

An OPF-Based Investigation of SVC and STATCOM for Power System Power Quality Enhancement

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Abstract

Power quality issues such as voltage instability, increased real and reactive power losses, and poor voltage profile have become critical challenges in modern interconnected power systems due to growing load demand and the integration of nonlinear loads. Flexible AC Transmission System (FACTS) devices provide an effective solution for dynamic reactive power compensation and voltage regulation. This paper presents a comparative analysis of two shunt FACTS devices, namely Static VAR Compensator (SVC) and Static Synchronous Compensator (STATCOM), for enhancing voltage profile and minimizing transmission losses using an Optimal Power Flow (OPF) approach. The IEEE-14 bus system is considered as a test system. Simulation results demonstrate that optimal placement and sizing of STATCOM yields superior performance compared to SVC in terms of real and reactive power loss reduction and voltage profile enhancement.

Keywords: Power Quality, FACTS, SVC, STATCOM, Optimal Power Flow, IEEE-14 Bus System

Introduction

Power quality problems are increasing rapidly in both industrial and domestic power systems due to the widespread integration of nonlinear loads, power electronic converters, and sensitive equipment. Poor power quality leads to severe consequences such as equipment malfunction, overheating, communication interference, voltage sag, voltage swell, and frequent system interruptions. These issues cause economic losses and reduce system reliability.

Modern power systems face limitations in effective utilization of generated power because power generation sites are often located far from load centres.[1] Although generators can supply active power, reactive power management remains a major challenge. Inadequate reactive power compensation leads to voltage instability and higher transmission losses.

Flexible AC Transmission System (FACTS) devices, based on advanced power electronic technology, provide enhanced controllability and flexibility in AC transmission networks. FACTS devices improve voltage regulation, increase power transfer capability, and enhance system stability. Among various FACTS controllers, shunt-connected devices such as Static

VAR Compensator (SVC) and Static Synchronous Compensator (STATCOM) play a crucial role in reactive power management.

Facts Controllers

According to IEEE, FACTS are defined as “AC transmission systems incorporating power electronic-based and other static controllers to enhance controllability and increase power transfer capability.” FACTS technology enables better utilization of existing transmission infrastructure while maintaining reliability and economic efficiency.

FACTS controllers regulate parameters such as voltage, line impedance, and phase angle, thereby improving system stability and reducing congestion.

SVC (Static VAR Compensator)

The static VAR compensator is design to decreases disturbance caused by change in reactive power and voltage fluctuation in the normal operation of transmission line and industry distribution system.[2] Disturbance may be caused by line switching, line fault, non-linear component such as thyristor control and rapidly varying active or reactive load. Typical source for this kind of disturbance is electric arc furnace and rolling meals. This disturbance is resulted harmonic that load supply in network and cause voltage fluctuation.

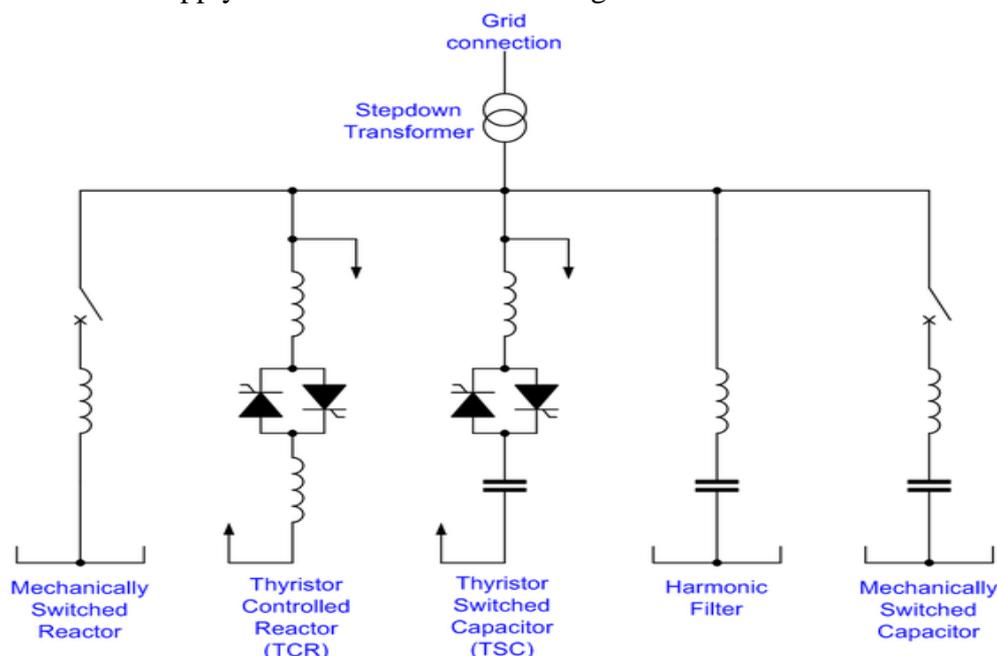


Fig. Static VAR Compensator

it consists of combination of TCR (Thyristor Controlled Reactor) and TSC (Thyristor Switched Capacitor) and FC (Fixed Capacitor). The capacitor banks and reactor bank are connected to the transmission line through the stepdown transformer. controller get the input by potential transformer through the stepdown transformer.

Controller send the triggering signal to the thyristor module according to the reference value, auxiliary input and parameter setting. Basically, we know that, electrical transmission and

distribution network is dominantly reactive in nature. So, when no load situation occurs then line capacitance increases and produce more reactive power in the system.[3] If load is not absorbing this reactive power, then system voltage increases and may cross the limit. So, in this situation for absorbing reactive power there are insert TCR in the system.

When pick load occur in the system, the majority of load are inductive in nature and as we know that for operate inductive load there are need reactive power. In this situation to fulfil the demand of reactive power, insert TSC in the power system. In TCR to control the effective inductance apply phase control method. similarly, in TSC to the control the effective capacitance applies integral cycle control method. There important role of controller for TSC and TCR. controller operate according to the requirement of the system.

V-I Characteristics of SVC

The SVC can be operated in two different modes:

1. In voltage regulating mode.
2. In VAR control mode.

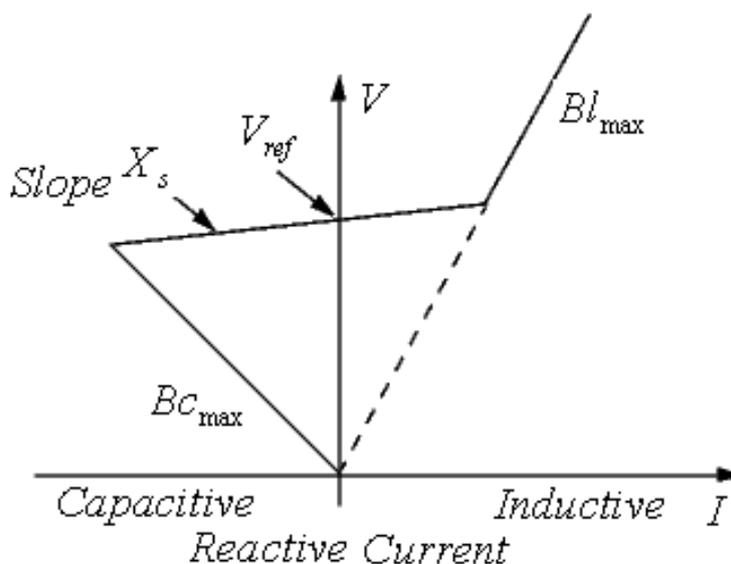


Fig. V-I Characteristics of SVC

STATCOM

STATCOM is a static synchronous compensator, it is a parallel shunt device which is connected with line in parallel. It can either absorb reactive power and generate reactive power when transmission network needed for voltage stabilization. If reactive power is less in any transmission system, then it generates reactive power for that network and if reactive power produces more losses in the transmission network, then this device is doing the work of reduction of reactive power from that transmission network. [5] If we need to compensate the real power at that time we use STATCOM. STATCOM generate three sinusoidal voltages of fundamental frequency which amplitude and phase angle are controllable.

Component of STATCOM

In STATCOM we use basically four component that are given below,

1. Voltage Source Converter (VSC)
2. Coupling Transformer
3. Controller
4. DC energy storage

We draw the diagram of STATCOM in which there are two voltages available first one is inverter output voltage and second one is system voltage. So, understand the working principle of STATCOM, firstly look at the reactive power transfer equation. There are consider two source V_1 and V_2 which are connected through an impedance,

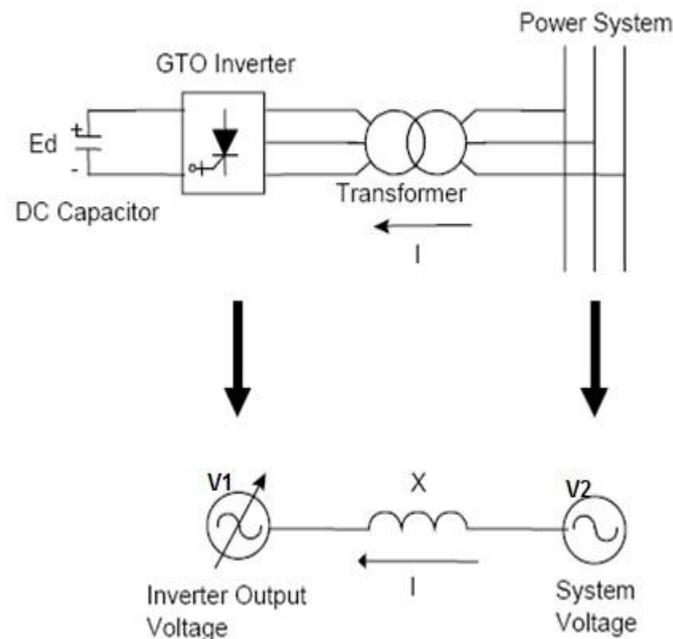
$$Z = R + jx \quad \text{So, } Q = \frac{V_2}{x} [V_1 \cos\Delta - V_2]$$

Where, Q = reactive power flow, Δ = angle between V_1 and V_2 , If, $\Delta = 0$ Then reactive power flow will,

$$a = \frac{V_2}{x} (V_1 - V_2) \text{ and active power flow is, } P = \frac{V_1 * V_2 \sin\Delta}{x} = 0$$

So, by the reactive power flow equation and active power flow equation we know that active power becomes zero when angle between V_1 and V_2 is zero and flow of reactive power depends on $(V_1 - V_2)$. So, there are two possibilities for flow of reactive power.

V-I Characteristic of STATCOM



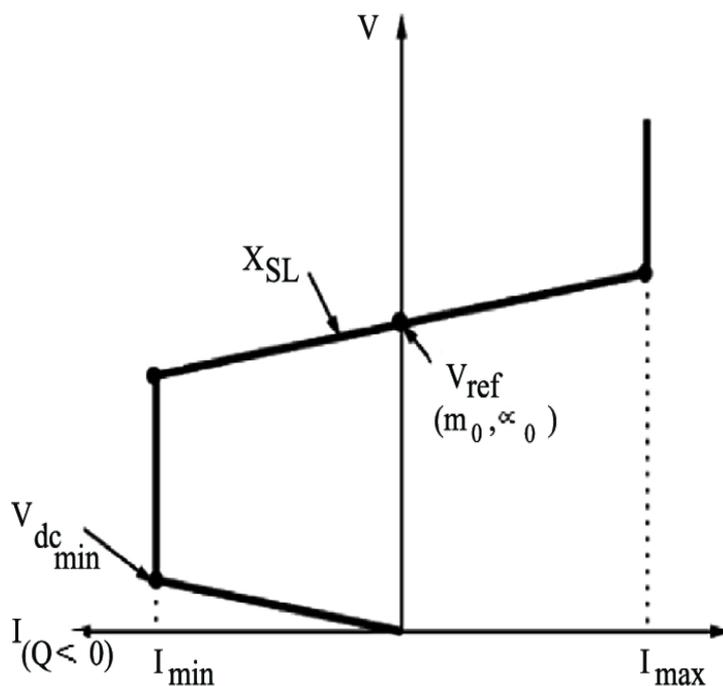


Fig. STATCOM

Fig. V-I Characteristic of STATCOM

1. If output voltage of STATCOM (V_1) is greater than bus voltage (V_2) then the direction of current will be STATCOM to AC supply system so in this situation STATCOM generates the reactive power.
2. If output voltage of STATCOM (V_1) is less than bus voltage (V_2) then the direction of current is opposite it means current flow from AC supply system to STATCOM so in this time STATCOM absorb the reactive power.

Simulation Based Calculation

In this thesis work we have taken IEEE-14 bus system for voltage profile and minimum power loss analysis. With the objective to bring i.e. to improve the voltage profile, Static VAR compensator (SVC) and Static Synchronous compensator (STATCOM), a shunt connected flexible AC transmission system (FACTS) device is incorporated in this test system.

OPF method is used for optimal location and optimal size of SVC and STATCOM to maintain losses in the transmission system.

For SVC

This whole calculation is done on the IEEE-14 bus system. In this calculation we inject the values only on reactive power and we get variation in both the powers. The injection value is started from 20MVA to 160MVA. Here is gapping of 20-20MVA between 20 to 160MVA.

After injecting this value, we get a minimum power loss when we inject 100MVA on bus no. 8 at that time, we have active power is 2.008MVA and reactive power is 43.50MVAR for finding minimum value we inject 85, 95, 90, 110 and 75MVA on all buses but we found less value in just two injection process i.e. 85 and 95MVA. The less value of active and reactive

power in 85MVA injection process is found on bus no. 6 i.e. 2.852MVA and 37.82MVAR respectively.

Case Study 1: IEEE-14 BUS SYSTEM without and with SVC

Table 1.1 Profile of PL for IEEE-14 Bus system without and with SVC of size 85MVA

Bus no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PL_WOSVC	9.287	9.287	9.287	9.287	9.287	9.287	9.287	9.287	9.287	9.287	9.287	9.287	9.287	9.287
PL_WSVC	10.510	9.456	10.700	9.726	9.553	2.852	11.135	4.946	3.284	3.020	11.188	7.465	4.490	21.926

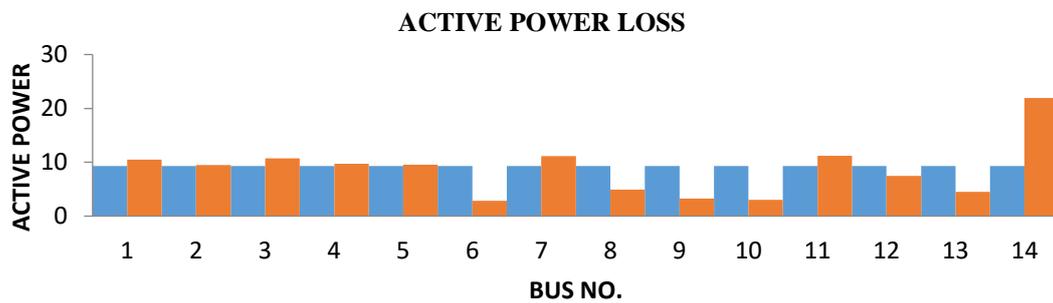


Fig. Profile of IEEE-14 Bus system without and with SVC

From graphical comparison in fig.3.1. it is observed that the real power loss of the system has been decreased after the placement of SVC for 85MVA at all bus consequently. The real power loss of the system has been decreased maximum when the SVC is placed at bus no. 6. The value of PL=9.287MVA without placement of SVC and it will become a PL=2.852MVA after the placement of SVC by OPF method.

Table 1.2 Profile of QL for IEEE-14 Bus system without and with SVC of size 85MVA

Bus no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
QL_WO	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.
SVC	16	16	16	16	16	16	16	16	16	16	16	16	16	16
QL_WS	44.	40.	44.	41.	41.	37.	51.	55.	23.	36.	46.	45.	40.	81.
VC	52	32	27	86	81	82	33	86	07	79	45	29	76	55



Fig. Profile of IEEE-14 Bus system without and with SVC

The reactive power loss of the system has been decreased maximum when the SVC placed at bus no. 6. The value of $QL=39.16\text{MVAR}$ without placement of SVC and it will become a $QL=37.82\text{MVAR}$ after the placement of SVC by OPF method.

Case Study 2: IEEE-14 BUS SYSTEM without and with SVC

Table 2.1 Profile of PL for IEEE-14 Bus system without and with SVC of size 95MVA

Bus no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PL_WO	9.28	9.2	9.28	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.28
SVC	7	87	7	87	87	87	87	87	87	87	87	87	87	7
PL_WS	10.8	9.5	11.1	9.9	9.7	3.2	7.1	2.7	3.5	4.8	9.4	8.7	5.2	24.9
VC	23	79	82	02	08	07	47	99	33	62	64	74	51	84

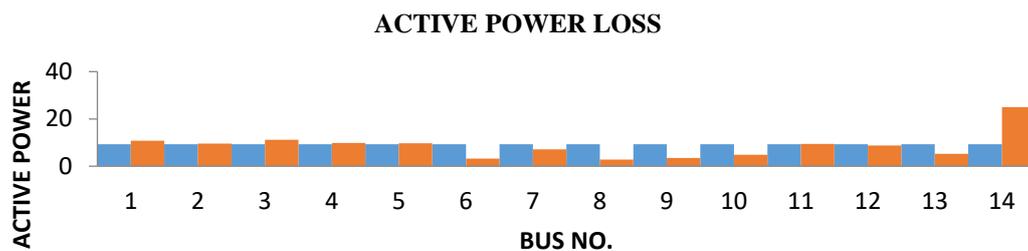


Fig. Profile of IEEE-14 Bus system without and with SVC

The real power loss of the system has been decreased maximum when the SVC is placed at the bus no.8, the value of $PL=9.287\text{MVA}$ without placement of SVC and it will become a $PL=2.799\text{MVA}$ after the placement of SVC by OPF method.

Table 2.2 Profile of QL for IEEE-14 Bus system without and with SVC of size 95MVA

Bus no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
QL_WO	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.
SVC	16	16	16	16	16	16	16	16	16	16	16	16	16	16
QL_WS	45.	40.	46.	42.	42.	39.	38.	45.	24.	26.	39.	48.	43.	91.
VC	92	98	15	31	28	73	25	45	82	74	94	79	26	86



Fig. Profile of IEEE-14 Bus system without and with SVC

In this graph we observed that the reactive power loss of the system has been increased after the placement of SVC for 95MVA at all bus consequently. The reactive power loss of the system has been increased when the SVC placed at bus no.9. the value of reactive power is 39.16MVAR without placement of SVC and it will become a 45.45MVAR after the placement of SVC by OPF method.

Case Study 3: IEEE-14 BUS SYSTEM without and with SVC

Table 3.1 Profile of PL for IEEE-14 Bus system without and with SVC of size 80MVA

Bus no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PL_WOS	9.28	9.2	9.28	9.2	9.2	9.2	9.28	9.2	9.2	9.2	9.28	9.2	9.2	9.28
VC	7	87	7	87	87	87	7	87	87	87	7	87	87	7
PL_WSV	10.3	9.4	10.4	9.6	9.4	2.6	10.8	4.8	7.6	2.7	11.4	6.8	4.1	20.2
C	69	03	79	50	87	55	67	61	99	36	89	38	33	68

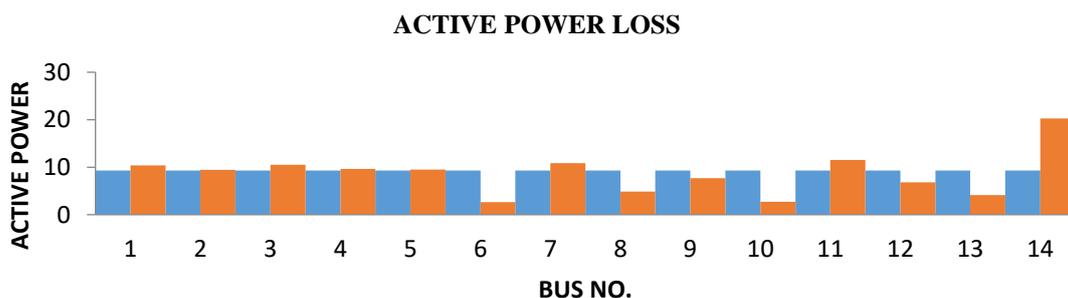


Fig. Profile of IEEE-14 Bus system without and with SVC

The real power loss of the system has been decreased maximum when the SVC placed at bus no.6. the value of active power is 9.287MVA without placement of SVC and it will become a PL=2.655MVA after the placement of SVC by OPF method.

Table 3.2 Profile of IEEE-14 Bus system without and with SVC of size 80MVA

Bus no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
QL_WO SVC	39. 16													
QL_WS VC	43. 92	40. 02	43. 41	41. 67	41. 62	36. 98	49. 56	54. 41	38. 78	36. 53	47. 01	43. 65	39. 60	75. 98

REACTIVE POWER LOSS

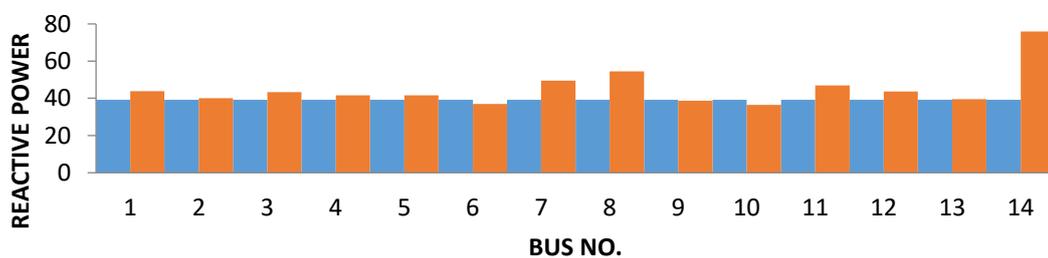


Fig. Profile of IEEE-14 Bus system without and with SVC

From the graphical comparison in figure 3.4.2 it is observed that the reactive power loss of the system has been decreased after the placement of SVC for 80MVA at all bus consequently. The reactive power of the system has been decreased maximum when the SVC placed at bus no .6. the value of reactive power 39.16MVAR without placement of SVC and it will become 39.98MVAR after the placement of OPF method.

Case Study 4: IEEE-14 BUS SYSTEM without and with SVC

Table 4.1 Profile of PL for IEEE-14 Bus system without and with SVC of size 120MVA

Bus no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PL_WO SVC	9.2 87	9.28 7	9.28 7	9.28 7	9.28 7	9.2 87	9.2 87	9.2 87	9.2 87	9.2 87	9.2 87	9.28 7	9.2 87	9.28 7
PL_WS VC	9.9 47	10.0 06	12.6 28	10.6 16	10.3 42	4.2 12	6.4 14	2.4 33	2.9 78	6.2 36	7.0 72	12.3 10	7.3 93	13.5 44

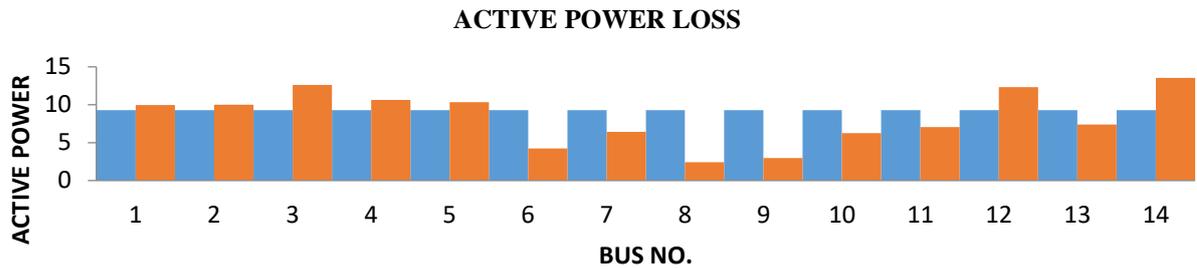


Fig. Profile of IEEE-14 Bus system without and with SVC

From this graphical comparison in figure 3.5.1 it is observed that the real power loss of the system has been decreased after the placement of SVC for 120MVA at all bus consequently. The real power loss of the system has been decreased maximum when the SVC placed at bus no.8. the value of active power is 9.287MVA without placement of SVC and it will become 2.433MVA after the placement of SVC by OPF method.

Table 4.2 Profile of QL for IEEE-14 Bus system without and with SVC of size 120MVA

Bus no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
QL_WO	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.
SVC	16	16	16	16	16	16	16	16	16	16	16	16	16	16
QL_WS	45.	43.	51.	44.	44.	45.	39.	49.	40.	32.	50.	57.	50.	50.
VC	27	55	81	57	40	11	53	97	69	80	36	08	34	98

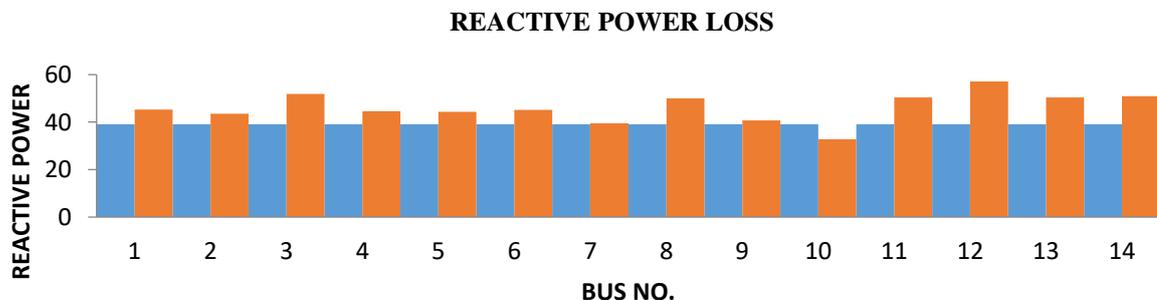


Fig. Profile of IEEE-14 Bus system without and with SVC

This power loss has been increased when SVC is placed at bus no. 8.the value of reactive power is 39.16MVAR without placement of SVC and it will become a 49.95MVAR after the placement of SVC by OPF method.

Case Study 5: IEEE-14 BUS SYSTEM without and with SVC

Table . Profile of PL for IEEE-14 Bus system without and with SVC of size 100MVA

Bus no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14

PL_WO	9.28	9.2	9.28	9.28	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.28
SVC	7	87	7	7	87	87	87	87	87	87	87	87	87	7
PL_WS	10.9	9.6	11.4	10.0	9.7	3.4	6.0	2.0	3.6	5.1	9.1	9.4	5.6	26.1
VC	94	51	42	02	97	00	65	08	73	18	09	60	53	88

ACTIVE POWER LOSS

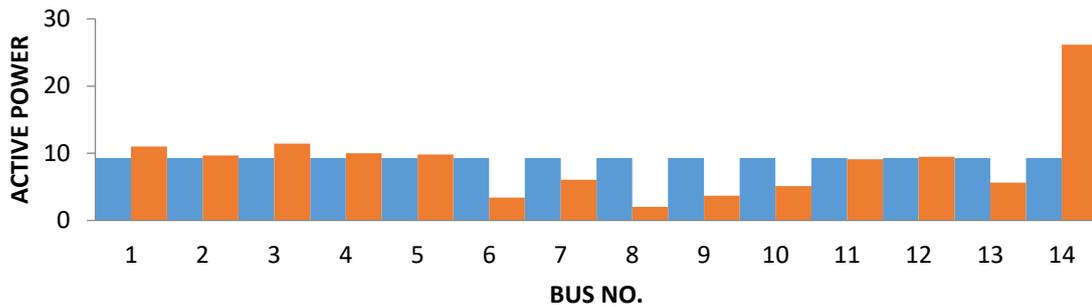


Fig. Profile of IEEE-14 Bus system without and with SVC

The real power loss of the system has been decreased maximum when the SVC placed at bus no. 8. The value of active power is 9.287MVA without placement of SVC and it will become a 2.008MVA after the placement of SVC by OPF method.

Table 5.2 Profile of QL for IEEE-14 Bus system without and with SVC of size 100MVA

Bus no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
QL_WO	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.
SVC	16	16	16	16	16	16	16	16	16	16	16	16	16	16
QL_WS	46.	41.	47.	42.	42.	40.	35.	43.	25.	27.	38.	50.	44.	95.
VC	72	38	17	57	54	84	20	50	78	86	07	50	58	89

REACTIVE POWER LOSS

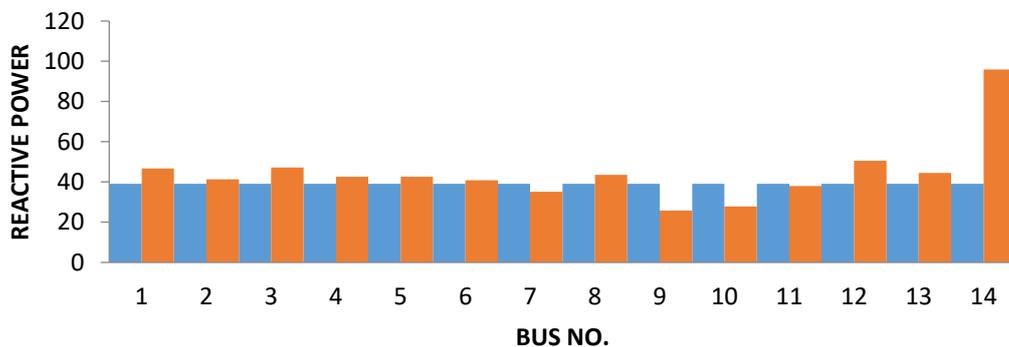


Fig. Profile of IEEE-14 Bus system without and with SVC

The reactive power loss of the system has been increased when SVC placed at bus no.8. the value of reactive power loss is 39.16MVAR without placement of SVC and it will become a 43.50MVAR after the placement of SVC.

For STATCOM

In this calculation we inject the value in both the active and reactive. The injected value is started from 20MVA to 220 MVA, here gapping between 20MVA to 220MVA is 20-20MVA. After this whole injecting process, we get a minimum value on bus no. 9. When we inject 120MVA on it and the value is 2.488MVA and 11.15MVAR respectively.

For getting further minimum value we inject 110,124,130MVA in all buses consequently, but we found a single minimum value when we inject 124MVA on bus no.9. i.e. 1.68MVA and 12.74MVAR respectively.

Case Study 6: IEEE Bus System Without And with STATCOM

Table 6.1 Profile of PL for IEEE-14 Bus system without and with STATCOM of size of 60MVA

Bus no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PL_WOST ATCOM	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2
PL_WSTA TCOM	12.	10.	8.3	8.9	9.4	10.	9.3	9.7	9.5	10.	11.	2.8	10.	10.
	897	936	49	76	93	455	11	14	58	120	183	94	632	811



Fig. Profile of IEEE-14 Bus system without and with STATCOM

After seeing this graph, we observed that real power loss of the system has been decreased after the placement of STATCOM for 60MVA at all bus consequently. The real power loss of the system has been decreased maximum, when the STATCOM at bus no.12. the value of active power loss is 9.287MVA without and it will become a 2.894MVA after the placement of STATCOM.

Table 6.2 Profile of QL for IEEE-14 Bus system without and with STATCOM of size 60MVA

Bus no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
QL_WOST ATCOM	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.
	16	16	16	16	16	16	16	16	16	16	16	16	16	16

QL_WSTA	52.	46.	36.	39.	41.	36.	38.	45.	35.	36.	38.	33.	36.	38.
TCOM	85	09	48	30	26	44	41	20	93	95	72	63	94	17

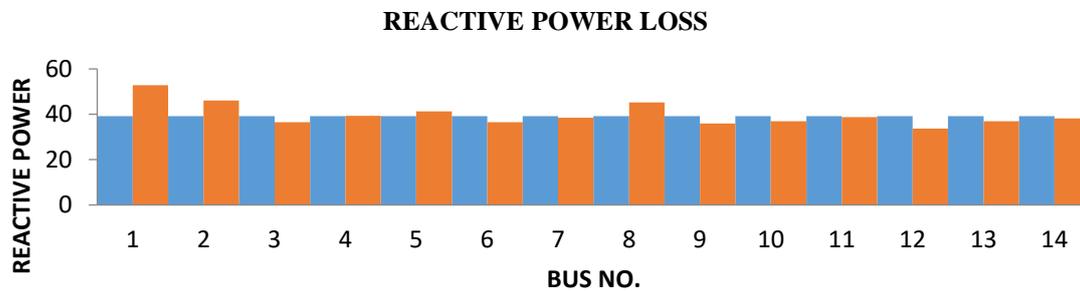


Fig. Profile of IEEE-14 Bus system without and with STATCOM

From graphical comparison in this graph, we observed that the reactive power loss of the system has been decreased after the placement of STATCOM for 60MVA. When we inject on bus no. 12. It gets decreased the value of reactive power loss is 39.16MVAR without and with STATCOM, and it will become 33.63MVAR after the placement of STATCOM.

Case Study 7: IEEE-14 BUS SYSTEM without and with STATCOM

Table 7.1 Profile of PL for IEEE-14 Bus system without and with STATCOM of size 140MVA

Bus no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PL_WOST	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2
ATCOM	87	87	87	87	87	87	87	87	87	87	87	87	87	87
PL_WSTA	15.	9.8	6.3	5.9	7.2	10.	6.1	5.8	2.8	8.4	13.	21.	13.	14.
TCOM	781	23	97	48	51	635	29	68	86	66	477	027	513	511

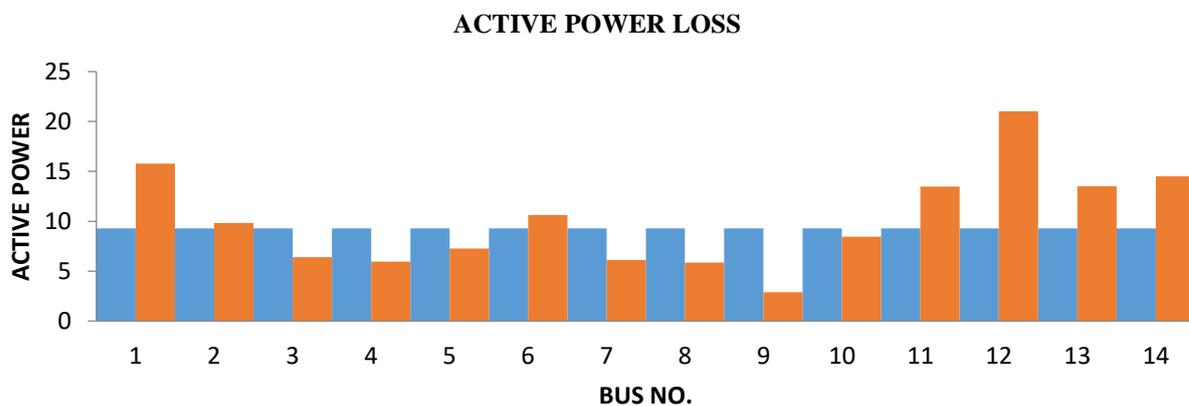


Fig. Profile of IEEE-14 Bus system without and with STATCOM

When we compare the value's, we observed that the real power loss of the system has been decreased after the placement of STATCOM for 140MVA at all bus consequently. The real power loss of the system has been decreased maximum when STATCOM is placed at bus no.9. the value of active power is 9.287MVA without placement of STATCOM and it will become a 2.886MVA after the placement of STATCOM by OPF method.

Table 7.2 Profile of QL for IEEE-14 Bus system without and with STATCOM of size 140MVA

Bus no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
QL_WOST	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.
ATCOM	16	16	16	16	16	16	16	16	16	16	16	16	16	16
QL_WSTA	63.	43.	29.	28.	33.	66.	46.	103	15.	42.	76.	98.	76.	53.
TCOM	63	06	69	71	69	29	04	.93	65	10	12	53	62	13

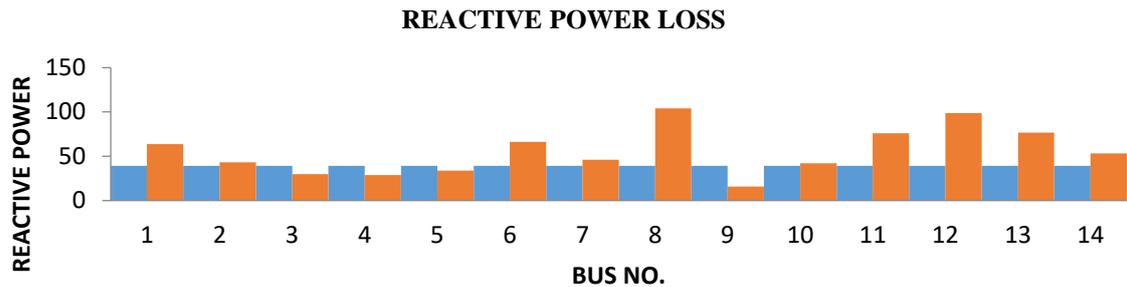


Fig. Profile of IEEE-14 Bus system without and with STATCOM

The graphical comparison in fig.3.14 it is observed that the reactive power loss of the system has been decreased after the placement of STATCOM for 140MVA at all bus consequently. The reactive power loss of the system has been decreased maximum when STATCOM placed at bus no. 9. The value of reactive power is 39.16MVAR without placement of STATCOM and it will become 15.65MVAR after the placement of STATCOM by OPF method.

Case Study 8: IEEE-14 BUS SYSTEM without and with STATCOM

Table 8.1 Profile of PL for IEEE-14 Bus system without and with STATCOM of size 130MVA

Bus no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PL_WOST	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2
ATCOM	87	87	87	87	87	87	87	87	87	87	87	87	87	87
PL_WSTA	15.	9.9	6.3	6.1	7.3	9.7	7.3	5.8	2.6	7.9	11.	13.	12.	10.
TCOM	519	27	82	45	87	92	25	53	37	52	316	304	404	902

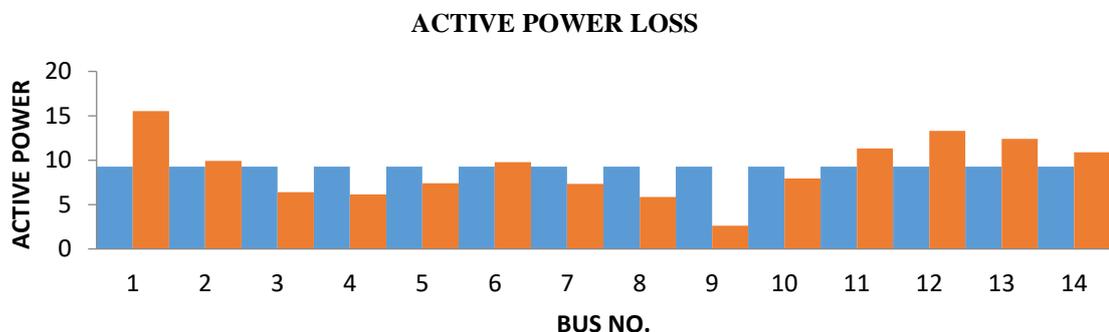


Fig. Profile of IEEE-14 Bus system without and with STATCOM

We compared all this graphical value after that we observed the real power loss of the system has been decreased after the placement of STATCOM for 130MVA at all bus consequently. The real power loss of the system has been decreased maximum when the STATCOM is placed at bus no.9. the value of active power is 9.287MVA without placement of STATCOM and it will become 14.07MVA after the placement of STATCOM.

Table: Profile of IEEE-14 Bus system without and with STATCOM

Bus no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
QL_WOST	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.
ATCOM	16	16	16	16	16	16	16	16	16	16	16	16	16	16
QL_WSTA	62.	43.	29.	29.	34.	63.	38.	52.	14.	38.	81.	26.	74.	63.
TCOM	71	24	61	52	23	10	25	60	07	71	63	83	70	05

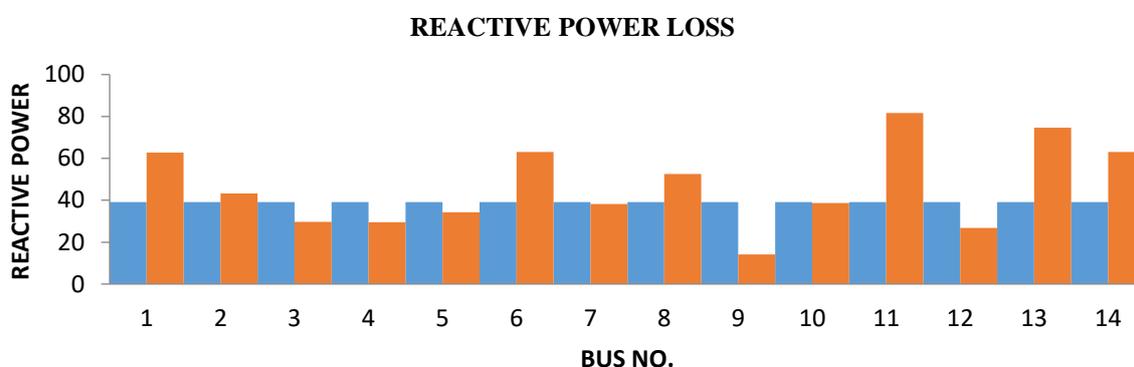


Fig. Profile of IEEE-14 Bus system without and with STATCOM

The graphical comparison of graph. It observed that the reactive power loss of the system has been decreased after the placement of STATCOM for 130MVA at all bus consequently. The reactive power loss of the system has been decreased maximum when the STATCOM placed at bus no. 9. The value of reactive power is 39.16MVAR without placement of STATCOM and it will become a 14.07MVAR after the placement of STATCOM.

Case Study 9: IEEE-14 BUS SYSTEM without and with STATCOM

Table 9.1 Profile of PL for IEEE-14 Bus system without and with STATCOM of size 120MVA

Bus no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PL_WOST	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2
ATCOM	87	87	87	87	87	87	87	87	87	87	87	87	87	87
PL_WSTA	15.	10.	6.4	6.3	7.5	8.9	7.9	5.9	2.4	7.4	11.	9.5	11.	8.3
TCOM	276	062	26	98	73	33	86	67	88	91	631	46	171	17

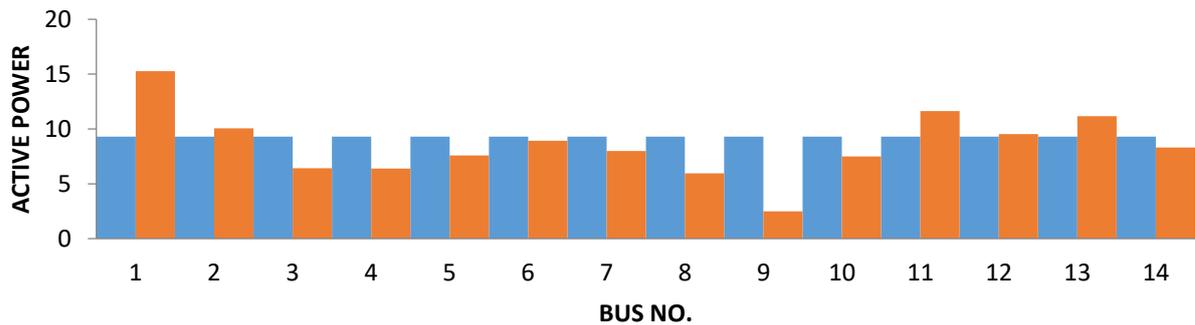


Fig. Profile of IEEE-14 Bus system without and with STATCOM

This loss has been decreased maximum when STATCOM is placed at bus no. 9. The value of active power loss is 9.287MVA without placement of STATCOM and it will become 2.488MVA after the placement of STATCOM.

Table 9.2 Profile of QL for IEEE-14 Bus system without and with STATCOM of size 120MVA

Bus no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
QL_WOST	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.
ATCOM	16	16	16	16	16	16	16	16	16	16	16	16	16	16
QL_WSTA	61.	43.	29.	30.	34.	59.	37.	81.	11.	35.	44.	51.	71.	20.
TCOM	77	44	73	55	96	40	81	71	15	59	35	10	12	90

REACTIVE POWER LOSS

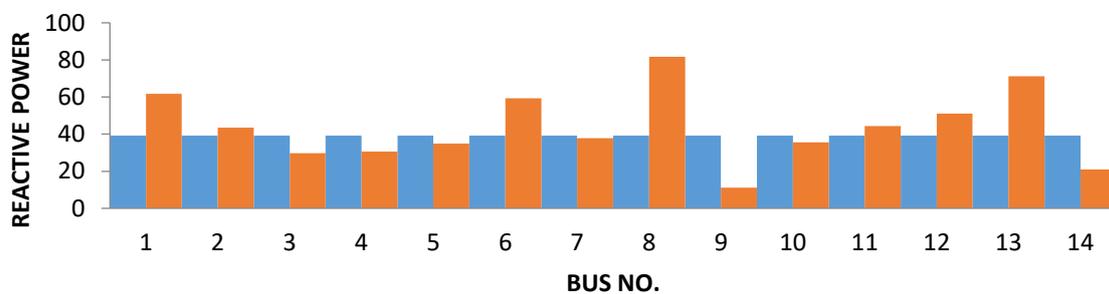


Fig. Profile of IEEE-14 Bus system without and with STATCOM

The reactive power loss of the system has been decreased maximum when the STATCOM placed at bus no. 9. The value of reactive power is 39.16MVAR without placement of STATCOM and it will become 11.15MVAR after the placement of STATCOM.

Case Study 10: IEEE-14 BUS SYSTEM without and with STATCOM

Table 10.1 Profile of PL for IEEE-14 Bus system without and with STATCOM of size 124MVA

Bus no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PL_WOST	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2
ATCOM	87	87	87	87	87	87	87	87	87	87	87	87	87	87

PL_WSTA	15.	10.	6.4	6.2	7.4	9.2	7.9	5.9	1.6	7.6	9.3	10.	11.	8.4
TCOM	371	004	01	83	86	70	84	03	80	68	63	101	662	47

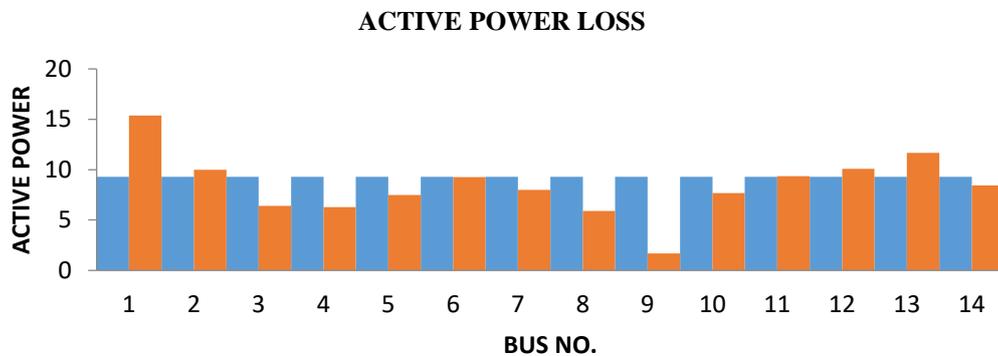


Fig. Profile of IEEE-14 Bus system without and with STATCOM

When we compare the graph. We see that the real power loss of the system has been decreased after the placement of STATCOM for 124MVA at all bus consequently. The real power loss of the system has been decreased maximum when the STATCOM placed at bus no. 9. The value of active power 9.287MVA and it will become 1.680MVA after the placement of STATCOM.

Table 10 .2 Profile of QL for IEEE-14 Bus system without and with STATCOM of size 124MVA

Bus no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
QL_WOST	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.	39.
ATCOM	16	16	16	16	16	16	16	16	16	16	16	16	16	16
QL_WSTA	62.	43.	29.	30.	34.	60.	38.	86.	12.	36.	59.	52.	72.	55.
TCOM	15	34	65	07	61	84	32	01	74	80	14	70	53	64



Fig. Profile of IEEE-14 Bus system without and with STATCOM

From graphical comparing we observed that reactive power loss of the system has been decreased after the placement of STATCOM for 124MVA at all bus consequently. The reactive power loss of the system has been decreased maximum when the STATCOM placed at bus no. 9. The value of reactive power is 39.16MVAR without placement of STATCOM and it will become 12.74MVAR.

Conclusion

In this thesis we introduced the static VAR Compensator and Static Synchronous Compensator, a shunt connected Flexible AC Transmission System (FACTS) device which is capable to increase the load ability, improve the voltage profile, minimize the real and reactive power losses, increased the available transfer capacity, enhance the transient and steady-state stability. This thesis work addresses the enhancement of voltage profile in power system network using SVC and STATCOM following conclusion made from this thesis work are as follows:

For Svc

- Active power loss without SVC =9.287MVA.
- Active power loss with SVC = 2.008MVA.
- Reactive power loss without SVC =39.16MVAR.
- Reactive power loss with SVC =43.50MVAR.
- Optimal location of SVC obtained by optimal power flow is bus number 8.
- Optimal size of SVC obtained by optimal flow analysis is 100MVA.
- Inject Active and reactive power flow in power system network.
- Real power loss and reactive power loss are minimized.
- Real and reactive power flow control capability.
- Power system performance will improve when we add the SVC.

For STATCOM

- Active power loss without STATCOM =9.287MVA.
- Active power loss with STATCOM =1.680MVA.
- Reactive power loss without STATCOM =39.16MVAR.
- Reactive power loss with STATCOM =12.74MVAR.
- Optimal location of STATCOM obtained by optimal power flow is bus number 9.
- Optimal size of STATCOM obtained by optimal flow analysis is 124MVA.
- Inject Active and Reactive Power flow in power system network.
- Real power loss and reactive power loss are minimized.
- Real and Reactive power flow control capability.
- Power system performance will improve when we add the STATCOM.

Performance Improvement Using SVC and STATCOM

Parameter	Without FACTS Device	With SVC	With STATCOM
FACTS Device Type	–	Static VAR Compensator	Static Synchronous Compensator
Connection Type	–	Shunt Connected	Shunt Connected
Optimal Location (Bus No.)	–	8	9
Optimal Size (MVA)	–	100 MVA	124 MVA

Active Power Loss (MVA)	9.287	2.008	1.680
Reactive Power Loss (MVAR)	39.16	43.50	12.74
Active Power Injection	No	Yes	Yes
Reactive Power Injection	No	Yes	Yes
Voltage Profile Improvement	Poor	Improved	Highly Improved
Power Quality Improvement	Poor	Moderate	High
Real Power Loss Reduction (%)	–	78.38 %	81.91 %
Reactive Power Loss Reduction (%)	–	–11.10 % (Increase)	67.46 % Reduction
Control Capability	–	Real & Reactive Power	Fast Real & Reactive Power
Dynamic Response	–	Moderate	Fast
System Stability	Low	Improved	Highly Improved
Overall Performance	–	Good	Excellent

Future scope

- The following future scopes of this thesis work are as follows:
- In future, with insertion of two or more FACTS controllers can be used in coordinated manner to enhance power quality.
- In future, other member of FACTS controllers such as SVC, STATCOM etc. is also used improving power quality and minimizing the real and reactive power losses.
- In future, the artificial intelligence techniques are used for verification of OPF results and for better enhancement of power quality.
- In future, the hybrid artificial intelligence techniques are used for verification of OPF results and for better enhancement of power quality.
- In future, other power system performances may be improved such as system power factor, power quality parameters (voltage sag and swell etc.) by optimally placed FACTS controllers with DGs.

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