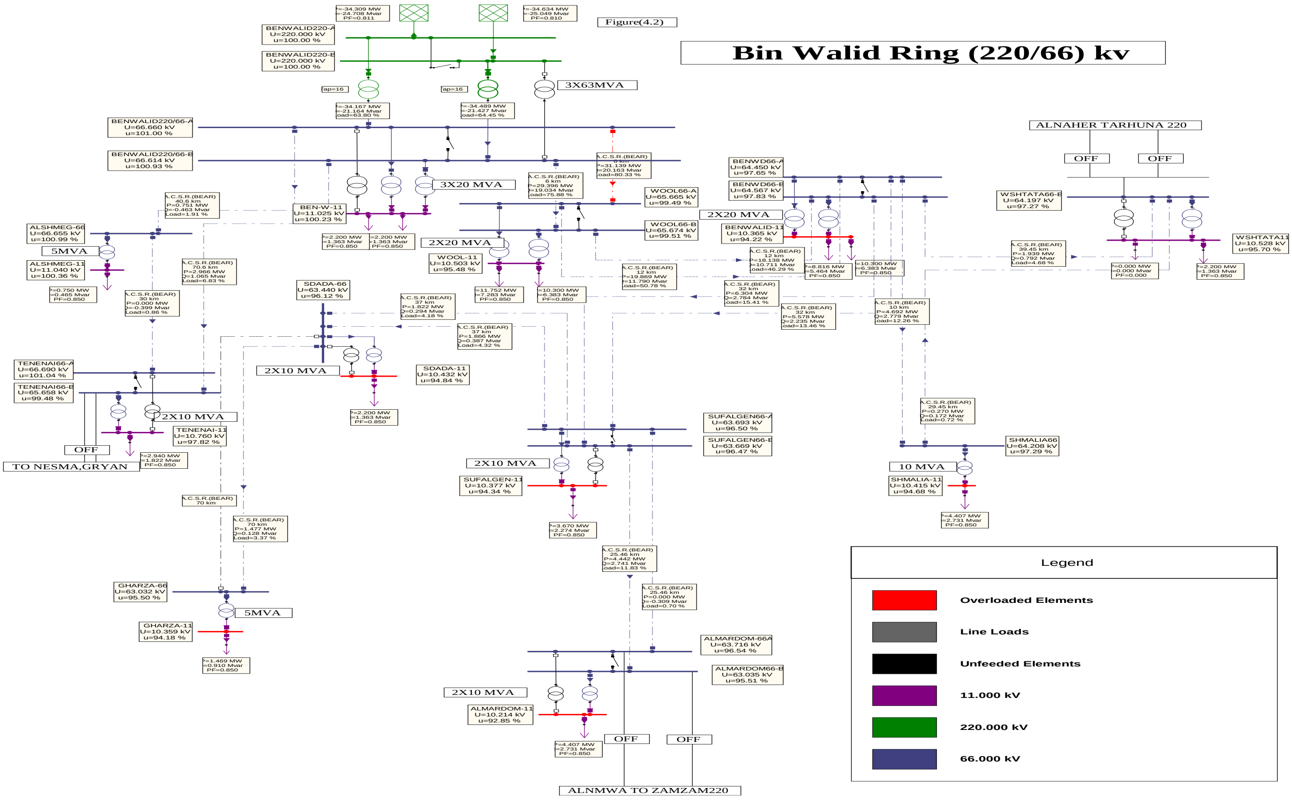


Figure 3. Shows The Structure Of The Studied System (Ring 220/66kV

C. *Contingency Cases.*

For the sub-transmission system a contingency analysis was carried out in order to identify the elements which if taken out of service can cause problems during normal operation, study results shown in table 6.

Table 6. Contingency Cases

Item	**Study case**	**Loading element**
Case. one	**T.R1(220/66kV) is out of service.**	**T.R2 is loaded up to 127%**
Case. two	Existing Ring is the feeder for adjacent ring1 with 13 MW .	Less than 80%
Case three	Existing Ring is the feeder for adjacent ring2 with 20 MW .	Transformers are loaded up to 85%

V. FUTURE SYSTEM EXPANSION

The load growth to be taken in this study is 8 % per year. So the predicted loading for 17 year next is 253 MW. This gives an approximation of the future load density. The next equation is used to estimate the load [7].

$$P_n = P_o(1+0.08)^n \qquad (3)$$

$$P_{17} = 68.4(1+0.08)^{17} = 253 \text{ MW}$$

A new 220 kV feeding points is a must for existing system since the one existing feeding point would not be enough .A suggested new feeding points are as shown in figure 4.

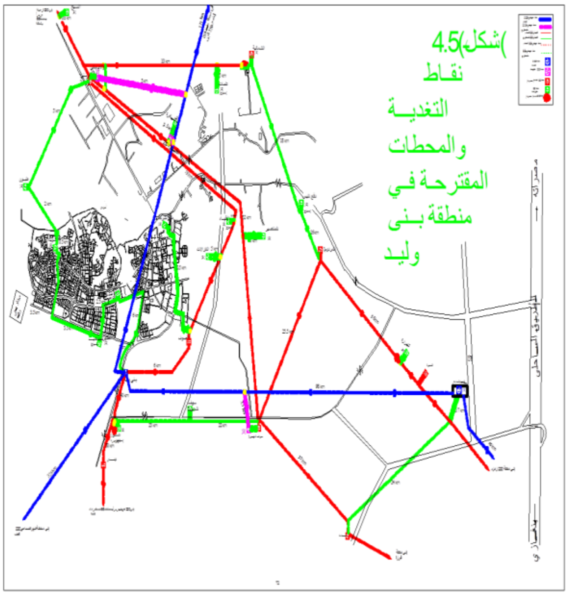


Figure 4. Suggesting New Feeding Points And Substation For City

This figure shows the schematic diagram for the future demand of the electric power in this area, We propose 14 substations in this area. The new substations are divided as follows:

(0) The work of the substation was completed
(1) The substation under construction
(2) The substation was contracted for execution
(3) Proposed substation

A. *Assumptions*

- The rate of load growth is 8 %
- Each substation will be loaded 80 % of its load.
- The standard network structure is “lines to adjacent stations” which are operated with an open point at the boarder of the supply area.
- The total load to supply for 17 years next is predicted to be about 253 MW.
- The 11 kV network is concentrated as a load on the 11 kV side of the 66 / 11 kV transformer.
- The loads are represented as loads with constant P and Q
- It is assumed that all loads are the loads at peak load condition.
- The transformers contain on load tap changers.
- The GPS data of the positions of the stations were used to place the stations. As background maps in the scale of 1:50 000.

B. The Proposal Rings

The number of old substations is 12 substations of 66 kV and 2 infeed substations of 220 kV .The proposed system should include 4 rings with 4-220 kV feeding points .

Each ring would be capable of supplying around 240 MW which means that 3-100 MVA transformer , and need at each ring 220/66 kV station .

A. The First Proposal of Rings

The proposed system should include 3 rings with 3-220 kV feeding points.

The system components are given in table 6.

B. The Second Proposal of Rings

The proposed system should include 3 rings with 3-220 kV feeding points.

The system components are given in table 6.

C. The Third Proposal of Rings

The proposed system should include 4 rings with 4-220 kV feeding points.

Figures 5-8 show The design of The Third Proposal of Rings(C1, C2, C3, C4), The system components are given in table 7.

C. *Results Of Study*

Careful examination of the results reflects that the study state for the three proposals are satisfactory, there is no over load on the element or voltage drop at the nodes.

The difference between the three cases in terms of some items mentioned in next table 7.

Table 7. Comparison Between The Proposal Rings

Item	Case one	Case Two	Case three
Old substations (66 kV)	12	12	12
New substations (66kV)	14	14	15
Feed points (220/66kV)	3	3	4
Cable type 630 cu	16 Km	15.5 Km	16 Km
Overhead line type Beer	130 Km	122 Km	16 Km
Total of power loss	2.47 MW	2.09 MW	1.46MW
Overloaded lines (Contingency)	14	6	-------
Overloaded nodes (Contingency)	5	3	-------

VI. CONCLUSION

The purpose of this plan is to help strike a balance between the customer's need for a secure, reliable, high quality electricity supply and the desire for this service to be provided at minimum cost. At same time, environmental and social considerations shall be taken into account.

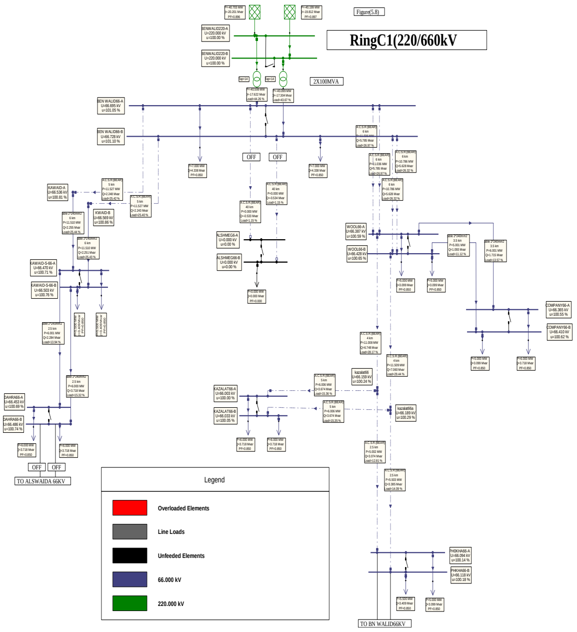
Using NEPLAN software, the existing network 66 kV of city was analyzed and the load flow calculations was performed for normal operation and for the assumed worst fault. The standard network structure is Line to adjacent stations type, which are operated with an open point at the boarder of the supply area.

The design of the 17 year next of the sub-transmission system was proposed and studied under three cases. And the criteria of the three cases was, Each ring for the proposed system has connection with another ring, which usually normally open and automatically connected in case any lost in the main supply.

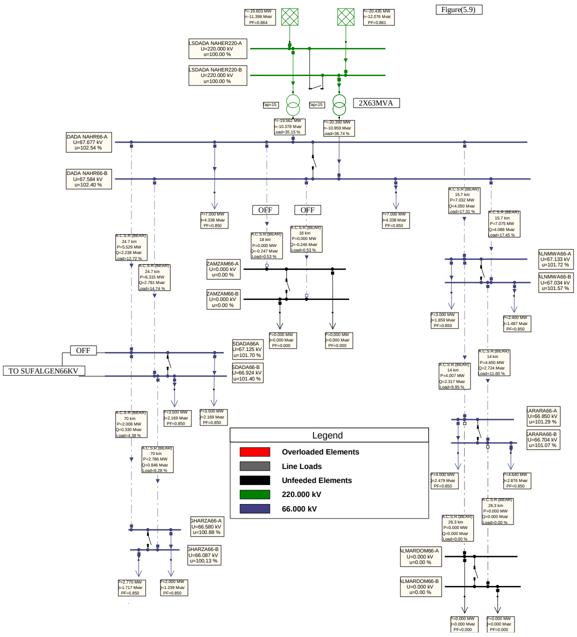
The results of the cases one and two are acceptable at normal operating, but at contingency case there are some elements overloaded and some nodes as well, and the results of the case three is acceptable at normal operating and contingency case.

The main constraints of the above objective are to secure the power for customers with high quality and with minimum losses.

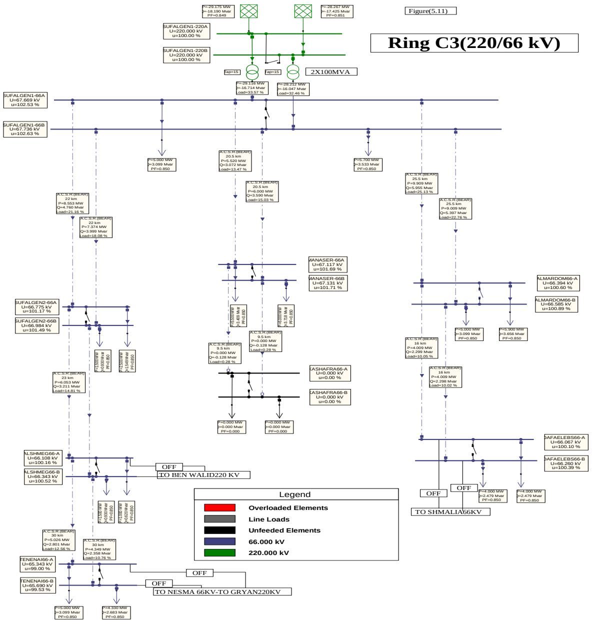
Due to the total load predicted will be about 253 MW, it was found that case three is more suitable for the network in that year. Although the number of substations that will be in service are more than the other cases but the total power loss is only 1.468 MW.



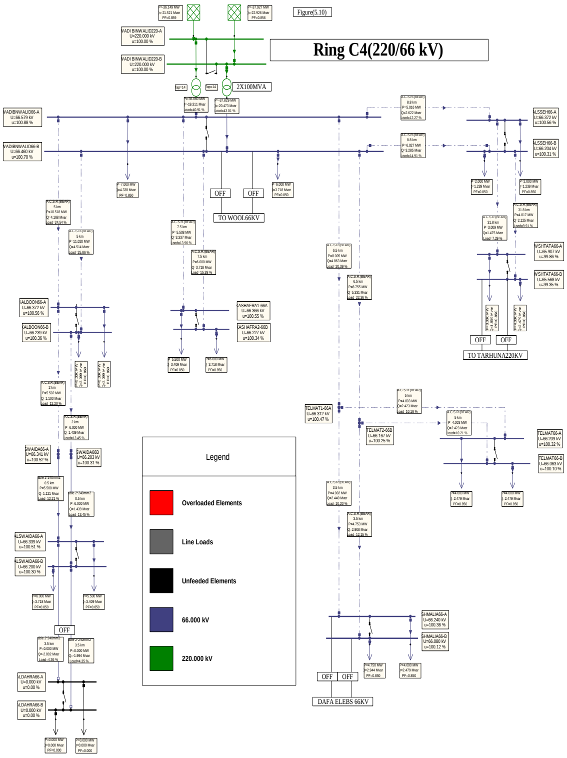
Figures 5. Shows The Design Of RingC1(220/66kV)



Figures 6. Shows The Design Of RingC2(220/66kV)



Figures 7. Shows The Design Of RingC3(220/66kV)



Figures 8. Shows The Design Of RingC4(220/66kV)

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