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PASHCHIMANCHAL CAMPUS, POKHARA

A PROJECT FINAL REPORT ON

Performance Analysis of Placement and Sizing of D-STATCOM in

Radial Distribution Network

A case study in Begnas Feeder, Lekhnath

by

Shankar Singh Thakuri

A FINAL PROJECT REPORT

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**Performance Analysis of Placement and Sizing of D-STATCOM in Radial
Distribution Network: A case study in Begnas Feeder, Lekhnath**

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ABSTARCT

An electric power system's distribution system connects high-voltage transmission networks to final consumers. This work provides a method for enhancing the voltage profile and lowering power loss in the distribution network by introducing reactive power into the system. Power quality problems such as low voltage and higher loss are typically found in radial distribution networks or systems with long line lengths and heavy loading. The Lekhnath Distribution Center's Begnas Feeder is the subject of this investigation. In this work, the first condition has aimed to find the size of D-STATCOM and its placement by using Variational Technique method and VSI method respectively. Backward and forward load flow analysis is selected to compute all the required parameters in the existing Distribution System. Placement of D-STATCOM has indeed improved voltage profile with active power loss reductions in the 11 KV Begnas Feeder of Lekhnath DC. The results obtained are compared without and with D-STATCOM.

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LIST OF ABBREVIATIONS

ABC	Aerial Bundled Conductor
AC	Alternating Current
ACSR	Aluminum Conductor Reinforced
DC	Direct Current
DCS	Distributed Control System
DG	Distributed Generation
D-STATCOM	Distribution Static Compensator
INPS	Integrated Nepal Power System
HT	High Tensile
NEA	Nepal Electricity Authority
PWM	Pulse Width Modulation
TAPL	Total Active Power Loss
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) 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 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.

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), followed by size calculation through a variational technique.

1.3 Objectives

The objectives of the project are:

- To assess the effectiveness of Voltage Stability Index (VSI) approach for the placement 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 placement and sizing of D-STATCOM.

1.4 Scope and Limitations

The project can be applied to assess the initial placement of D-STATCOM in radial system of Begnas Feeder for voltage profile improvement. As the approach involves finding the size of D-STATCOM based on minimum feeder's total active power loss, the voltage profile improves but does not meet the voltage regulation standards. There is a trade-off one has to pay for either having minimum feeder losses or having voltage

profile improvement on par the voltage regulation standards. This limitation is posed by the technique used for sizing and placement of D-STATCOM.

1.5 Report Organization

The first chapter deals with a brief introduction of the project background, problem statement, objectives, scope and limitation and report organization. In the second chapter, the brief of review of different literature during the study regarding the project is presented. The third chapter provides description of the methodology followed in the course of the study in brief. In the fourth chapter, the results obtained are presented and discussed in detail. The fifth chapter presents conclusions of the study and recommendations for the further additions that can be done in the study.

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 a method for allocating D-STATCOM in radial distribution network: voltage stability index (VSI). The 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 value 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 profile.

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 2.1.

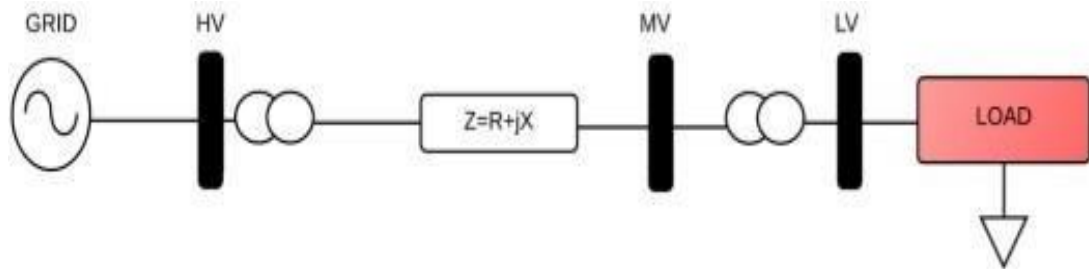


Figure 2.1: Radial Distribution Network

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. R_{dc} and R_{dc} 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 V_i 's amplitude. The phasor graphs in Figure 2.2 provide an illustration of the D-STATCOM operation.

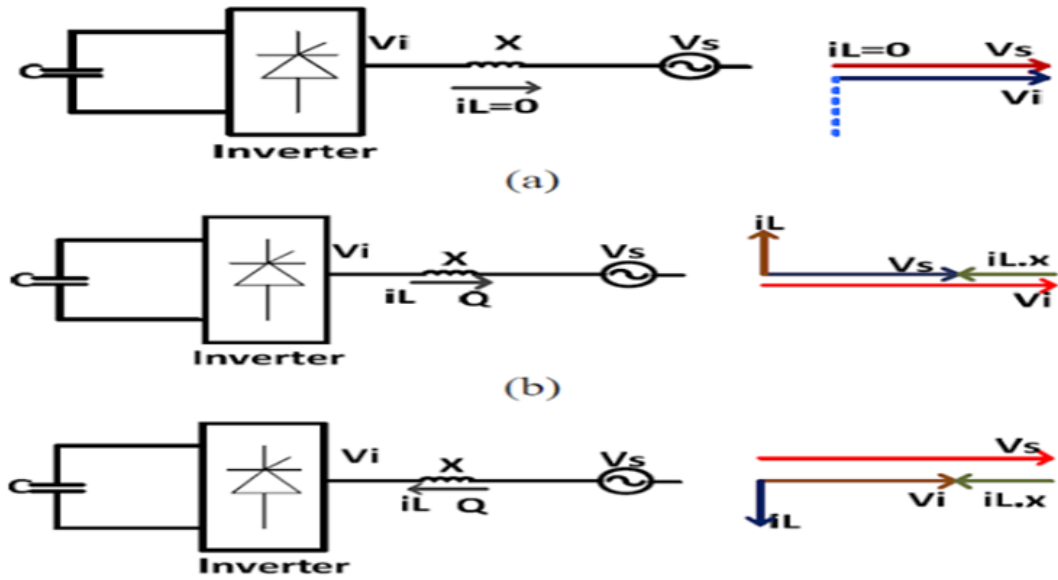


Figure 2.2: D-STATCOM

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.

Calculation of Load Current:

$$I_{Ln} = (P_n - jQ_n)/V_n \quad n = 1, 2. \quad [1]$$

I_{Ln} = Load Current

N = total. No. of buses

P_n = Active power

Q_n = Reactive power

V_n = Bus Voltage

Backward Forward Sweep Method:

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

$$[I_B] = [BIBC] [I_L] \quad [2]$$

I_B = 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.

$$V_n(K) = V_m(K) - I_B(K) * Z_m(K) \quad [3]$$

Where $K = 1, 2, \dots, N_b$ N_b = total no. of Branches.

$V_n(K)$ = 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. It is concluded that the following load flow method is an efficient method for fast convergence tendency in radial distribution networks.

CHAPTER THREE: METHODOLOGY

3.1 Collection of Data

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. The Linedata and Load data are appended in the Appendix I.

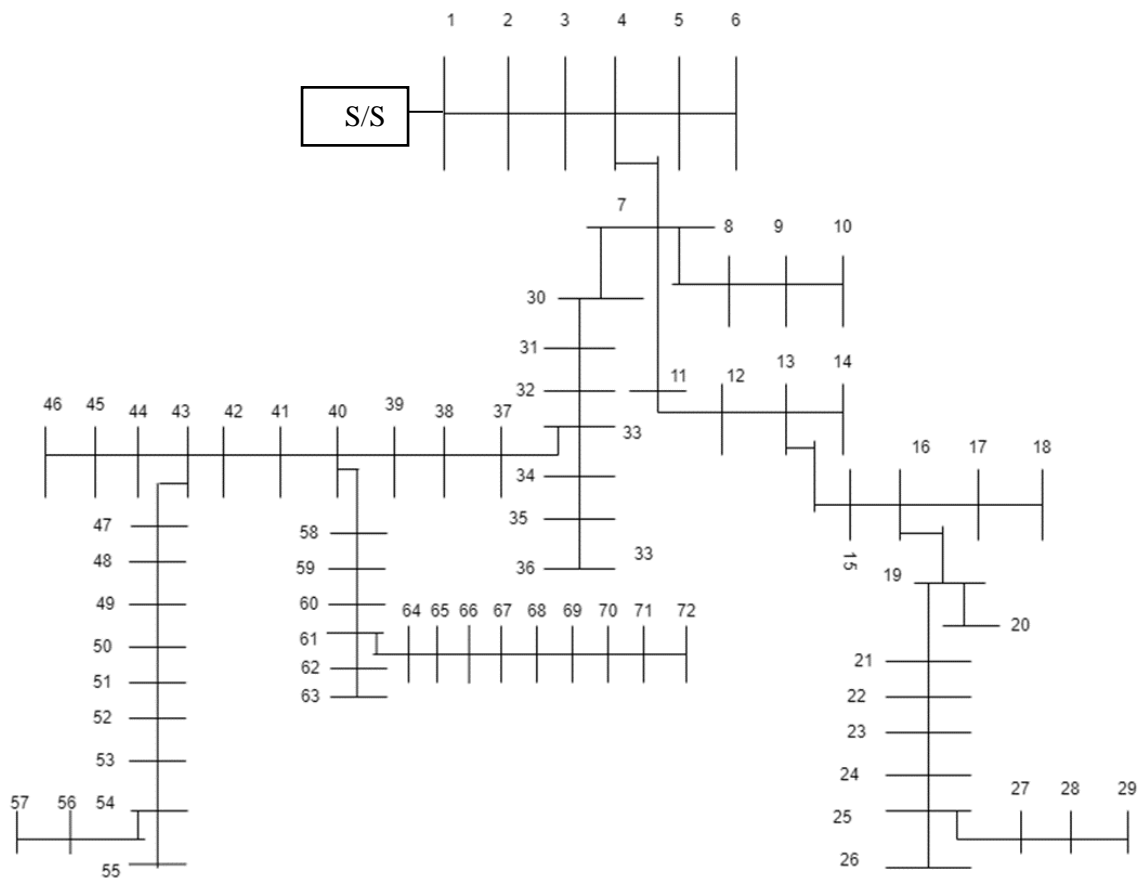


Figure 3.1: Line Diagram of Begnas Feeder

3.2 Location of D-STATCOM

3.2.1 Voltage Stability Index for finding location of D-STATCOM

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

$$VSI = \frac{4R_m (P_n^2 + Q_n^2)}{(V_m^2 P_n)} \quad [4]$$

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 (3.1).
- Step 4: Select the candidate bus with highest value of stability index.
- Step 5: Stop.

The required code for calculating VSI is appended in Appendix-II.

3.2.2 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 size of D-STATCOM. Steps for calculating the 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 Voltage Stability Index (VSI).
- Step 2: Place the D-STATCOM at candidate bus with size varying in steps of 50 kvar.
- Step 3: Find the feeder's total active power losses after placement of D-STATCOM.

- Step 4: Select the size of D-STATCOM which gives minimum losses.
- Step 5: Stop.

The required code for calculating is appended in Appendix-II.

Flow Chart of Proposed Methodology

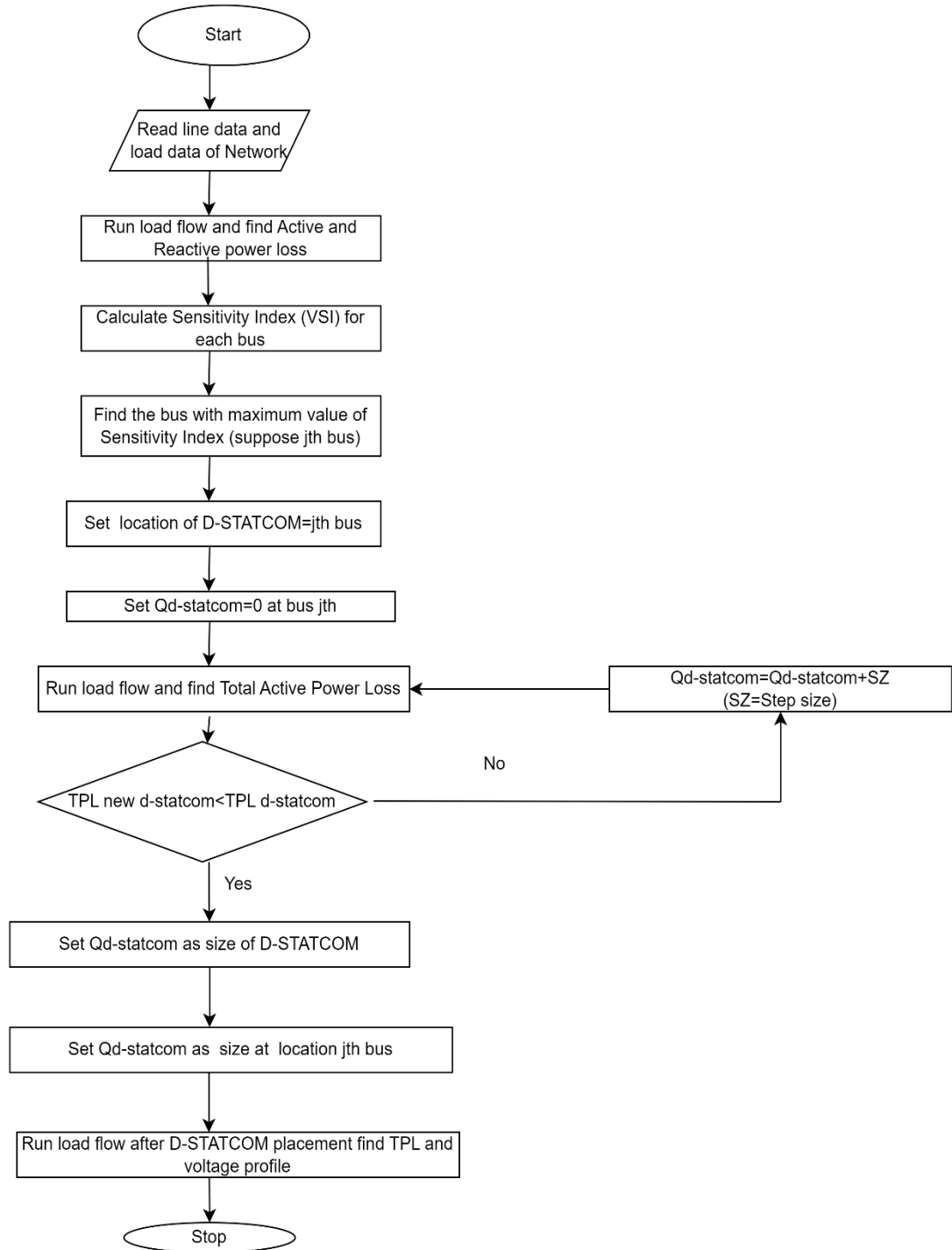


Figure 3.2: Flowchart of Proposed Methodology

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 Load Flow Analysis of Begnas Feeder at BaseCase.

The Linedata and Load data were obtained and fed to the load flow analysis code written in MATLAB. The code was based on the Backward Forward Sweep Method. The corresponding code is appended in the Appendix. The results of the Load Flow Analysis graphed in Figure 4.1, Figure 4.2 and Figure 4.3 in terms of voltage profile, active power loss and reactive power loss of the feeder respectively.

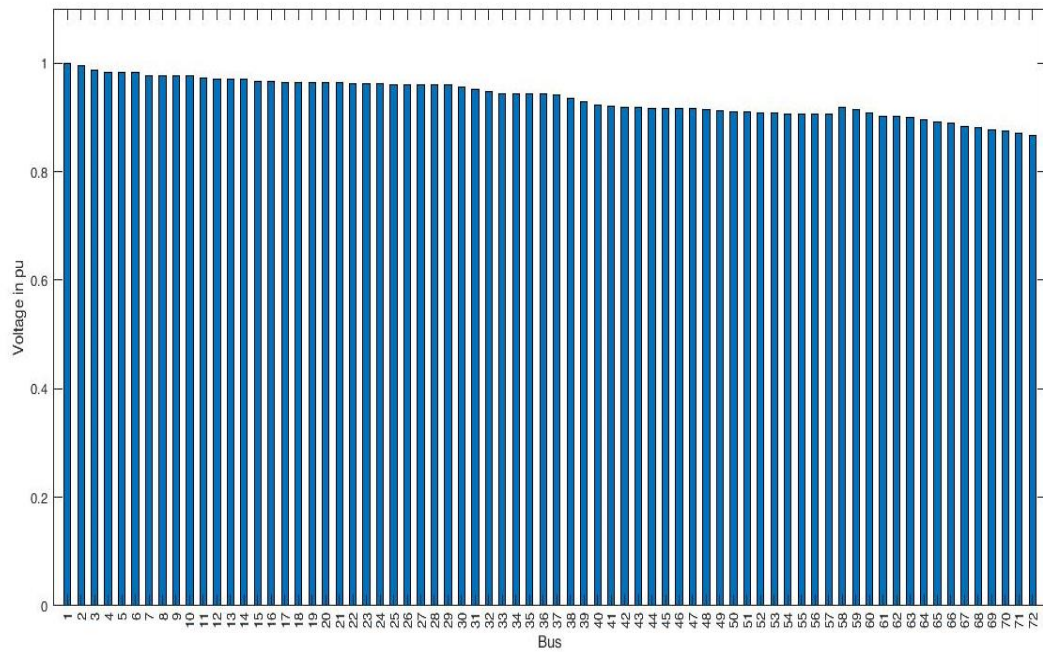


Figure 4.1: Voltage Profile of Begnas Feeder at BaseCase.

Figure 4.1 shows the voltage profile of each bus at the base case scenario. Bus 72 has the lowest voltage with the value of 0.8673 pu, which is justified as the bus 72 is the farthest bus from the substation.

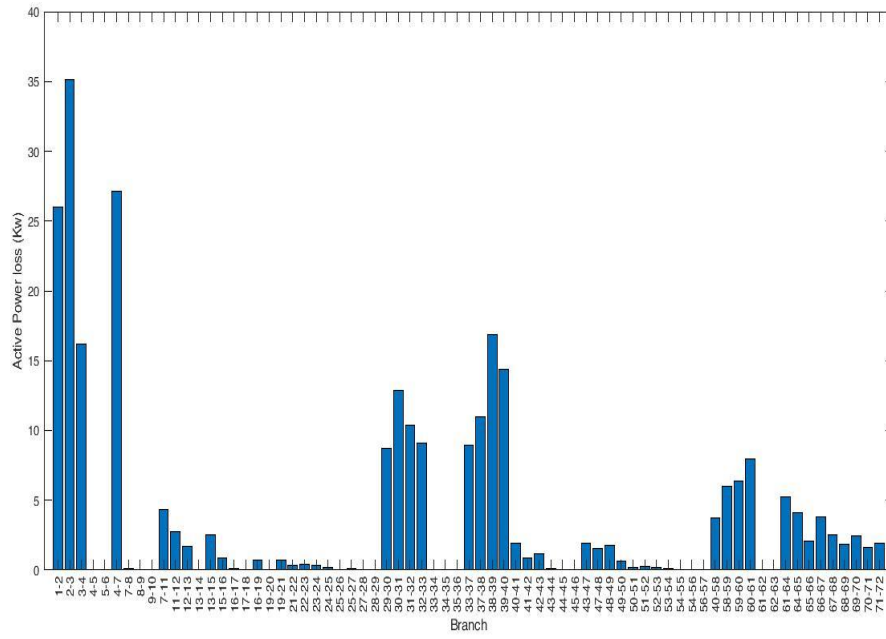


Figure 4.2: Active Power Loss of Begnas Feeder at BaseCase.

Figure 4.2 shows the distribution of active power loss across the branches in the feeder network. The total active power loss during base case scenario is 272.528 kW.

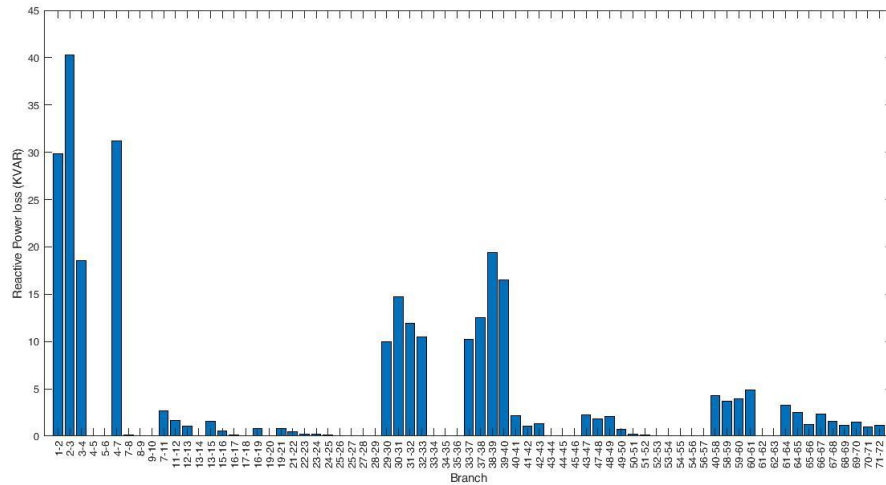


Figure 4.3: Reactive Power Loss of Begnas Feeder at BaseCase.

Figure 4.3 portrays the reactive power loss of each branch in the feeder. The total reactive power loss in the feeder for base case scenario is found to be 280.484 kvar.

4.2 Voltage Stability Index Calculation

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. It is found that VSI is highest at bus no 72 in our feeder. Hence the location of D-STATCOM for its placement is Bus 72 by VSI method. Figure 4.4 shows the VSI of all the buses and shows that Bus 72 has the highest among the all. The value obtained for bus 72 was 0.0014. The other is tabulated and appended in the Appendix.

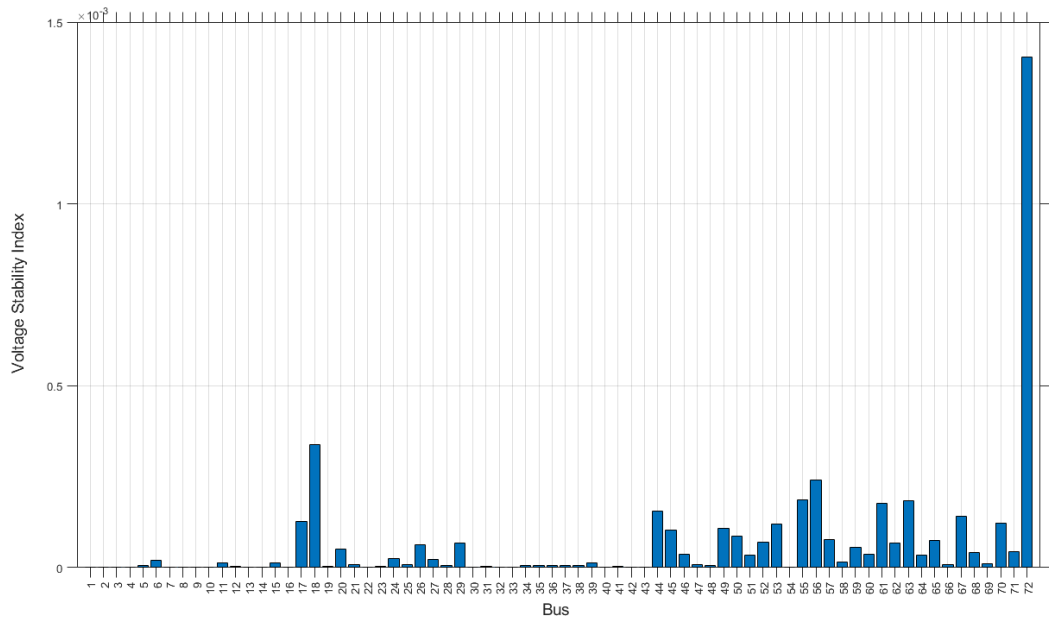


Figure 4.4: VSI for each bus in the Feeder.

4.3 Load Flow Analysis for Minimum Feeder Active Power Loss

To find the size of the D-STATCOM 50kvar of penetration size was chosen and penetrated at Bus 72. Then in steps of 50kvar D-STATCOM was introduced successively and load flow Analysis was performed and total losses were determined for up to 800kvar. Figure 4.5 show the loss vs the size of the D-STATCOM. The graph indicates that as the size increase TAPL decreases and continues for some sizes but once the threshold reaches for the size of D-STATCOM the TAPL increases again. The

D-STATCOM size corresponding to final minimum point was chosen as the required size for placement at bus 72.

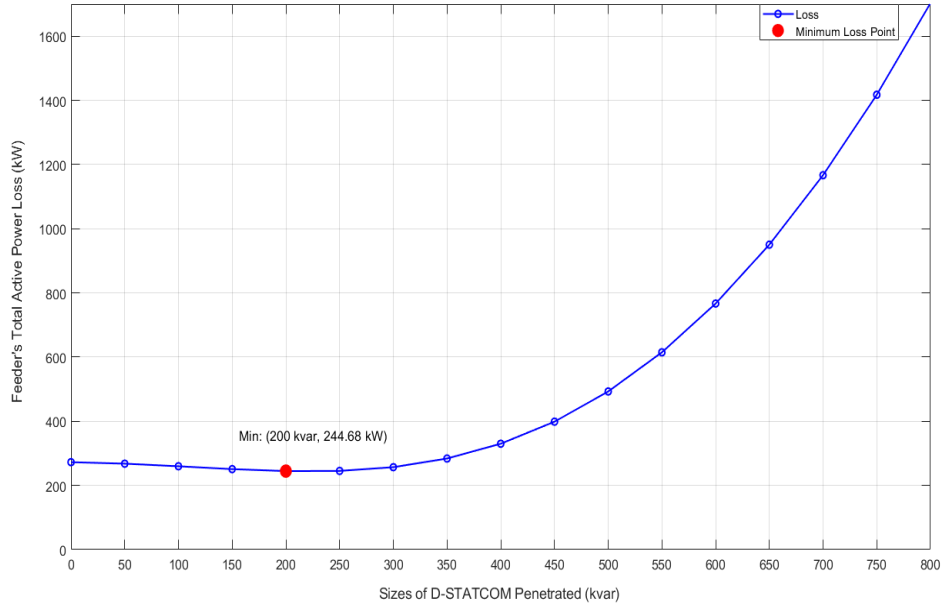


Figure 4.5: Total Active Power Loss vs Incremental Sizes of D-STATCOM

After the selection of size, the voltage profile at the corresponding size was compared to the voltage profile at base case scenario. Figure 4.6 depicts the comparison with a clear show of voltage improvement but not in par with the voltage regulation standards.

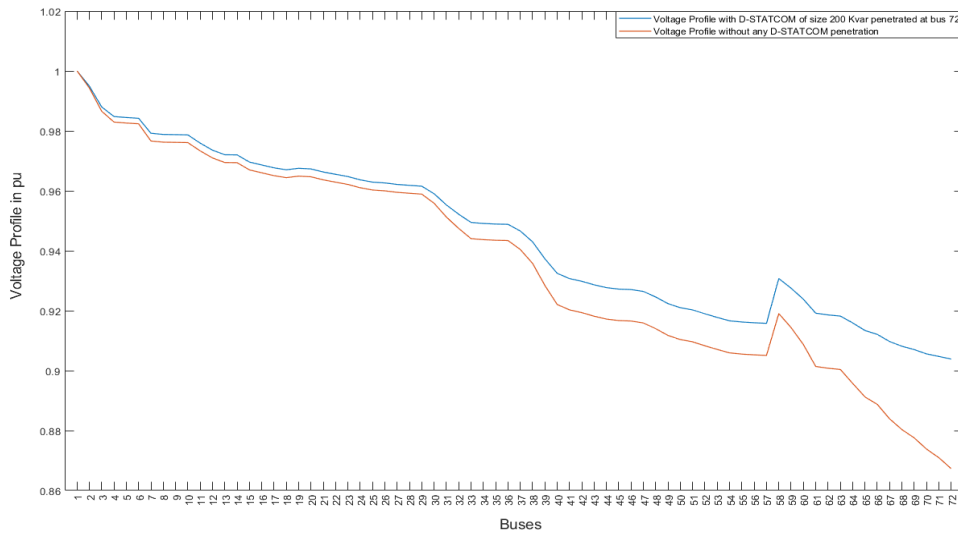


Figure 4.6: Voltage profile Comparison between base case and after D-STATCOM placement at bus 72 of size 200kvar.

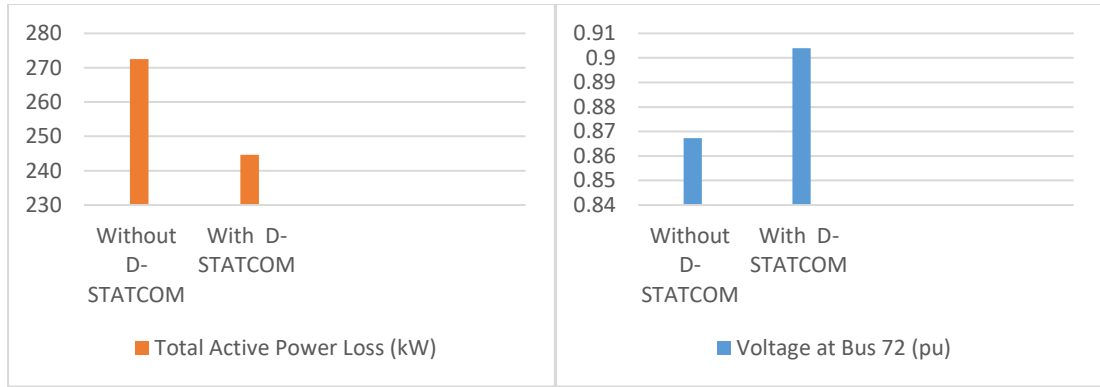


Figure 4.7: Comparative analysis between without and with D-STATCOM penetration at Bus 72.

Figure 4.7 depicts the comparison between base case scenario (without D-STACOM penetration) and scenario with D-STATCOM penetration based on voltage and total active power loss. It shows the improvement on both the attributes; voltage and total active power loss after the penetration of D-STATCOM at bus 72.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

This project focuses on improving the voltage profile of the Begnas Feeder distribution system. The load flow analysis, voltage stability index analysis, and variational techniques were employed in this work. Using this approach 200kvar size of D-STATCOM was placed at Bus-72 for the reactive power compensation and eventually voltage profile improvement. The voltage profile did improve than the base case. The minimum active power loss criterion was the main attribute that selected the size of the D-STATCOM. The corresponding line loss was found to be 244.68kW which is an improvement of 10.21 % than the base case scenario.

Though the voltage profile and line loss did reduce the voltage profile still couldn't meet the voltage regulation standards which indicates the limitation of this technique. So, it recommended to incorporate the optimization algorithm for finding the size and location as they are correlated parameter for optimal sizing and placement.

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APPENDIX -I

Table A.1: 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 A.2: 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 A.3: Load Data of the 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

Table A.4: VSI Data of each Bus

Bus	VSI
1	0
2	1.15E-06
3	1.56E-06
4	6.45E-07
5	6.47E-06
6	1.99E-05
7	0
8	2.33E-06
9	6.49E-08
10	1.52E-06
11	1.41E-05
12	3.66E-06
13	0
14	1.40E-07
15	1.24E-05
16	0
17	0.00012714
18	0.000337661
19	3.32E-06
20	5.10E-05
21	7.86E-06
22	1.35E-06
23	4.27E-06
24	2.51E-05
25	8.92E-06
26	6.26E-05
27	2.14E-05
28	6.53E-06
29	6.74E-05
30	8.99E-07
31	3.33E-06
32	2.07E-06
33	0
34	5.20E-06
35	6.26E-06
36	6.81E-06
37	4.95E-06
38	6.37E-06
39	1.41E-05
40	0
41	4.46E-06

42	3.64E-07
43	0
44	0.000155115
45	0.000102907
46	3.62E-05
47	8.17E-06
48	5.55E-06
49	0.000107769
50	8.62E-05
51	3.35E-05
52	6.98E-05
53	0.000118757
54	0
55	0.000187118
56	0.000240515
57	7.76E-05
58	1.48E-05
59	5.49E-05
60	3.68E-05
61	0.000176731
62	6.85E-05
63	0.000184357
64	3.37E-05
65	7.42E-05
66	8.37E-06
67	0.000142306
68	4.07E-05
69	1.15E-05
70	0.00012335
71	4.31E-05
72	0.001402992

Table A.5: Voltage Profile during each step size Penetration

Bus/ Step:	0	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	0.994	0.994	0.994	0.994	0.995	0.995	0.996	0.996	0.996	0.997	0.997	0.998	0.998	0.999	0.999	1.000	1.000
3	0.987	0.987	0.987	0.987	0.988	0.989	0.989	0.990	0.991	0.992	0.994	0.995	0.996	0.997	0.999	1.000	1.001
4	0.983	0.983	0.984	0.984	0.985	0.986	0.987	0.988	0.989	0.990	0.992	0.993	0.995	0.997	0.998	1.000	1.002
5	0.983	0.983	0.983	0.984	0.984	0.985	0.986	0.988	0.989	0.990	0.992	0.993	0.995	0.996	0.998	1.000	1.001
6	0.982	0.983	0.983	0.983	0.984	0.985	0.986	0.987	0.989	0.990	0.991	0.993	0.994	0.996	0.998	0.999	1.001
7	0.977	0.977	0.977	0.978	0.979	0.980	0.982	0.983	0.985	0.987	0.989	0.991	0.993	0.996	0.998	1.000	1.003
8	0.976	0.976	0.977	0.978	0.979	0.980	0.981	0.983	0.985	0.987	0.989	0.991	0.993	0.995	0.998	1.000	1.002
9	0.976	0.976	0.977	0.978	0.979	0.980	0.981	0.983	0.985	0.987	0.989	0.991	0.993	0.995	0.997	1.000	1.002
10	0.976	0.976	0.977	0.978	0.979	0.980	0.981	0.983	0.985	0.987	0.989	0.991	0.993	0.995	0.997	1.000	1.002
11	0.973	0.974	0.974	0.975	0.976	0.977	0.979	0.980	0.982	0.984	0.986	0.988	0.990	0.992	0.995	0.997	0.999
12	0.971	0.971	0.972	0.973	0.974	0.975	0.976	0.978	0.980	0.982	0.984	0.986	0.988	0.990	0.992	0.995	0.997
13	0.969	0.970	0.970	0.971	0.972	0.973	0.975	0.976	0.978	0.980	0.982	0.984	0.986	0.989	0.991	0.993	0.996
14	0.969	0.970	0.970	0.971	0.972	0.973	0.975	0.976	0.978	0.980	0.982	0.984	0.986	0.989	0.991	0.993	0.996
15	0.967	0.967	0.968	0.969	0.970	0.971	0.972	0.974	0.976	0.978	0.980	0.982	0.984	0.986	0.989	0.991	0.993
16	0.966	0.966	0.967	0.968	0.969	0.970	0.971	0.973	0.975	0.977	0.979	0.981	0.983	0.985	0.988	0.990	0.992
17	0.965	0.965	0.966	0.967	0.968	0.969	0.970	0.972	0.974	0.976	0.978	0.980	0.982	0.984	0.987	0.989	0.991
18	0.964	0.965	0.965	0.966	0.967	0.968	0.970	0.971	0.973	0.975	0.977	0.979	0.981	0.984	0.986	0.988	0.991
19	0.965	0.965	0.966	0.966	0.968	0.969	0.970	0.972	0.974	0.976	0.978	0.980	0.982	0.984	0.987	0.989	0.991
20	0.965	0.965	0.965	0.966	0.967	0.969	0.970	0.972	0.973	0.975	0.977	0.980	0.982	0.984	0.986	0.989	0.991
21	0.964	0.964	0.964	0.965	0.966	0.968	0.969	0.971	0.972	0.974	0.976	0.979	0.981	0.983	0.985	0.988	0.990
22	0.963	0.963	0.964	0.964	0.966	0.967	0.968	0.970	0.972	0.974	0.976	0.978	0.980	0.982	0.985	0.987	0.989
23	0.962	0.962	0.963	0.964	0.965	0.966	0.967	0.969	0.971	0.973	0.975	0.977	0.979	0.982	0.984	0.986	0.989
24	0.961	0.961	0.962	0.963	0.964	0.965	0.966	0.968	0.970	0.972	0.974	0.976	0.978	0.980	0.983	0.985	0.988
25	0.960	0.961	0.961	0.962	0.963	0.964	0.966	0.967	0.969	0.971	0.973	0.975	0.977	0.980	0.982	0.984	0.987
26	0.960	0.960	0.961	0.962	0.963	0.964	0.965	0.967	0.969	0.971	0.973	0.975	0.977	0.979	0.982	0.984	0.987
27	0.959	0.960	0.960	0.961	0.962	0.963	0.965	0.967	0.968	0.970	0.972	0.974	0.977	0.979	0.981	0.984	0.986
28	0.959	0.959	0.960	0.961	0.962	0.963	0.965	0.966	0.968	0.970	0.972	0.974	0.976	0.979	0.981	0.983	0.986
29	0.959	0.959	0.960	0.960	0.962	0.963	0.964	0.966	0.968	0.970	0.972	0.974	0.976	0.978	0.981	0.983	0.986
30	0.956	0.956	0.957	0.958	0.959	0.961	0.962	0.964	0.966	0.969	0.971	0.974	0.977	0.979	0.982	0.985	0.988
31	0.951	0.952	0.952	0.954	0.955	0.957	0.959	0.962	0.965	0.968	0.971	0.974	0.977	0.981	0.985	0.988	0.992
32	0.947	0.948	0.949	0.950	0.952	0.954	0.957	0.960	0.963	0.967	0.970	0.974	0.978	0.982	0.987	0.991	0.995
33	0.944	0.945	0.946	0.947	0.949	0.952	0.955	0.958	0.962	0.966	0.970	0.975	0.979	0.984	0.989	0.994	0.999
34	0.944	0.944	0.945	0.947	0.949	0.952	0.955	0.958	0.962	0.966	0.970	0.974	0.979	0.984	0.988	0.993	0.998
35	0.944	0.944	0.945	0.947	0.949	0.952	0.955	0.958	0.962	0.966	0.970	0.974	0.979	0.983	0.988	0.993	0.998
36	0.943	0.944	0.945	0.947	0.949	0.951	0.954	0.958	0.962	0.965	0.970	0.974	0.979	0.983	0.988	0.993	0.998
37	0.940	0.941	0.942	0.944	0.947	0.950	0.953	0.957	0.961	0.966	0.970	0.975	0.981	0.986	0.991	0.997	1.003
38	0.936	0.937	0.938	0.940	0.943	0.946	0.950	0.955	0.960	0.965	0.971	0.977	0.983	0.989	0.995	1.002	1.008
39	0.928	0.929	0.931	0.934	0.937	0.942	0.947	0.952	0.958	0.965	0.972	0.979	0.986	0.994	1.002	1.010	1.018
40	0.922	0.923	0.925	0.928	0.932	0.937	0.943	0.950	0.957	0.965	0.973	0.981	0.990	0.999	1.008	1.017	1.027
41	0.920	0.921	0.923	0.927	0.931	0.936	0.942	0.948	0.955	0.963	0.971	0.979	0.988	0.997	1.006	1.016	1.025
42	0.919	0.920	0.923	0.926	0.930	0.935	0.941	0.947	0.954	0.962	0.970	0.979	0.987	0.996	1.006	1.015	1.025
43	0.918	0.919	0.921	0.925	0.929	0.934	0.939	0.946	0.953	0.961	0.969	0.978	0.986	0.995	1.005	1.014	1.024
44	0.917	0.918	0.920	0.924	0.928	0.933	0.939	0.945	0.952	0.960	0.968	0.977	0.985	0.994	1.004	1.013	1.023
45	0.917	0.918	0.920	0.923	0.927	0.932	0.938	0.945	0.952	0.960	0.968	0.976	0.985	0.994	1.003	1.013	1.022
46	0.917	0.918	0.920	0.923	0.927	0.932	0.938	0.944	0.952	0.959	0.968	0.976	0.985	0.994	1.003	1.013	1.022
47	0.916	0.917	0.919	0.922	0.926	0.931	0.937	0.944	0.951	0.959	0.967	0.975	0.984	0.993	1.003	1.012	1.022
48	0.914	0.915	0.917	0.920	0.925	0.930	0.936	0.942	0.949	0.957	0.965	0.974	0.983	0.992	1.001	1.011	1.020
49	0.912	0.913	0.915	0.918	0.922	0.927	0.933	0.940	0.947	0.955	0.963	0.972	0.981	0.990	0.999	1.009	1.018
50	0.910	0.911	0.914	0.917	0.921	0.926	0.932	0.939	0.946	0.954	0.962	0.970	0.979	0.989	0.998	1.007	1.017
51	0.910	0.911	0.913	0.916	0.920	0.925	0.931	0.938	0.945	0.953	0.961	0.970	0.979	0.989	0.997	1.007	1.016
52	0.908	0.909	0.912	0.915	0.919	0.924	0.930	0.937	0.944	0.952	0.960	0.969	0.977	0.987	0.996	1.006	1.015
53	0.907	0.908	0.910	0.914	0.918	0.923	0.929	0.935	0.943	0.951	0.959	0.967	0.976	0.986	0.995	1.004	1.014
54	0.906	0.907	0.909	0.912	0.917	0.922	0.928	0.934	0.942	0.949	0.958	0.966	0.975	0.984	0.994	1.003	1.013
55	0.906	0.907	0.909	0.912	0.916	0.921	0.927	0.934	0.941	0.949	0.957	0.966	0.975	0.984	0.994	1.003	1.013
56	0.905	0.906	0.909	0.912	0.916	0.921	0.927	0.934	0.941	0.949	0.957	0.966	0.975	0.984	0.993	1.003	1.013
57	0.905	0.906	0.908	0.912	0.916	0.921	0.927	0.934	0.941	0.949	0.957	0.966	0.975	0.984	0.993	1.003	1.012
58	0.919	0.920	0.923	0.926	0.931	0.936	0.943	0.950	0.958	0.967	0.976	0.985	0.995	1.005	1.016	1.026	1.037
59	0.914	0.916	0.918	0.922	0.927	0.934	0.941	0.949	0.959	0.968	0.979	0.989	1.001	1.012	1.024	1.036	1.048
60	0.909	0.910	0.913	0.918	0.924	0.931	0.940	0.949	0.960	0.971	0.983	0.996	1.009	1.022	1.036	1.051	1.065
61	0.901	0.903	0.907	0.912	0.919	0.928	0.938	0.949	0.962	0.975	0.990	1.005	1.020	1.037	1.053	1.070	1.088
62	0.901	0.903	0.906	0.912	0.919	0.927	0.937	0.949	0.961	0.975	0.989	1.004	1.020	1.036	1.053	1.070	1.087
63	0.900	0.902	0.906	0.911	0.918	0.927	0.937	0.948	0.961	0.974	0.989	1.004	1.020	1.036	1.052	1.070	1.087
64	0.896	0.898	0.902	0.908	0.916	0.926	0.937	0.950	0.965	0.980	0.997	1.014	1.032	1.051	1.070	1.089	1.109
65	0.891	0.893	0.898	0.905	0.913	0.924	0.937	0.951	0.967	0.984	1.003	1.022	1.042	1.062	1.084	1.105	1.127
66	0.889	0.891	0.896	0.903	0.912	0.924	0.937	0.952	0.969	0.987	1.006	1.027	1.048	1.070	1.092	1.115	1.139
67	0.884	0.887	0.892	0.899	0.910	0.922	0.937	0.954	0.973	0.993	1.014	1.037	1.061	1.085	1.110	1.136	1.162
68	0.880	0.883	0.889														

Table A.6: Total Line Loss and the corresponding step sizes of D-STATCOM

Steps(kvar)	Active Power Loss(kW)
0	272.529
50	267.822
100	259.754
150	250.875
200	244.682
250	245.264
300	256.930
350	283.880
400	329.982
450	398.639
500	492.765
550	614.799
600	766.762
650	950.315
700	1166.823
750	1417.404
800	1702.981

APPENDIX -II

The code referenced in the project is given below.

```
clc
clear all;
m=load('loaddata.m');
l=load('linedata.m');
br=length(l);
numberOfBuses=length(m);
[voltagesmag,active,reactive,res,ind]=indLoadFlow(m,l);
[penetrationBus, vsi]=
findTargetBus(voltagesmag,active,reactive,res,ind)
[loss,size,volt]=variation(penetrationBus,m,l)
[minValue,idx]=min(loss)
bus=1:1:72;

%% to plot the VSI of each bus
bar(bus,vsi)
xlim([0 72])
xlabel('Bus')
ylabel('Voltage Stability Index')
xticks(bus);
xlim([0 73])
%to plot the voltage profile at each penetration of D -STATCOM
voltbase=volt(:,1)
voltaData=volt(:,idx);
plot(bus,voltaData)
xlim([0 73])
xticks(bus);
xlabel('Buses')
ylabel('Voltage Profile in pu')
hold on
plot(bus,voltbase)

%% This code find the minimum loss point and marks the point in the
graph and plot it
[min_loss, min_index] = min(loss);
ylab=0:200:1600
%Create the plot
figure;
plot(size, loss, 'b-o', 'LineWidth', 1.5, 'MarkerSize', 6);
xticks(size)
yticks(ylab)
ylim([0 1700])
hold on;
plot(size(min_index), min_loss, 'ro', 'MarkerSize', 8,
'MarkerFaceColor', 'r');
xlabel('Sizes of D-STATCOM Penetrated');
ylabel('Feeder Total Active Power Loss (kW)');
legend('Loss', 'Minimum Loss Point', 'Location', 'northeast');
grid on;
text(size(min_index), min_loss, sprintf(' Min: (%.0f, %.2f)',
size(min_index), min_loss), ...
```

```

    'VerticalAlignment', 'bottom', 'HorizontalAlignment', 'left');
set(gca, 'FontSize', 12);
set(gcf, 'Color', 'white');

function [penBus,vsi] =
findTargetBus(voltagesmag,active,reactive,res,ind)
% % This bit of code calculates the voltage stability index for each
bus
p=active;
q=reactive;
voltage=abs(voltagesmag);
vsi1=[];
for ho = 1: 71
    zeq= abs(res(ho)+1i*ind(ho));
    vsi1(1,end+1)= (4*(zeq)^2*q(ho+1))/(voltage(ho))^2*ind(ho);
end
[~,indices]=sort(vsi1);
penBus=indices(end)+1;
vsi1=[0,vsi1];
vsi=vsi1';
end
% this determines the minimum size of D-statcom without considering the
% Ploss
function bestSize= profile(volt)
for i=1:33
    volt1=volt(:,i);
    for k= 1:length(volt1)
        if volt1(k)<0.95
            logic=0;
            break
        else
            logic=1;
        end
    end
    if logic==1
        bestSize=i
        break;
    end
end
end
% D_statcom Placement
function [loss,size,volt]= variation(penetrationBus,m,l)
steps=0:50:800
loss=[];
voltage1=[];
for i =1:length(steps)
    data=m(penetrationBus,3)-steps(i);
    m(penetrationBus,3)= data;
    [voltage,~,~,~,losses]=indLoadFlow(m,l);
    voltage1=[voltage1,voltage];
    loss=[loss,sum(losses)];
end
loss=loss';
size=steps;

```

```

volt=voltage1;
% size=optSize;
end
% Basic load flow Function
function [voltageModify,powBranch1,qowBranch1,res,ind,losses] =
indLoadFlow(m,l)
format short;
br=length(l);
no=length(m);
f=0;
d=0;
MVA=100;
KVb=11;
Zb=(KVb^2)/MVA;
Pg = zeros(no,1);
Pg1 = zeros(no,1);

for i=1:br
    R(i,1)=(l(i,4))/Zb;
    X(i,1)=(l(i,5))/Zb;
end
for i=1:no
    P(i,1)=(m(i,2)/(1000*MVA));
    Q(i,1)=(m(i,3)/(1000*MVA));
end
R;
X;
res=R;
ind=X;
powBranch1=P;
qowBranch1=Q;
C=zeros(br,no);
for i=1:br
    a=l(i,2);
    b=l(i,3);
    for j=1:no
        if a==j
            C(i,j)=-1;
        end
        if b==j
            C(i,j)=1;
        end
    end
end
C;
e=1;
for i=1:no
    d=0;
    for j=1:br
        if C(j,i)==-1
            d=1;
        end
    end
end

```

```

    end
    if d==0
        endnode(e,1)=i;
        e=e+1;
    end
end
endnode;
h=length(endnode);
for j=1:h
    e=2;

    f=endnode(j,1);
    % while (f~=1)
    for s=1:no
        if (f~=1)
            k=1;
            for i=1:br
                if ((C(i,f)==1)&&(k==1))
                    f=i;
                    k=2;
                end
            end
            k=1;
            for i=1:no
                if ((C(f,i)==-1)&&(k==1));
                    f=i;
                    g(j,e)=i;
                    e=e+1;
                    k=3;
                end
            end
        end
    end
end
end
for i=1:h
    g(i,1)=endnode(i,1);
end
g;
w=length(g(1,:));
for i=1:h
    j=1;
    for k=1:no
        for t=1:w
            if g(i,t)==k
                g(i,t)=g(i,j);
                g(i,j)=k;
                j=j+1;
            end
        end
    end
end
end
g;

```



```

for k=1:br
    e=1;
    for i=1:h
        for j=1:w-1
            if (g(i,j)==k)
                if g(i,j+1)~=0
                    adjb(k,e)=g(i,j+1);
                    e=e+1;
                else
                    adjb(k,1)=0;
                end
            end
        end
    end
end
adjb;
for i=1:br-1
    for j=h:-1:1
        for k=j:-1:2
            if adjb(i,j)==adjb(i,k-1)
                adjb(i,j)=0;
            end
        end
    end
end
adjb;
x=length(adjb(:,1));
ab=length(adjb(1,:));
for i=1:x
    for j=1:ab
        if adjb(i,j)==0 && j~=ab
            if adjb(i,j+1)~=0
                adjb(i,j)=adjb(i,j+1);
                adjb(i,j+1)=0;
            end
        end
        if adjb(i,j)~=0
            adjb(i,j)=adjb(i,j)-1;
        end
    end
end
adjb;
for i=1:x-1
    for j=1:ab
        adjcb(i,j)=adjb(i+1,j);
    end
end
b=length(adjcb);
% voltage current program
for i=1:no
    vb(i,1)=1;
end
for s=1:10

```

```

for i=1:no
    nlc(i,1)=conj(complex(P(i,1),Q(i,1)))/(vb(i,1));
end
nlc;
for i=1:br
    Ibr(i,1)=nlc(i+1,1);
end
Ibr;
xy=length(adjcb(1,:));
for i=br-1:-1:1
    for k=1:xy
        if adjcb(i,k)~=0
            u=adjcb(i,k);
            Ibr(i,1)=Ibr(i,1)+Ibr(u,1);
        end
    end
end
Ibr;
for i=2:no
    g=0;
    for a=1:b
        if xy>1
            if adjcb(a,2)==i-1
                u=adjcb(a,1);
                vb(i,1)=((vb(u,1))-((Ibr(i-1,1))*(complex((R(i-
1,1)),X(i-1,1))))));
                g=1;
            end
            if adjcb(a,3)==i-1
                u=adjcb(a,1);
                vb(i,1)=((vb(u,1))-((Ibr(i-1,1))*(complex((R(i-
1,1)),X(i-1,1))))));
                g=1;
            end
        end
    end
    if g==0
        vb(i,1)=((vb(i-1,1))-((Ibr(i-1,1))*(complex((R(i-1,1)),X(i-
1,1))))));
    end
end
s=s+1;
end
nlc;
Ibr;
iBranch=Ibr;
bcurrent=iBranch;
vb;
vbp=[abs(vb)];
for i=1:no
    va(i,2)=vbp(i,1);
end
for i=1:no

```

```

        va(i,1)=i;
        P1(i) = P(i);
        Q1(i) = Q(i);
    end
    va;
    Ibrp=[abs(Ibr)];
    PL(1,1)=0;
    QL(1,1)=0;
    powBranch=[];
    qowBranch=[];
    % losses at base case
    for f=1:br
        P1(f,1)=(Ibrp(f,1)^2)*R(f,1);
        Q1(f,1)=X(f,1)*(Ibrp(f,1)^2);
        powBranch(1,end+1)=P1(f);
        qowBranch(1,end+1)=Q1(f);
        PL(1,1)=PL(1,1)+P1(f,1);
        QL(1,1)=QL(1,1)+Q1(f,1);
    end
    Plosskw=(P1)*100000;
    Qlosskw=(Q1)*100000;
    PL=(PL)*100000;
    QL=(QL)*100000;
    losses=Plosskw;
    voltage = vbp(:,1);
    v_mag = va(:,2);
    voltageModify=v_mag;
    % for plotting bar and formatting the graph
    bus=1:1:29;
    bus=bus.';
    bar(bus,voltage,0.2)
    xticks(bus);
    xlabel('Bus');
    ylabel('Voltage in pu');
    ylim([0 1.1]);
    % for plotting bar and formatting the graph
    bus=1:1:no;
    bus=bus.';
    pBus= bus(2:end);
    %subplot(2,1,1)
    bar(pBus,Plosskw);
    xticks(pBus);
    xticklabels({'1-2','2-3','3-4','4-5','5-6','6-7','7-8','8-9','9-10',
    '10-11','11-12','12-13','13-14','2-15','5-16','16-17','8-18','18-19',
    '19-20','20-21','11-22','22-23','22-24','24-25','12-26','26-27',
    '26-28','28-29'});
    xlabel('Branch');
    ylabel('Active Power loss (Kw)');
    %ylim([0 1.1]);
    %subplot(2,1,2)
    figure()
    bar(bus,voltage,0.5);
    xticks(bus);

```

```

xlabel('Bus');
ylabel('Voltage in pu');
ylim([0 1.1]);
figure()
bar(pBus,Qlosskw);
xticks(pBus);
xticklabels({'1-2','2-3','3-4','4-5','5-6','6-7','7-8','8-9','9-10',
'10-11','11-12','12-13','13-14','2-15','5-16','16-17','8-18','18-19',
'19-20','20-21','11-22','22-23','22-24','24-25','12-26','26-27',
'26-28','28-29'})
xlabel('Branch');
ylabel('Reactive Power loss (KVAR);
end

```