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PASCHIMANCHAL CAMPUS

**Performance Analysis on Placement and Sizing of D-STATCOM in Radial Distribution Network:**

**A Case study in Begnas Feeder, Lekhnath**

BY

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# TABLE OF CONTENTS

## LIST OF FIGURES

# LIST OF TABLE

## LIST OF ABBREVIATION

| | |
|---|---|
| ABC | AERIAL BUNDLED CONDUCTOR |
| AC | ALTERNATING CURRENT |
| ACSR | ALUMINUM CONDUCTOR STEEL REINFORCED |
| DC | DIRECT CURRENT |
| DCS | DISTRIBUTED CONTROL SYSTEM |
| DG | DISTRIBUTED GENERATION |
| INPS | INTEGRATED NEPAL POWER SYSTEM |
| HT | HIGH TENSILE |
| NEA | NEPAL ELECTRICITY AUTHORITY |
| VSI | VOLTAGE STABILITY INDEX |

# CHAPTER ONE: INTRODUCTION

## 1.1 BACKGROUND

To enhance voltage profiles, lower losses, and conserve energy, distribution systems integrating distributed generation (DG), custom power devices (CPDs), and capacitors must conduct an optimal load flow assessment. Reactive power management, loss reduction, distribution system pricing, and reserve management during peak loads are among the challenges that are addressed by the proper placement of these components. Reactive power demands rise in distribution systems because most loads are reactive. This reactive power can be provided by capacitors, but they may oscillate and their output is dependent on the system voltage. Originally designed for transmission systems, FACTS devices are now utilized in distribution to compensate for reactive power, taking on the role of capacitors or inductors as required.

CPDs that regulate voltage, phase angle, and line impedance effectively and dependably include DVR, D-STATCOM, and UPQC. D-STATCOM is a particularly useful one among them, providing better bus voltage profiles and continuously changing reactive power compensation. A transformer, PWM control technique, inverter modules, ac filter, and dc capacitor are among its primary parts. In both steady-state and dynamic scenarios, D-STATCOM improves voltage control, balancing, and power losses. The effectiveness of D-STATCOM in enhancing voltage profiles and lowering losses in distribution networks has been demonstrated by a number of studies that have suggested methods for appropriate D-STATCOM placement and sizing.

With size estimations made using a variational strategy, this article analyzes D-STATCOM allocation strategies for radial distribution networks using the voltage stability index (VSI) and power loss index (PLI) approaches. This technique enhances voltage profiles while reducing line losses. The load flow method consists of three basic steps: figuring out the load current, creating the BIBC matrix, and sweeping the line forward. The bus with the greatest VSI and PLI values is chosen as the candidate bus after a load flow study is performed. We then apply the variational technique to determine the D-STATCOM size. Lastly, using MATLAB, the load flow is reevaluated at the candidate bus for IEEE 33-bus test systems with the D-STATCOM.

## 1.2 PROBLEM STATEMENT

The electrical power distribution system is an essential part of the infrastructure that ensures the efficient and reliable transport of electricity from generation sources to end consumers. However, maintaining the optimal voltage profile and minimizing losses in the distribution network remain formidable obstacles. These issues could lead to excessive power consumption, increased operational costs, and a deterioration in the reliability and quality of the services.

Research paper's problem statement focuses on solving problems with reactive power management, improving voltage profiles, and lowering power losses in radial distribution systems. It draws attention to the drawbacks of employing capacitors for reactive power adjustment, including their propensity to cause oscillations and reliance on system voltage. As a substitute, the study suggests using D-STATCOM, a static compensator based on a shunt-connected voltage source converter. In order to improve the effectiveness and efficiency of radial distribution networks, the study intends to identify the ideal placement and size of D-STATCOM utilizing voltage stability index (VSI) and power loss index (PLI) methodologies, followed by size calculation through a variational technique.

## 1.3 RATIONALE OF PROJECT

Our everyday existence depends on the electrical power distribution system, which supplies energy to our residences, workplaces, and enterprises. On the other hand, preserving an ideal voltage profile and reducing distribution network losses are major obstacles that may affect the effectiveness, dependability, and affordability of power transmission.

The purpose of this research study is to discuss the necessity of loss reduction and efficient voltage profile management in radial distribution systems. This research investigates the best locations and sizes for Distribution Static Compensators (D-STATCOMs) by combining the Power Loss Index (PLI) and Voltage Stability Index (VSI) methodologies. The study's objectives are to improve voltage stability, lower power losses, and save energy overall by figuring out where and how big of D-STATCOMs to put. This is especially crucial since scattered generation sources and rising reactive loads need for sophisticated reactive power management techniques and effective system operation.

## 1.4 OBJECTIVES

The objectives of this research paper are:

- ✓ To compare the effectiveness of Voltage Stability Index (VSI) approach for the optimal allocation of D-STATCOM in a radial distribution network.
- ✓ To determine the corresponding sizes of D-STATCOM using a variational technique.
- ✓ To demonstrate the reduction of line losses and improvement in the voltage profile of the distribution network through the optimal placement and sizing of D-STATCOM.
- ✓ To conduct load flow analysis on a radial distribution system to identify candidate buses for D-STATCOM placement.
- ✓ To validate the proposed methodology using the IEEE 33-bus test system with MATLAB software and implement it in city feeder.
- ✓ To analysis the energy saving after placement of D-STATCOM

## 1.5 LIMITATIONS

- ✓ The paper assumes a constant load profile while calculating the optimal placement and size of D-STATCOM. In real-world scenarios, the load profile can vary significantly, which might affect the performance and effectiveness of the D-STATCOM installation.

- ✓ The study uses a simplified model of the distribution system, which may not capture all the complexities and interactions in an actual distribution network

- ✓ The study examines the placement of a single D-STATCOM device. In practical applications, multiple devices may be required, and their interactions could complicate the optimization process.

- ✓

# CHAPTER TWO : LITERATURE REVIEW

The increasing use of capacitors, custom power devices, and distributed generation in distribution systems necessitates a thorough load flow study to determine their optimal placement for improved voltage profile management, loss reduction, and overall energy savings. Reactive power compensation is crucial due to the prevalence of reactive loads like motors and pumps [9]. While capacitors are traditionally used for this purpose, their dependency on system voltage and potential for oscillations pose challenges. FACTS devices, including D-STATCOM, offer a more flexible solution by dynamically adjusting reactive power compensation based on system needs. D-STATCOM, a shunt-connected device, excels in voltage profile improvement and loss reduction. Its advantages include low harmonic distortion, compact size, and continuous operation. This paper focuses on comparing D-STATCOM allocation methods using voltage stability and power loss indices, along with size calculation using a variational technique, to enhance distribution system performance.

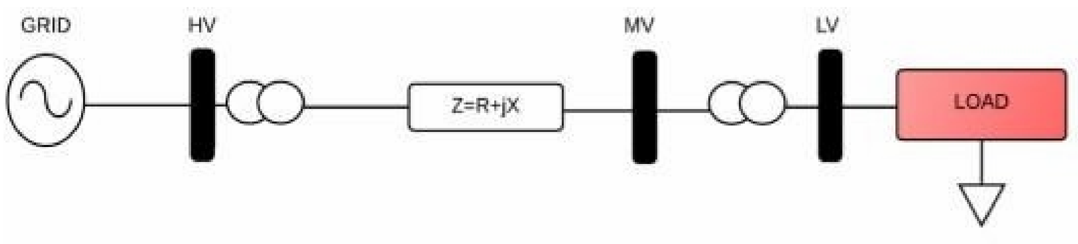
Flexible AC Transmission System (FACTS) devices, such as DSTATCOM and UPQC, are increasingly used to address issues in power systems, including low voltage distribution, power quality improvement, and reliability for sensitive loads. These devices offer solutions for reactive power compensation and unbalanced loading under various system conditions. Optimal placement of these devices is crucial for their effectiveness. DSTATCOM, a shunt-connected device, is favored for its advantages like low harmonic distortion, compact size, and continuous operation. Previous research has explored various optimization algorithms for DSTATCOM placement, including immune algorithms, Particle Swarm Optimization (PSO), hybrid heuristic techniques, gravitational search algorithms, firefly algorithms, and modified bat algorithms.

Paper presents two methods for allocating D-STATCOM in radial distribution networks: voltage stability index (VSI) and power loss index (PLI). The optimal size of the D-STATCOM is determined using a variational technique. The load flow method used in this paper involves calculating load current, forming a BIBC matrix, and performing a forward sweep across the line [10]. Initially, a load flow analysis is conducted to calculate line losses and voltage profiles, and the bus with the highest VSI and PLI values is chosen as the candidate bus. Subsequently, the size of the D-STATCOM is determined using a variational technique. Finally, a load flow analysis is performed again, this time with the calculated D-STATCOM size at the candidate bus. This method effectively reduces line losses and improves voltage profiles.

## 2.1 Overview of Distribution Network:

Distribution systems serve as the conduit between the consumers and the distribution substation. This system provides a range of clients with the safe and dependable transportation of electric energy throughout the service area. generally beginning as a medium-voltage three-phase circuit (between 30 and 60 KV), a distribution system terminates at the customer's location, typically at the meter, at a lower secondary three- or single-phase voltage (generally less than 11 kV).

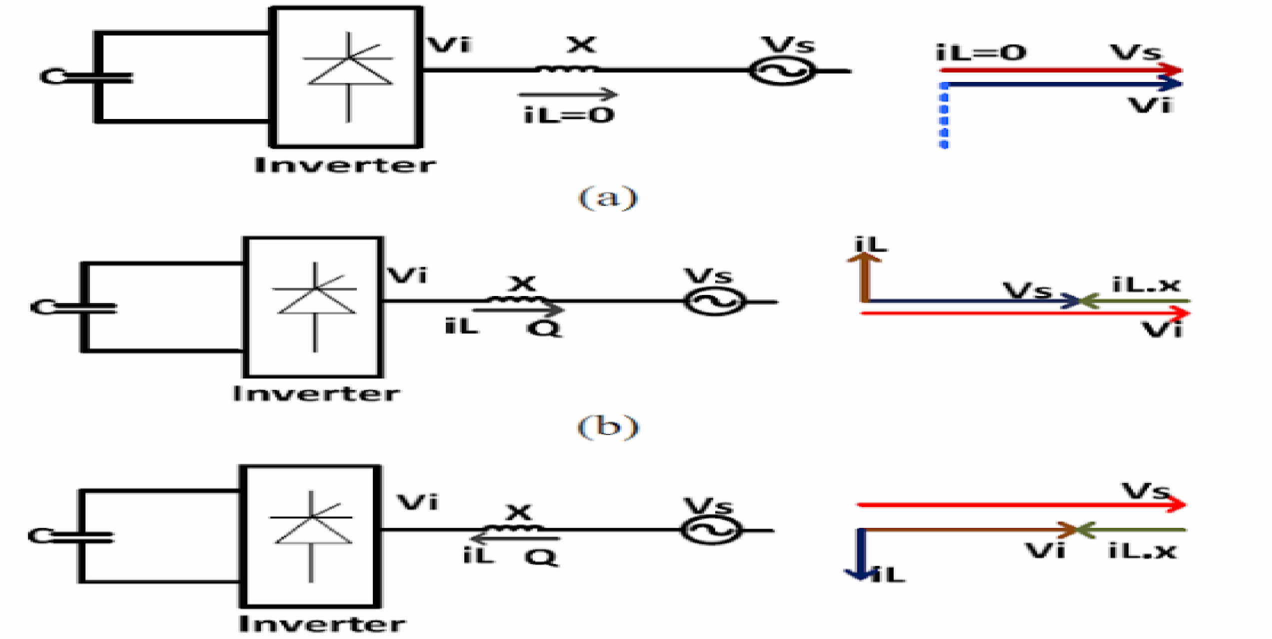
A simple model of radial distribution feeder is as shown in Figure 1.




## 2.2 D-STATCOM Allocation Technique for Loss Reduction

In essence, the D-STATCOM is a bespoke power device. All that is involved is the use of a STATCOM at the distribution level. A custom power device, the D-STATCOM is connected in series with the power supply and is based on an inverter that measures voltage or current. It is linked to the distribution systems in close proximity to the load. A power VSC that is built on high power electronics technologies is the essential part of the D-STATCOM. A VSC, a group of coupling reactors, and a controller make up the three primary components of the D-STATCOM system. A voltage source converter (VSC) coupled to a direct current capacitor (energy storage device) generates a programmable ac voltage source, which is the fundamental working principle of a D-STATCOM installed in a power system.

D-STATCOM is made up of an inverter, a control unit that produces PWM signals for the inverter switches, a coupling inductance L that is used for current filtering and reactive power exchange between D-STATCOM and the power system, and dc link capacitance C that supplies the inverter with dc voltage. Rdc and R stand for the coupling inductance's winding resistance and switching losses in the inverter, respectively. Reactive power exchange between the distribution system and D-STATCOM is accomplished by controlling the inverter output voltage Vi's amplitude. The phasor graphs in Figure 2 provide an illustration of the D-STATCOM operation.




## 2.3 Power flow/Load Flow:

The computations of load flow can be solved in a variety of ways. To be deemed acceptable, a load flow approach must meet a number of requirements, such as quick speed, low storage requirements, high dependability, and widely acknowledged simplicity and adaptability, power transmission through the grid system from generators to consumers. Load flow analysis is a crucial precondition for power system research. Regarding the radial feeder for load flow, the backward-forward sweep method is employed.

### 2.3.1 Calculation of load current

The load current at any bus is given as:

$I_{Ln}$= ( $P_n$-j$Q_n$) / $V_n$ Where n =1,2 ….N …. (1) where,

$I_L$= Load Current

N= total. No. of buses

$P_n$= Active power

$Q_n$ = Reactive power

$V_n$= Bus Voltage

### 2.3.2 Backward Forward Sweep Method:

The relation between load current and branch current can be found by using KCL equation. The matrix can Written as:

[IB]= [BIBC] [IL]

Where,

IB= Branch Current

BIBC= Bus injection to Branch Current Matrix

Forward sweep algorithm is used to calculate the voltage at each bus starting from branches from first layer to last layer. Backward Sweep algorithm is used to calculate the branch current starting from the last layer towards the branches connected to root node.

$V_n$ (K)= $V_m$(K)-IB(K)*$Z_m$(K) …….(3)

Where,

K = 1, 2,…..$N_b$

$N_b$= total no. of. Branches= N

$V_n$ (K) = receiving end Voltage $V_m$ (K) = sending end Voltage

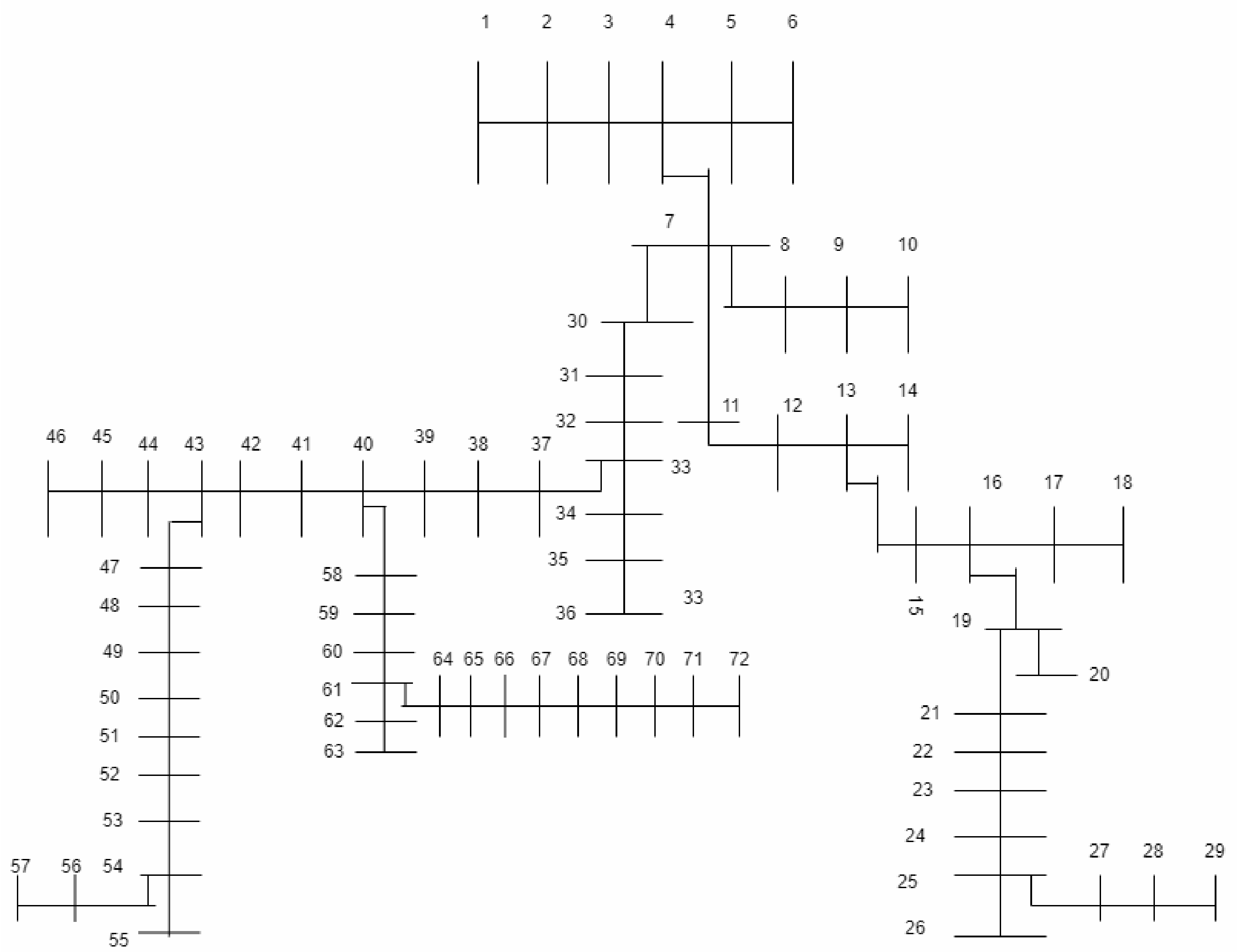
The power flow is calculated using backward and forward propagation using iterations. The forward sweep will provide the voltage magnitudes whereas the backward propagation provides the power of each branch. The iterative method has fast convergence as compared to conventional methods. The results for IEEE 33 bus test system are calculated for this Project. It is concluded that the following load flow method is an efficient method for fast convergence tendency in radial distribution networks.

# CHAPTER THREE: METHODOLOGY

This section discusses the methods and case studies used in this project to evaluate the system performance. The power flow along with the optimization technique applied throughout the project are programmed and simulated in MATLAB software.

## 3.1 Collection of Data:

The process involves choosing an IEEE bus test system that can accurately simulate a low-voltage distribution feeder and reviewing relevant literature to address the issue. For this effort, the IEEE 33 bus test system has been selected. Collection of real feeder data (Substation feeder data, voltage level, resistance and reactance of line, daily monthly and annual loading condition, load and its line configuration) of 11 kV Begnas feeder and finding the low voltage point, nodes and their values at different location from DTR installed, HT metering unit, TOD meter installed in substation and industries.




## 3.2 Optimal Location of D-STATCOM

### 3.2.1 Voltage Stability Index for finding optimal location of D-STATCOM

Optimal location of D-STATCOM is found by calculating the voltage stability index of all the buses. The VSI is calculated from the following equation:

$$VSI = 4R_m (P_n^2+Q_n^2) / (V_m^2 P_n) \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where $V_m$ and $V_n$ are sending and receiving end voltages respectively; $I_m$ is the branch current; $R_m$ & $X_m$ are branch resistance and reactance respectively.

Voltage stability index has been obtained and the bus with highest value of VSI is most unstable and is selected as candidate bus for D-STATCOM. The steps for calculating VSI are described as follows:

Step 1: Read the radial distribution system line data and bus data.

Step 2: Perform the load flow to calculate voltages for all the buses and power losses for all the branches.

Step 3: Calculate VSI for all the buses using equation (2).

Step 4: Select the candidate bus with highest value of stability index.

Step 5: Stop.

### 3.2.2 Optimal size calculation by variational technique

The size of D-STATCOM is calculated using the variational technique. First the base case load flow is made for finding the losses. Then by following steps is used for finding the optimum size of D-STATCOM. Steps for calculating the optimum size of D-STATCOM by variational technique are as follows:

Step 1: Read the line data and bus data and find the candidate bus for D-STATCOM placement by sensitivity method ( VSI ).

Step 2: Place the D-STATCOM at candidate bus with size varying in steps of 50 KVAR

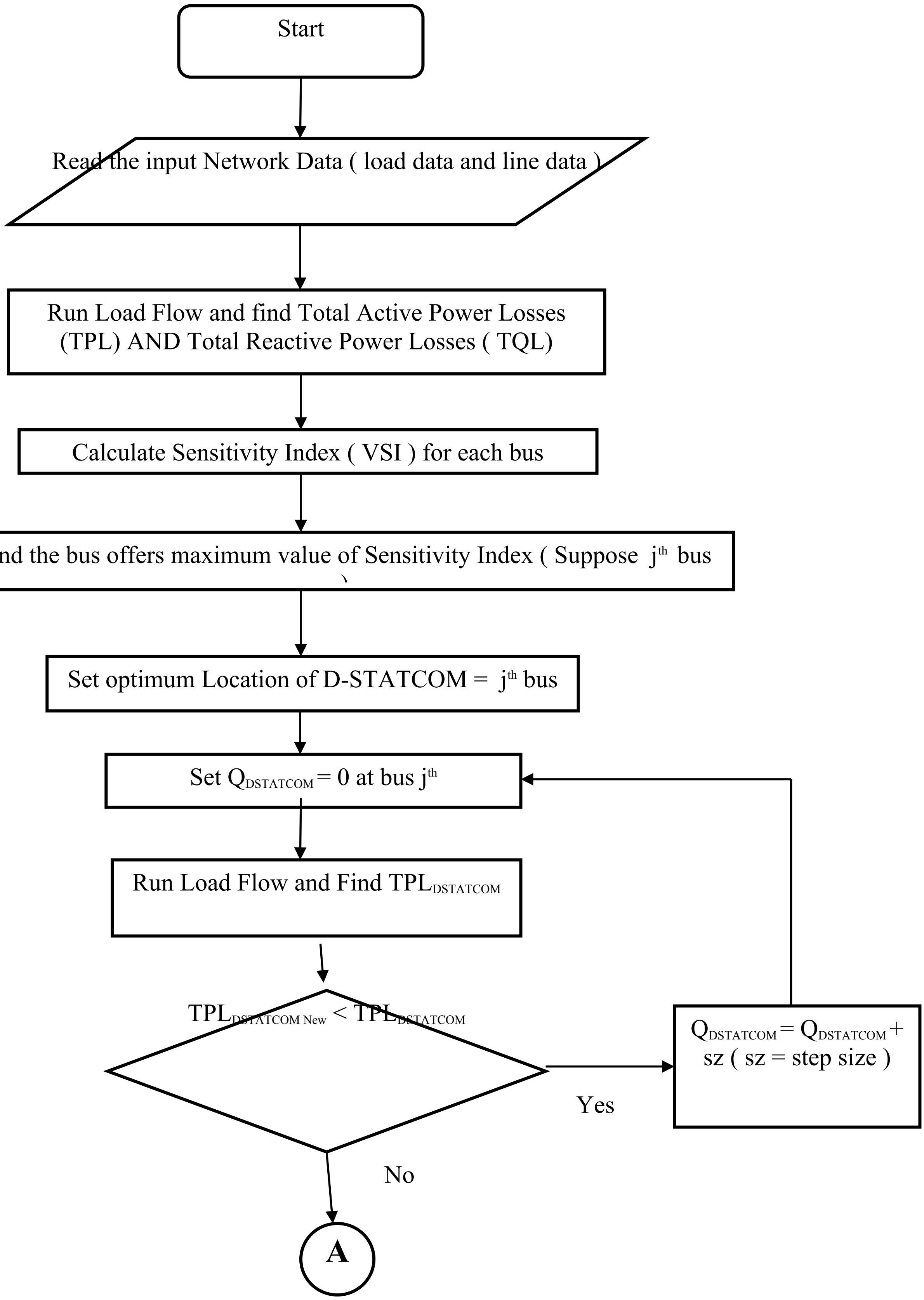
.

Step 3: Find the losses after placement of D-STATCOM.

Step 4: Select the size of D-STATCOM which gives minimum losses.

Step 5: Stop.

### 3.3 Flow Chart of Proposed Methodology



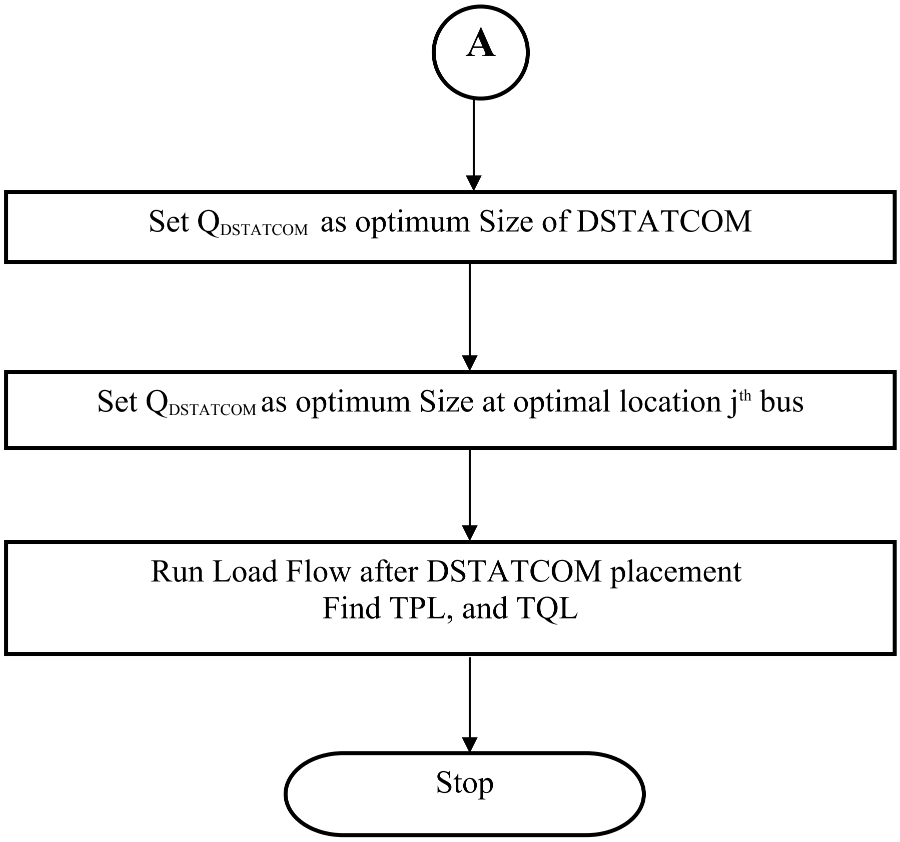



*Figure 3:Flowchart of Proposed System*

# CHAPTER FOUR: EXPECTED OUTCOMES

- Improve distribution system by reducing power losses and improving voltage profiles using D-STATCOM devices in the optimal locations and sizes as determined by this proposed method.

- Energy savings are anticipated due to the lesser size of D- STATCOM required along with the reduction of line losses will enhance the power transmission capability.

# CHAPTER FIVE: RESULT AND DISCUSSION

## 5.1 Load Flow Analysis of 33 Test Bus System

*Table 1:Voltage Profile and Power loss in 33 Test Bus System*

| Bus No | Voltage (pu) | Branch No | Active Power Loss(KW) | Reactive Power Loss(KVAR) |
|---|---|---|---|---|
| 1 | 1 | | 0 | 0 |
| 2 | 0.997038547 | 1-2 | 12.19332189 | 15.36051758 |
| 3 | 0.982978213 | 2-3 | 51.5711351 | 48.29247661 |
| 4 | 0.975521707 | 3-4 | 19.79340576 | 21.65437072 |
| 5 | 0.968150394 | 4-5 | 18.59307931 | 21.03622619 |
| 6 | 0.949796508 | 5-6 | 38.02565427 | 74.06301088 |
| 7 | 0.94634273 | 6-7 | 1.913078362 | 52.05597305 |
| 8 | 0.941495231 | 7-8 | 4.834177391 | 17.24247674 |
| 9 | 0.935242526 | 8-9 | 4.177332944 | 38.60396591 |
| 10 | 0.929442973 | 9-10 | 3.557541344 | 36.72228607 |
| 11 | 0.928582046 | 10-11 | 0.553073448 | 3.060581379 |
| 12 | 0.927080926 | 11-12 | 0.880221606 | 1.337247846 |
| 13 | 0.920992127 | 12-13 | 2.663757376 | 3.38885528 |
| 14 | 0.918745444 | 13-14 | 0.728555663 | 1.622033486 |
| 15 | 0.917343326 | 14-15 | 0.356856434 | 0.623206166 |
| 16 | 0.915982221 | 15-16 | 0.281320134 | 0.452560561 |
| 17 | 0.913977769 | 16-17 | 0.251482745 | 0.899885446 |
| 18 | 0.913373718 | 17-18 | 0.053102918 | 0.172378172 |
| 19 | 0.996183863 | 2-19 | 0.25926263 | 3.940388191 |
| 20 | 0.992608821 | 19-20 | 0.832707742 | 18.27019756 |
| 21 | 0.991905277 | 20-21 | 0.10082228 | 5.592183727 |
| 22 | 0.991269024 | 21-22 | 0.043662262 | 9.181230293 |
| 23 | 0.979393336 | 3-23 | 3.181201344 | 2.4830946 |
| 24 | 0.97272481 | 23-24 | 5.143202368 | 4.699233982 |
| 25 | 0.969401695 | 24-25 | 1.287331231 | 1.317460163 |
| 26 | 0.947880076 | 6-26 | 2.594008193 | 0.08260666 |
| 27 | 0.945334416 | 26-27 | 3.321056189 | 0.074781348 |
| 28 | 0.933930866 | 27-28 | 11.27662095 | 0.276293464 |
| 29 | 0.925743161 | 28-29 | 7.817989336 | 0.0988582 |
| 30 | 0.92221882 | 29-30 | 3.888125789 | 1.988934441 |
| 31 | 0.918038551 | 30-31 | 1.592823445 | 1.58097857 |
| 32 | 0.917117945 | 31-32 | 0.213084662 | 0.249427438 |
| 33 | 0.916832579 | 32-33 | 0.013161647 | 0.020552165 |
| | | | **201.99** | **134.74** |

*Figure 4:Active Power Loss in 33 Test Bus System*

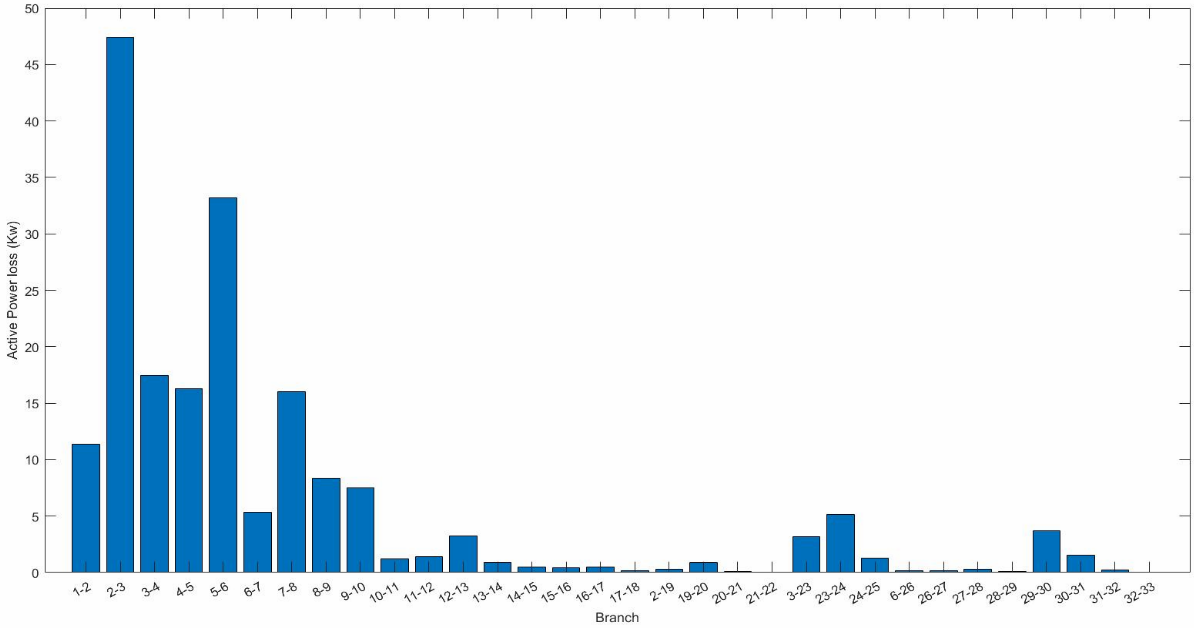
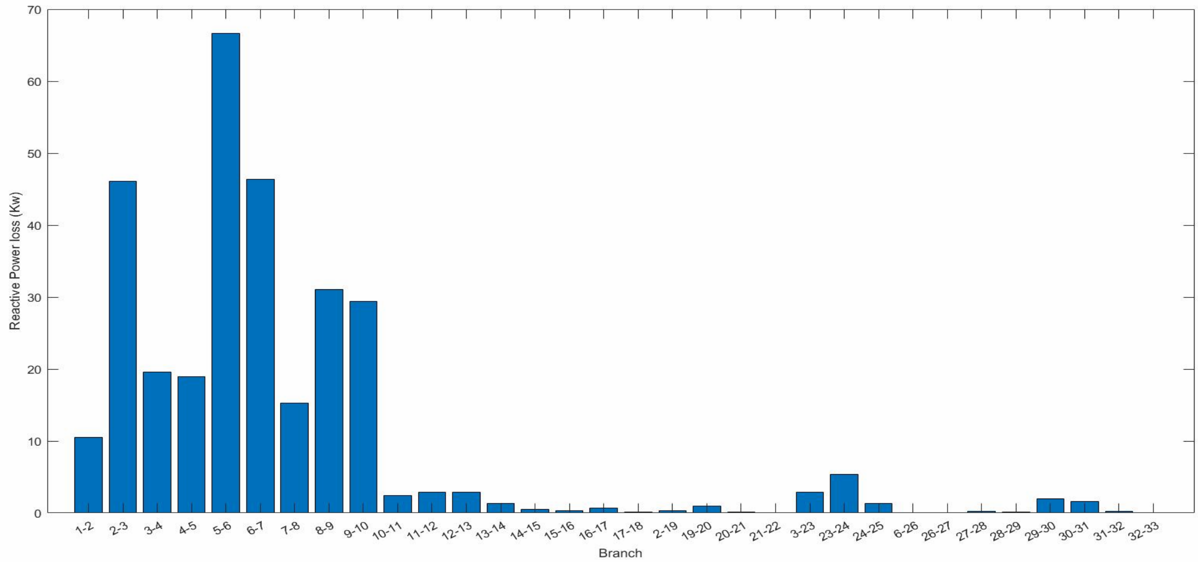



*Figure 5:Reactive Power Loss in 33 Test Bus System*



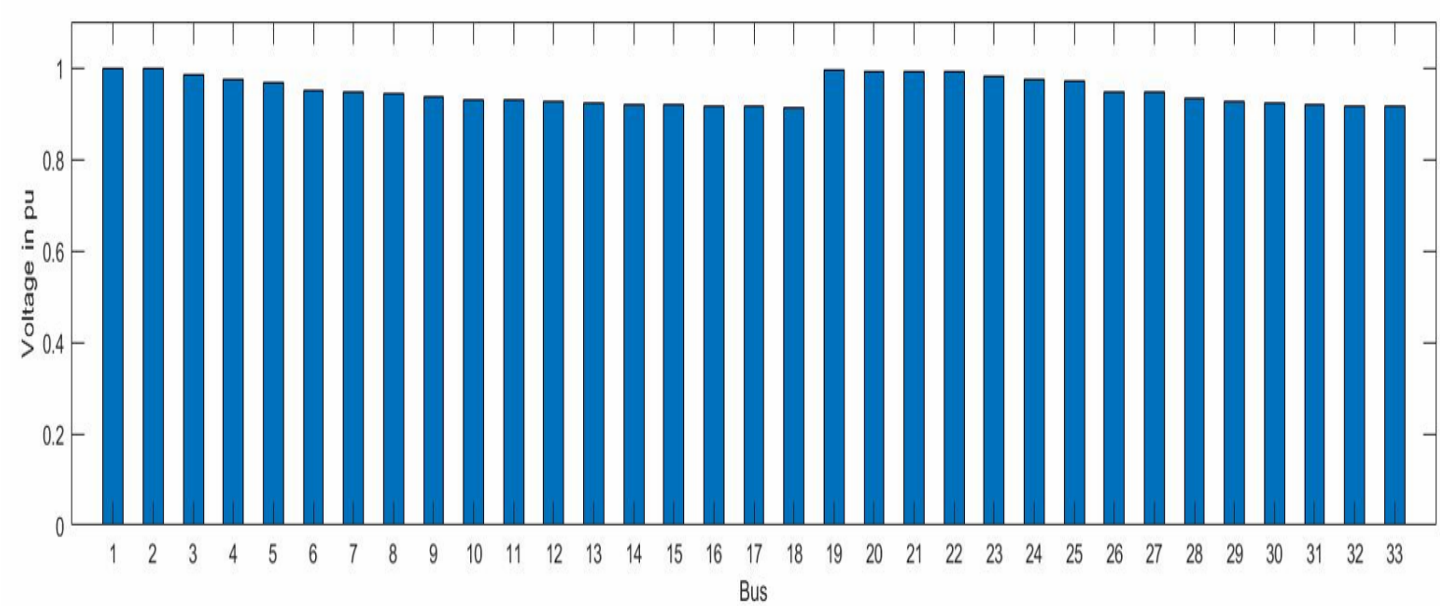



*Figure 6:Voltage Profile of 33 Test Bus*

Backward/Forward sweep algorithm is purposed in testing IEEE 33–bus radial distribution system using MATLAB coding. IEEE 33 bus radial distribution network consists of 33 nodes and 32 branches. The base voltage for this system is 12.66 kV and base MVA is 100. The Total Real power loss is 201.99KW and Total Reactive power loss is 134.74KVAR.The maximum voltage drop occurs in Bus no 18 which is of value 0.9133 pu and becomes 0.9168 pu at Bus no 33.

## 5.2 Load flow Analysis of Begnas Feeder

*Table 2:Voltage Profile and Power loss in Begnas Feeder*

| Bus No | Voltage (pu) | Branch No | Active Power Loss(KW) | Reactive Power Loss(KVAR) |
|---|---|---|---|---|
| 1 | 1 | 1 | 0 | 0 |
| 2 | 0.994313148 | 1-2 | 25.98540153 | 29.81931323 |
| 3 | 0.986543414 | 2-3 | 35.12130338 | 40.30313502 |
| 4 | 0.982950887 | 3-4 | 16.16423758 | 18.54912509 |
| 5 | 0.982617885 | 4-5 | 0.035539319 | 0.021849279 |
| 6 | 0.982361875 | 5-6 | 0.018216972 | 0.011199643 |
| 7 | 0.976623293 | 4-7 | 27.15561829 | 31.16218492 |
| 8 | 0.976233884 | 7-8 | 0.121884953 | 0.139867979 |
| 9 | 0.976163065 | 8-9 | 0.013301777 | 0.015264334 |
| 10 | 0.976077885 | 9-10 | 0.005333521 | 0.006120434 |
| 11 | 0.973325205 | 7-11 | 4.31250971 | 2.651295197 |
| 12 | 0.970971121 | 11-12 | 2.739771982 | 1.684389088 |
| 13 | 0.969435339 | 12-13 | 1.676767618 | 1.030862823 |
| 14 | 0.969386135 | 13-14 | 0.003557572 | 0.002187166 |
| 15 | 0.966985927 | 13-15 | 2.497482506 | 1.535431528 |
| 16 | 0.966012486 | 15-16 | 0.851490205 | 0.523489115 |
| 17 | 0.965058247 | 16-17 | 0.138725945 | 0.08528756 |
| 18 | 0.964397768 | 17-18 | 0.048029566 | 0.029528178 |
| 19 | 0.964905768 | 16-19 | 0.706216649 | 0.810412548 |
| 20 | 0.964684293 | 19-20 | 0.008051787 | 0.004950172 |
| 21 | 0.963651534 | 19-21 | 0.681071554 | 0.781557521 |
| 22 | 0.962876956 | 21-22 | 0.371414576 | 0.426213448 |
| 23 | 0.962129183 | 22-23 | 0.382401834 | 0.235097475 |
| 24 | 0.961017212 | 23-24 | 0.32530236 | 0.199993192 |
| 25 | 0.960272808 | 24-25 | 0.163405398 | 0.100460283 |
| 26 | 0.95999463 | 25-26 | 0.010855688 | 0.004108394 |

| | | | | |
|---|---|---|---|---|
| 27 | 0.959494598 | 25-27 | 0.121578347 | 0.046011989 |
| 28 | 0.95918261 | 27-28 | 0.036559866 | 0.013836281 |
| 29 | 0.958897404 | 28-29 | 0.011142728 | 0.004217026 |
| 30 | 0.955846744 | 29-30 | 8.710958792 | 9.99618222 |
| 31 | 0.951252375 | 30-31 | 12.84529369 | 14.74050096 |
| 32 | 0.947446504 | 31-32 | 10.41370752 | 11.95015617 |
| 33 | 0.944042486 | 32-33 | 9.106792226 | 10.45041731 |
| 34 | 0.943709067 | 33-34 | 0.06603901 | 0.07578247 |
| 35 | 0.94350606 | 34-35 | 0.020110158 | 0.023077231 |
| 36 | 0.94341839 | 35-36 | 0.002895373 | 0.00332256 |
| 37 | 0.940436875 | 33-37 | 8.948138897 | 10.26835611 |
| 38 | 0.935785205 | 37-38 | 10.94908656 | 12.56452556 |
| 39 | 0.928418329 | 38-39 | 16.89773465 | 19.39084304 |
| 40 | 0.922072188 | 39-40 | 14.39158268 | 16.51493095 |
| 41 | 0.920273036 | 40-41 | 1.893130829 | 2.172445214 |
| 42 | 0.919357118 | 41-42 | 0.90099725 | 1.033931271 |
| 43 | 0.918155344 | 42-43 | 1.141147237 | 1.309513222 |
| 44 | 0.917203796 | 43-44 | 0.09767931 | 0.036967268 |
| 45 | 0.916706085 | 44-45 | 0.030662629 | 0.011604439 |
| 46 | 0.916558504 | 45-46 | 0.003031051 | 0.001147118 |
| 47 | 0.915902638 | 43-47 | 1.944711275 | 2.23163589 |
| 48 | 0.914006525 | 47-48 | 1.572383353 | 1.804374339 |
| 49 | 0.91174654 | 48-49 | 1.79687188 | 2.061984125 |
| 50 | 0.910367051 | 49-50 | 0.611116283 | 0.701280981 |
| 51 | 0.909612124 | 50-51 | 0.174337775 | 0.200059742 |
| 52 | 0.908294913 | 51-52 | 0.246607544 | 0.093329972 |
| 53 | 0.907072223 | 52-53 | 0.178155637 | 0.067423974 |
| 54 | 0.905924804 | 53-54 | 0.119489368 | 0.045221404 |
| 55 | 0.905518884 | 54-55 | 0.016905176 | 0.006397856 |
| 56 | 0.90526275 | 54-56 | 0.04137339 | 0.015657985 |

| | | | | |
|---|---|---|---|---|
| 57 | 0.905072053 | 56-57 | 0.003972961 | 0.001503589 |
| 58 | 0.919032137 | 40-58 | 3.711482937 | 4.25907878 |
| 59 | 0.914356977 | 58-59 | 5.993611825 | 3.684822832 |
| 60 | 0.908681704 | 59-60 | 6.393444671 | 3.930636749 |
| 61 | 0.901386576 | 60-61 | 7.937571636 | 4.879953199 |
| 62 | 0.900804347 | 61-62 | 0.04874443 | 0.018447596 |
| 63 | 0.900399541 | 62-63 | 0.016949278 | 0.006414547 |
| 64 | 0.895738511 | 61-64 | 5.252013787 | 3.22889451 |
| 65 | 0.89122954 | 64-65 | 4.105217855 | 2.523853884 |
| 66 | 0.888738105 | 65-66 | 2.068583638 | 1.271748061 |
| 67 | 0.883913519 | 66-67 | 3.812577377 | 2.343940945 |
| 68 | 0.880336771 | 67-68 | 2.536859384 | 1.559640106 |
| 69 | 0.877560601 | 68-69 | 1.856311186 | 1.141244719 |
| 70 | 0.873831146 | 69-70 | 2.41826034 | 1.486726398 |
| 71 | 0.870953993 | 70-71 | 1.628862987 | 1.001411453 |
| 72 | 0.867303993 | 71-72 | 1.916012357 | 1.177948504 |
| | | | **272.5285894** | **280.4847242** |

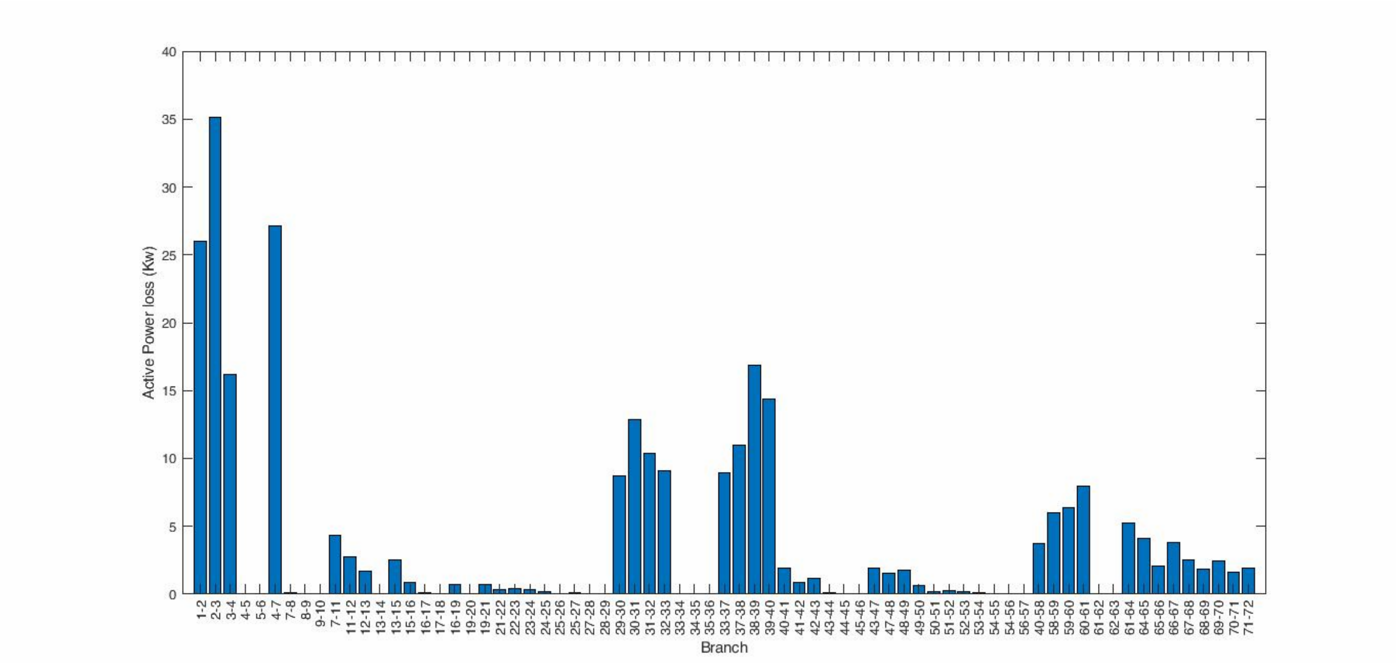
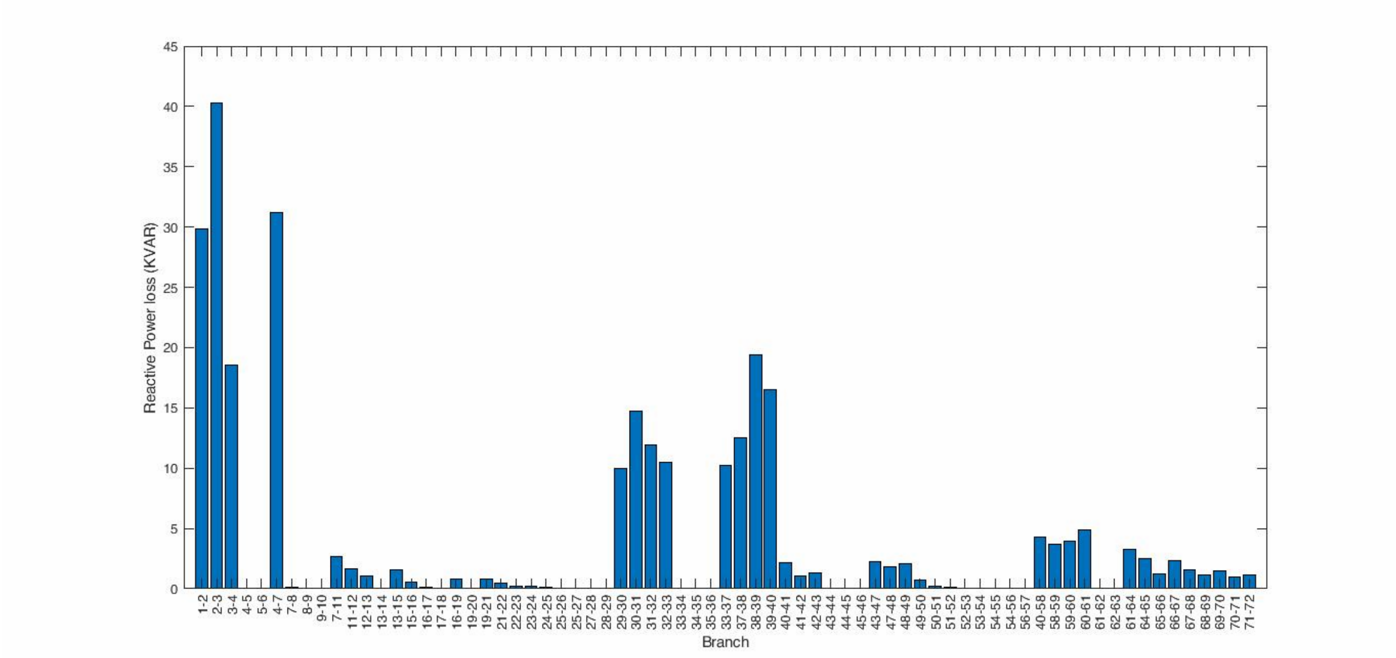



*Figure 7: Active Power Loss in Begnas Feeder*

*Figure 8: Reactive Power Loss of Begnas Feeder*



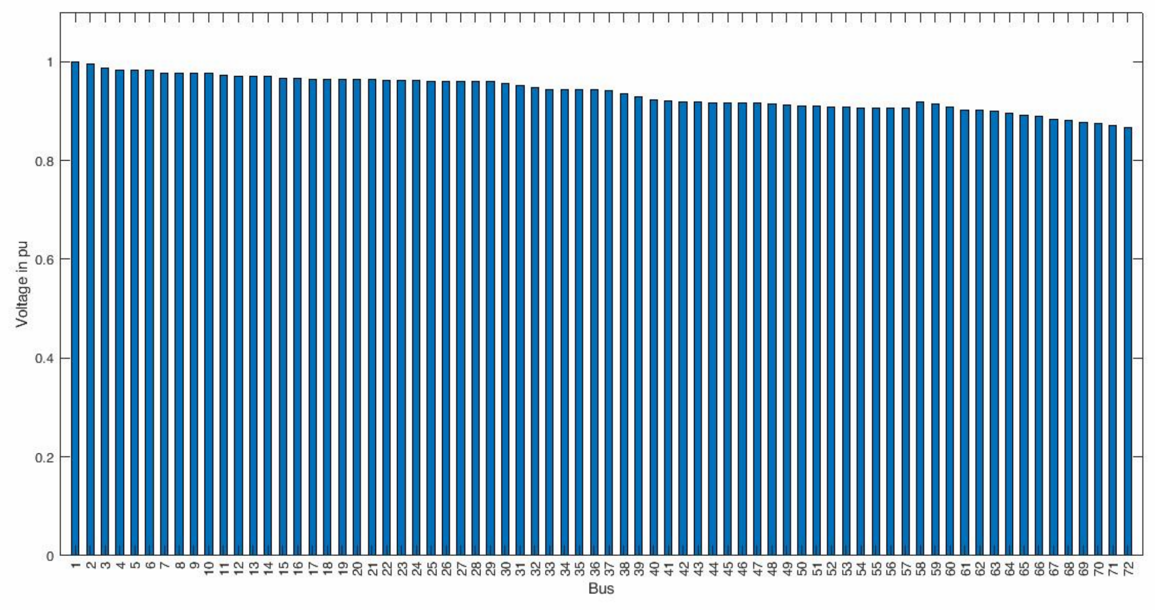



*Figure 9 : Voltage Profile of Begnas Feedder*

For the load flow in the 11 kv Begnas feeder, The base voltage for this system is 11 kV and base MVA is 100. The Total Real power loss is 272.528 KW and Total Reactive power loss is 280.484 KVAR. The maximum voltage drop occurs in Bus no 72 which is of value 0.8673 pu .

# CHAPTER SIX : REMAINING WORKS

The remaining works in the project are:

- Calculation of VSI for all the buses and selection of candidate bus with the highest value of VSI for the optimal placement of D-STATCOM in Begnas Feeder .
- Calculation of Losses after placement of D-STATCOM in the candidate bus with the size varying in the steps of 50 kVAR and select the size of D-STATCOM which gives the minimum losses
- Compare Power loss and load flow in a bus before and after placement of D-STATCOM in Begnas Feeder .

# CHAPTER SEVEN : WORK SCHEDULE

| Tasks | June 14 | June 21 | Jun 30 | July 10 | July31 | Aug 10 | Aug20 | Aug 25 | Sep5 |
|---|---|---|---|---|---|---|---|---|---|
| Project Selection & Proposal writing | | | | | | | | | |
| Proposal Defense | | | | | | | | | |
| Literature review | | | | | | | | | |
| Data Collection | | | | | | | | | |
| Load Flow Analysis of IEEE 33 Bus System | | | | | | | | | |
| Load Flow Analysis in the Real Feeder System | | | | | | | | | |
| Load Flow Analysis and Optimal Size / location selection in real feeder system after D-STATCOM penetration. | | | | | | | | | |
| Documentation and report writing | | | | | | | | | |

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# APPENDIX

*Table 3: Specification of ACSR Conductor*

| Data for Aluminium Conductors Steel Reinforced (ACSR) As per IS 398 (Part-II): 1996 | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Code Words** | **Aluminium Area (Sq.mm)** | | **Total Sectional Area (Sq.mm)** | **Stranding & Wire Diameter** | | | | **Overall Dia (mm) (Approximate)** | **Weight Mass** | | | **Resistance at 20°C (ohm/ km) (Max)** | **Ultimate Breaking Load (N)** | **Current Carrying Capacity** | | |
| | **Sectional Area** | **Nominal Area** | | **Conductor (Al)** | | **Conductor (Steel)** | | | **Al kg/ km** | **Steel kg/ km** | **Total kg/ km** | | | **90°C** | **75°C** | **65°C** |
| | | | | **No.** | **Dia (mm)** | **No.** | **Dia (mm)** | | | | | | | **Amp** | **Amp** | **Amp** |
| Kundah | 404.1 | 400 | 425.2 | 42 | 1.96 | 7 | 1.96 | 26.88 | 1119 | 163 | 1282 | 0.07311 | 88790 | - | 705 | 566 |
| Zebra | 428.9 | 420 | 484.5 | 54 | 3.18 | 7 | 3.18 | 28.62 | 1182 | 439 | 1621 | 0.06868 | 130320 | - | 737 | 590 |
| Moose | 528.5 | 520 | 597 | 54 | 3.53 | 7 | 3.53 | 31.77 | 1463 | 535 | 1998 | 0.05595 | 159600 | - | 836 | 667 |
| Racoon | 78.83 | 80 | 91.97 | 6 | 4.09 | 1 | 4.09 | 12.27 | 215 | 103 | 318 | 0.3712 | 26910 | - | 244 | 200 |
| Panther | 212.1 | 200 | 261.5 | 30 | 3 | 7 | 3 | 21 | 588.5 | 387.5 | 976 | 0.139 | 89670 | - | 487 | 395 |
| Squirrel | 20.98 | 20 | 24.48 | 6 | 2.11 | 1 | 2.11 | 6.33 | 58 | 27 | 85 | 1.394 | 7610 | - | 107 | 89 |
| Weasel | 31.61 | 30 | 36.88 | 6 | 2.59 | 1 | 2.59 | 7.77 | 87 | 41 | 128 | 0.9289 | 11120 | - | 138 | 114 |
| Mole | 10.6 | 10 | 12.37 | 6 | 1.5 | 1 | 1.5 | 4.5 | 29 | 14 | 43 | 2.78 | 3970 | - | 70 | 58 |
| **Dog** | **105** | **100** | **118.5** | **6** | **4.72** | **7** | **1.57** | **14.15** | **288.3** | **105.7** | **394** | **0.2792** | **32410** | **-** | **291** | **239** |
| Rabbit | 52.88 | 50 | 61.7 | 6 | 3.35 | 1 | 3.35 | 10.05 | 145 | 69 | 214 | 0.5524 | 18250 | - | 190 | 157 |
| Wolf | 158.1 | 150 | 194.9 | 30 | 2.59 | 7 | 2.59 | 18.13 | 438 | 289 | 727 | 0.1871 | 67340 | - | 405 | 329 |

| ACSR Code Number | Type of ACSR | Calculated Resistance at 20°C (ohms/km) (Max) | Current Rating Max. (Amps) | Nominal Aluminium Area (sq. mm) | Inductive Reactance (ohm/km) | Weight (kg/km) |
|---|---|---|---|---|---|---|
| 1 | Squirrel | 1.374 | 76 | 20 | 0.355 | 80 |
| 2 | Gopher | 1.098 | 85 | 25 | 0.349 | 106 |
| 3 | Weasel | 0.9116 | 95 | 30 | 0.345 | 128 |
| 4 | Rabbit | 0.5449 | 135 | 50 | 0.335 | 214 |
| 5 | Otter | 0.3434 | 185 | 80 | 0.328 | 339 |
| **6** | **Dog** | **0.2792** | **205** | **100** | **0.315** | **394** |

*Table 4 : Line Data of 33 Test Bus System*

| Branch No | From | To | R (ohm) | X (ohm) |
|---|---|---|---|---|
| 1 | 1 | 2 | 0.0922 | 0.047 |
| 2 | 2 | 3 | 0.493 | 0.2511 |
| 3 | 3 | 4 | 0.366 | 0.1864 |
| 4 | 4 | 5 | 0.3811 | 0.1941 |
| 4 | 5 | 6 | 0.819 | 0.707 |
| 6 | 6 | 7 | 0.1872 | 0.6188 |
| 7 | 7 | 8 | 0.7114 | 0.2351 |
| 8 | 8 | 9 | 1.03 | 0.74 |
| 9 | 9 | 10 | 1.044 | 0.74 |
| 10 | 10 | 11 | 0.1966 | 0.065 |
| 11 | 11 | 12 | 0.3744 | 0.1238 |
| 12 | 12 | 13 | 1.468 | 1.155 |
| 13 | 13 | 14 | 0.5416 | 0.7129 |
| 14 | 14 | 15 | 0.591 | 0.526 |
| 15 | 15 | 16 | 0.7463 | 0.545 |
| 16 | 16 | 17 | 1.289 | 1.721 |
| 17 | 17 | 18 | 0.732 | 0.574 |
| 18 | 2 | 19 | 0.264 | 0.2565 |
| 19 | 19 | 20 | 1.5042 | 1.3554 |
| 20 | 20 | 21 | 0.4095 | 0.4784 |
| 21 | 21 | 22 | 0.7089 | 0.9373 |
| 22 | 3 | 23 | 0.4512 | 0.3083 |
| 23 | 23 | 24 | 0.898 | 0.7091 |
| 24 | 24 | 25 | 0.896 | 0.7011 |
| 25 | 6 | 26 | 0.203 | 0.1034 |
| 26 | 26 | 27 | 0.2842 | 0.1447 |
| 27 | 27 | 28 | 1.059 | 0.9337 |
| 28 | 28 | 29 | 0.8042 | 0.7006 |
| 29 | 29 | 30 | 0.5075 | 0.2585 |
| 30 | 30 | 31 | 0.9744 | 0.963 |
| 31 | 31 | 32 | 0.3105 | 0.3619 |
| 32 | 32 | 33 | 0.341 | 0.5302 |

*Table 5:Load Data 33 Test Bus System*

| **Branch No** | **P (KW)** | **Q (KVAR)** |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 100 | 60 |
| 3 | 90 | 40 |
| 4 | 120 | 80 |
| 4 | 60 | 30 |
| 6 | 60 | 20 |
| 7 | 200 | 100 |
| 8 | 200 | 100 |
| 9 | 60 | 20 |
| 10 | 60 | 20 |
| 11 | 45 | 30 |
| 12 | 60 | 35 |
| 13 | 60 | 35 |
| 14 | 120 | 80 |
| 15 | 60 | 10 |
| 16 | 60 | 20 |
| 17 | 60 | 20 |
| 18 | 90 | 40 |
| 19 | 90 | 40 |
| 20 | 90 | 40 |
| 21 | 90 | 40 |
| 22 | 90 | 40 |
| 23 | 90 | 50 |
| 24 | 420 | 200 |
| 25 | 420 | 200 |
| 26 | 60 | 25 |
| 27 | 60 | 25 |
| 28 | 60 | 20 |
| 29 | 120 | 70 |
| 30 | 200 | 600 |
| 31 | 150 | 70 |
| 32 | 210 | 100 |
| 33 | 60 | 40 |

*Table 6:Line Data of Begnas Feeder*

| Branch Number | From Bus | To Bus | Length(km) | R(ohm) | X(ohm) |
|---|---|---|---|---|---|
| | | 1 | | | |
| 1 | 1 | 2 | 0.324 | 0.088938 | 0.10206 |
| 2 | 2 | 3 | 0.45 | 0.123525 | 0.14175 |
| 3 | 3 | 4 | 0.21 | 0.057645 | 0.06615 |
| 4 | 4 | 5 | 0.529 | 0.288252 | 0.177215 |
| 5 | 5 | 6 | 0.61 | 0.332389 | 0.20435 |
| 6 | 4 | 7 | 0.39 | 0.107055 | 0.12285 |
| 7 | 7 | 8 | 0.32 | 0.08784 | 0.1008 |
| 8 | 8 | 9 | 0.097 | 0.026627 | 0.030555 |
| 9 | 9 | 10 | 0.35 | 0.096075 | 0.11025 |
| 10 | 7 | 11 | 0.43 | 0.234307 | 0.14405 |
| 11 | 11 | 12 | 0.345 | 0.187991 | 0.115575 |
| 12 | 12 | 13 | 0.24 | 0.130776 | 0.0804 |
| 13 | 13 | 14 | 0.116 | 0.063208 | 0.03886 |
| 14 | 13 | 15 | 0.41 | 0.223409 | 0.13735 |
| 15 | 15 | 16 | 0.19 | 0.103531 | 0.06365 |
| 16 | 16 | 17 | 1.12 | 0.610288 | 0.3752 |
| 17 | 17 | 18 | 1.55 | 0.844595 | 0.51925 |
| 18 | 16 | 19 | 0.45 | 0.123525 | 0.14175 |
| 19 | 19 | 20 | 1.04 | 0.566696 | 0.3484 |
| 20 | 19 | 21 | 0.6 | 0.1647 | 0.189 |
| 21 | 21 | 22 | 0.42 | 0.11529 | 0.1323 |
| 22 | 22 | 23 | 0.25 | 0.136225 | 0.08375 |
| 23 | 23 | 24 | 0.65 | 0.354185 | 0.21775 |
| 24 | 24 | 25 | 0.58 | 0.316042 | 0.1943 |
| 25 | 25 | 26 | 0.83 | 0.756628 | 0.28635 |
| 26 | 25 | 27 | 0.58 | 0.528728 | 0.2001 |

| | | | | | |
|---|---|---|---|---|---|
| 27 | 27 | 28 | 0.31 | 0.282596 | 0.10695 |
| 28 | 28 | 29 | 0.85 | 0.77486 | 0.29325 |
| 29 | 7 | 30 | 0.29 | 0.079605 | 0.09135 |
| 30 | 30 | 31 | 0.448 | 0.122976 | 0.14112 |
| 31 | 31 | 32 | 0.381 | 0.104585 | 0.120015 |
| 32 | 32 | 33 | 0.35 | 0.096075 | 0.11025 |
| 33 | 33 | 34 | 0.45 | 0.123525 | 0.14175 |
| 34 | 34 | 35 | 0.548 | 0.150426 | 0.17262 |
| 35 | 35 | 36 | 0.71 | 0.194895 | 0.22365 |
| 36 | 33 | 37 | 0.402 | 0.110349 | 0.12663 |
| 37 | 37 | 38 | 0.55 | 0.150975 | 0.17325 |
| 38 | 38 | 39 | 0.9 | 0.24705 | 0.2835 |
| 39 | 39 | 40 | 0.79 | 0.216855 | 0.24885 |
| 40 | 40 | 41 | 0.482 | 0.132309 | 0.15183 |
| 41 | 41 | 42 | 0.263 | 0.072194 | 0.082845 |
| 42 | 42 | 43 | 0.358 | 0.098271 | 0.11277 |
| 43 | 43 | 44 | 1.09 | 0.993644 | 0.37605 |
| 44 | 44 | 45 | 0.95 | 0.86602 | 0.32775 |
| 45 | 45 | 46 | 0.845 | 0.770302 | 0.291525 |
| 46 | 43 | 47 | 0.74 | 0.20313 | 0.2331 |
| 47 | 47 | 48 | 0.65 | 0.178425 | 0.20475 |
| 48 | 48 | 49 | 0.81 | 0.222345 | 0.25515 |
| 49 | 49 | 50 | 0.89 | 0.244305 | 0.28035 |
| 50 | 50 | 51 | 0.936 | 0.256932 | 0.29484 |
| 51 | 51 | 52 | 0.83 | 0.756628 | 0.28635 |
| 52 | 52 | 53 | 0.99 | 0.902484 | 0.34155 |
| 53 | 53 | 54 | 1.3 | 1.18508 | 0.4485 |
| 54 | 54 | 55 | 1.15 | 1.04834 | 0.39675 |
| 55 | 54 | 56 | 1.25 | 1.1395 | 0.43125 |
| 56 | 56 | 57 | 1.08 | 0.984528 | 0.3726 |

| | | | | | |
|---|---|---|---|---|---|
| 57 | 40 | 58 | 0.71 | 0.194895 | 0.22365 |
| 58 | 58 | 59 | 0.65 | 0.354185 | 0.21775 |
| 59 | 59 | 60 | 0.9 | 0.49041 | 0.3015 |
| 60 | 60 | 61 | 1.2 | 0.65388 | 0.402 |
| 61 | 61 | 62 | 0.82 | 0.747512 | 0.2829 |
| 62 | 62 | 63 | 1.14 | 1.039224 | 0.3933 |
| 63 | 61 | 64 | 1.09 | 0.593941 | 0.36515 |
| 64 | 64 | 65 | 0.89 | 0.484961 | 0.29815 |
| 65 | 65 | 66 | 0.54 | 0.294246 | 0.1809 |
| 66 | 66 | 67 | 1.1 | 0.59939 | 0.3685 |
| 67 | 67 | 68 | 0.91 | 0.495859 | 0.30485 |
| 68 | 68 | 69 | 0.75 | 0.408675 | 0.25125 |
| 69 | 69 | 70 | 1.04 | 0.566696 | 0.3484 |
| 70 | 70 | 71 | 0.92 | 0.501308 | 0.3082 |
| 71 | 71 | 72 | 1.26 | 0.686574 | 0.4221 |

*Table 7:Load Data of Begnas Feeder*

| Branch Number | From Bus | To Bus | PL (KW) | QL(KVAR) |
|---|---|---|---|---|
| | | 1 | 0 | 0 |
| 1 | 1 | 2 | 75.2 | 27.288 |
| 2 | 2 | 3 | 37.6 | 13.644 |
| 3 | 3 | 4 | 150.4 | 54.576 |
| 4 | 4 | 5 | 37.6 | 13.644 |
| 5 | 5 | 6 | 75.2 | 27.288 |
| 6 | 4 | 7 | 0 | 0 |
| 7 | 7 | 8 | 150.4 | 54.576 |
| 8 | 8 | 9 | 150.4 | 54.576 |
| 9 | 9 | 10 | 75.2 | 27.288 |
| 10 | 7 | 11 | 150.4 | 54.576 |
| 11 | 11 | 12 | 75.2 | 27.288 |
| 12 | 12 | 13 | 0 | 0 |
| 13 | 13 | 14 | 75.2 | 27.288 |
| 14 | 13 | 15 | 150.4 | 54.576 |
| 15 | 15 | 16 | 0 | 0 |
| 16 | 16 | 17 | 75.2 | 27.288 |
| 17 | 17 | 18 | 75.2 | 27.288 |
| 18 | 16 | 19 | 75.2 | 27.288 |
| 19 | 19 | 20 | 37.6 | 13.644 |
| 20 | 19 | 21 | 75.2 | 27.288 |
| 21 | 21 | 22 | 37.6 | 13.644 |
| 22 | 22 | 23 | 225.6 | 81.864 |
| 23 | 23 | 24 | 75.2 | 27.288 |
| 24 | 24 | 25 | 37.6 | 13.644 |
| 25 | 25 | 26 | 37.6 | 13.644 |
| 26 | 25 | 27 | 37.6 | 13.644 |
| 27 | 27 | 28 | 75.2 | 27.288 |
| 28 | 28 | 29 | 37.6 | 13.644 |
| 29 | 7 | 30 | 75.2 | 27.288 |
| 30 | 30 | 31 | 75.2 | 27.288 |
| 31 | 31 | 32 | 75.2 | 27.288 |
| 32 | 32 | 33 | 0 | 0 |
| 33 | 33 | 34 | 112.8 | 40.932 |
| 34 | 34 | 35 | 75.2 | 27.288 |
| 35 | 35 | 36 | 37.6 | 13.644 |
| 36 | 33 | 37 | 150.4 | 54.576 |
| 37 | 37 | 38 | 75.2 | 27.288 |
| 38 | 38 | 39 | 37.6 | 13.644 |

| | | | | |
|---|---|---|---|---|
| 39 | 39 | 40 | 0 | 0 |
| 40 | 40 | 41 | 75.2 | 27.288 |
| 41 | 41 | 42 | 37.6 | 13.644 |
| 42 | 42 | 43 | 0 | 0 |
| 43 | 43 | 44 | 37.6 | 13.644 |
| 44 | 44 | 45 | 37.6 | 13.644 |
| 45 | 45 | 46 | 18.8 | 6.822 |
| 46 | 43 | 47 | 37.6 | 13.644 |
| 47 | 47 | 48 | 37.6 | 13.644 |
| 48 | 48 | 49 | 376 | 136.44 |
| 49 | 49 | 50 | 225.6 | 81.864 |
| 50 | 50 | 51 | 75.2 | 27.288 |
| 51 | 51 | 52 | 37.6 | 13.644 |
| 52 | 52 | 53 | 37.6 | 13.644 |
| 53 | 53 | 54 | 0 | 0 |
| 54 | 54 | 55 | 37.6 | 13.644 |
| 55 | 54 | 56 | 37.6 | 13.644 |
| 56 | 56 | 57 | 18.8 | 6.822 |
| 57 | 40 | 58 | 75.2 | 27.288 |
| 58 | 58 | 59 | 150.4 | 54.576 |
| 59 | 59 | 60 | 37.6 | 13.644 |
| 60 | 60 | 61 | 75.2 | 27.288 |
| 61 | 61 | 62 | 37.6 | 13.644 |
| 62 | 62 | 63 | 37.6 | 13.644 |
| 63 | 61 | 64 | 18.8 | 6.822 |
| 64 | 64 | 65 | 75.2 | 27.288 |
| 65 | 65 | 66 | 37.6 | 13.644 |
| 66 | 66 | 67 | 75.2 | 27.288 |
| 67 | 67 | 68 | 37.6 | 13.644 |
| 68 | 68 | 69 | 18.8 | 6.822 |
| 69 | 69 | 70 | 75.2 | 27.288 |
| 70 | 70 | 71 | 37.6 | 13.644 |
| 71 | 71 | 72 | 473.76 | 171.9144 |