Best Location of Shunt Connected STATCOM of Long Interconnected Two AC System Bus with different Power Angle for Voltage and Power Control

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ABSTRACT: In present scenario power system dealing with many types of compensating devises for reactive power management and voltage control of long high voltage transmission line. Recently Shunt connected STATCOM based FACT device reveal a vitals roll in comparison of passive compensating devices. it based on voltage-sourced converter, the STATCOM regulates system voltage by absorbing or generating reactive power. The STATCOM may located at different places such as sending , Middle and Receiving end of transmission line for reactive power compensation. Many research paper shows that Middle location is the best location for optimal compensation when compared to other end of line. But i analysed with MATLAB simulink environment with two-machine system some parameter that affect the degree of compensation of STATCOM at different location. As power angle increases the degree of shunt FACT compensation increased. At steady state limit 90 degree angle is best for midpoint location of STATCOM.

Keywords—FACT device, STATCOM, Matlab Simulink

1. INTRODUCTION

The introduction of Flexible AC Transmission System (FACTS) controllers are increasingly used to provide voltage and power flow controls. Insertion of FACTS devices is found to be highly effective in preventing voltage instability [3]. However, the benefits and performance of FACTS controllers are determined by their location and size [1]. The SVC and STATCOM are members Of the FACTS family that are connected in shunt with the system with the system and are highly Effective in improving the voltage stability and power transmission of system. The analytical method is used here to find out the optimal location of FACTS device, in which first system model simulated, and after simulation observe the voltage magnitude and reactive power consumption in per unit at all buses. Now select the lowest voltage magnitude and highest reactive power Consumption bus, for considerable voltage and power transfer capability this lowest voltage magnitude and highest reactive power consumption bus is the optimal location to install FACTS devices. In this report performance strategy were conducted on STATCOM at different locations such as sending end, middle and the receiving end of the long distance transmission line. In every part of the location the power flow is tested with and without compensation strategy. In this report also shows the effect of STATCOM on voltages of system buses and power flows in both steady state and abnormal conditions. The simulink model of the three bus system is developed and tested using MATLAB Simulink environment.

2. RELATED WORK

In Present scenario the applications of the power electronics devices in power systems are very much augmented. It is an urgent need to control the power flow, in a long distance transmission line. The FACTS devices are introduced in the power system transmission for the reduction of the transmission line losses, Increases Power System Stability and also to increase the transfer capability. STATCOM is VSC based controller to regulate the voltage by varying the reactive power in a long transmission line. Tan Y.L., et al [1] have demonstrated the effectiveness of SVC and STATCOM of same rating for the enhancement of power flow. Xia Jiang Xinghao Fang Chow et al [2] have focused on modelling converter-based controllers when two or more VSCs are coupled to a dc link (e.g., unified power-flow controller (UPFC), interline power-flow controller, and a generalized unified power-flow controller) and in their approach they allowed efficient implementation of various VSC operating limits, where one or more VSCs are loaded to their rated capacity. Chandrakar, V.K. et al [3] have investigated the optimal location of shunt FACTS devices in transmission line for highest possible benefit under normal condition and also they considered three different line models namely, line impedance model, reactance model and pi(π) model. B.K.[5] has presented an overview of how series connected and combined series/shunt connected FACTS controllers are studied in an AC system. Shakib, STATCOMs. Larki, F. et al [14] have presented a new approach for identification of optimal locations of STATCOM and SVC and also simulated case studies conducted on Kouzestan power networks in Iran based on the proposed techniques. Wolanski, Z. Galiana, F.D. ; McGillis, D. ; Joos, G. At [4] shows Many controllers of flexible AC transmission systems (FACTS), such as the STATCOM, the unified power flow controller (UPFC), the PWM asynchronous DC link, the thyristor-controlled series capacitor (TCSC) and the PWM series static VAr compensator have stabilized AC voltage support. Thus, they can be sited at the mid-point of the transmission line, which has been proven by the late E.W. Kimbark, as the optimum location for shunt capacitor compensation. This paper points out that the ability to double the power transfer of the uncompensated line applies also to the aforementioned FACTS devices. The mid-point sitting also facilitates the independent control of reactive power at both ends of the transmission line. Nouri, H. ; Davies, T.S. ;Mukhedkar, R.A. at [8] focused on the injection of reactive power with STATCOM for the control of load bus voltage of a radial system at various locations is examined. The STATCOM which consists of a fixed capacitor bank and a three phase single level voltage source inverter is defined in brief. Also highlighted are new concepts of variable pulse widths and delay angles on the effectiveness of STATCOM for loads such as induction machines and synchronous machines illustrated by simulation. Results suggest, for the load bus voltage to remain within statuary limits, the cost of inverter per reactive power injection is more economical at the load bus. Karthikeyan, M. ; Ajay-D-Vimalraj, P. At [13] describe the Power flow control, in an existing long transmission line, plays a vital role in Power System area. This paper employs the shunt connected compensation (STATCOM) based FACTS device for the control of voltage and the power flow in long distance transmission line. The proposed device is used in different locations such as sending end of the transmission line, middle and receiving end of the transmission line. The PWM control strategy is used to generate the firing pulses of the controller circuit. Simulations were carried out using MATLAB Simulink environment. The suitable location and the performance of the proposed model were examined. Based on a voltage-sourced converter, the STATCOM regulates system voltage by absorbing or generating reactive power. Contrary to a thyristor-based Static Var Compensator (SVC), STATCOM output current (inductive or capacitive) can be controlled independent of the AC system voltage. The simulation results reveals that the reactive power generated is better at the middle of the transmission line when compared with the other ends of the transmission line and also the voltage is controlled at the middle of the line. Henceforth the location of STATCOM is optimum when connected at the middle of the line.

B.T. Ooi(SM) M. Kazerani (M) R. Marceau*(M) 2. Wolanski(M) F.D. Galiana (F) D. McGillis G. Joos**(SM) at [4] expalained that the double power transfer is a consequence of the steady-state stability limit of the radial line between idealized sending-end and receiving-end voltages only. It might not be possible to double the power transfer when non-ideal voltage regulation in the alternators, transient stability, and parallel paths are taken into account. However, the steady-state stability limits points to the opportunity.

The late E.W. Kimbark pointed out that with shunt capacitor voltage support at the mid-point of the

transmission line (which he proved to be the optimum location), it is possible to transmit twice the power of the uncompensated line and to extend the steady-state stability limit from 90" to 180" [1o]. This conclusion *can* be extended to the FACTS devices. When the thermal limit is above twice the transmission power of the line, the FACTS device *can* provide savings if its cost is below that of a second transmission line. Another reason for mid-point sitting is related to the voltage limit set by equipment and transmission design. For a given voltage limit, the mid-point sitting controls a larger reactive power simply because each side of the FACTS device addresses only half the line impedance and not the full line impedance as in the case of the transmission line end-sitting. The paper develops the case, in a tutorial form, using a number of phasor diagrams. To keep the presentation simple, a lossless transmission line is assumed. A proof of
The steady-state stability limit is given in [4]. It is necessary to point out that real power systems deviate in detail from the simplified assumptions used in the tutorial. Furthermore, the double power transfer is a consequence of the steady-state stability limit of the radial line between idealized sending-end and receiving-end voltages only. It might not be possible to double the power transfer when non-ideal voltage regulation in the alternators, transient stability, and parallel paths are taken into account. However, the steady-state stability limit points to the opportunity. Devices [6-81].

3. MODEL DESCRIPTION

The Static Synchronous Compensator (STATCOM) is one of the key FACTS devices. Based on a voltage-sourced converter, the STATCOM regulates system voltage by absorbing or generating reactive power. STATCOM output current (inductive or capacitive) can be controlled independent of the AC system voltage.

The Model taken from matlab 7.7.0 consists of two 500-kV equivalents (respectively 3000 MVA and 2500 MVA) connected by a 600-km transmission line. Three resistive load each rating is 100 MW. When the STATCOM is not in operation, the "natural" power flow on the transmission line from bus B1 to B3. In our demo, the STATCOM is located at the different location of the line and has a rating of +/- 100MVA. This STATCOM is a phasor model of a typical three-level PWM STATCOM. Transmission line and other ratings are same as in matlab model.

4. SIMULATION MODEL WITH DIFFERENT LOCATION OF STATCOM

Given model represent a system which consist of interconnected two machine buses in between two section of 300 km transmission line.100 MW load is connected in each segment of line.Fig1 simulate the result for without STATCOM condition then Fig2 to Fig4 represent for different location of STATCOM.

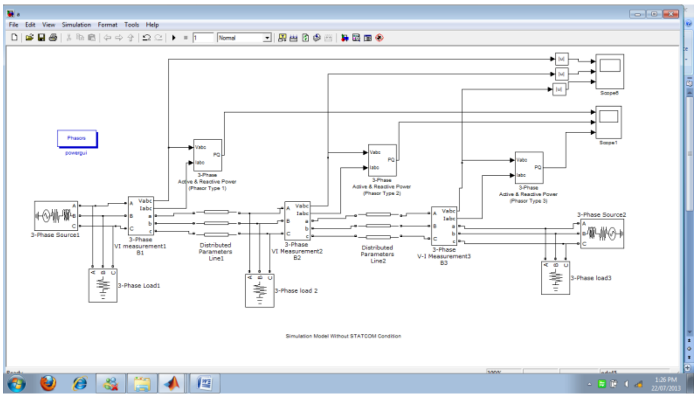


Fig.1 Simulation Model at Without STATCOM Condition.

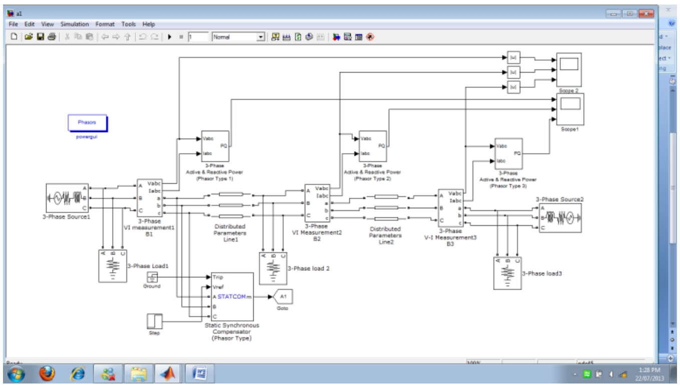


Fig.2 Simulation model at STATCOM at Sending End Condition.

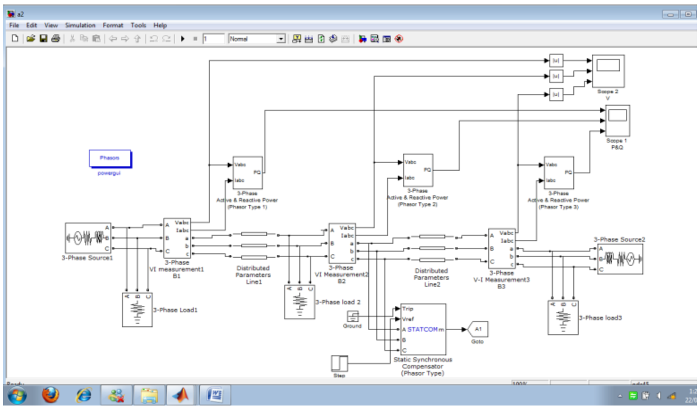


Fig.3 Simulation Model when STATCOM at Middle

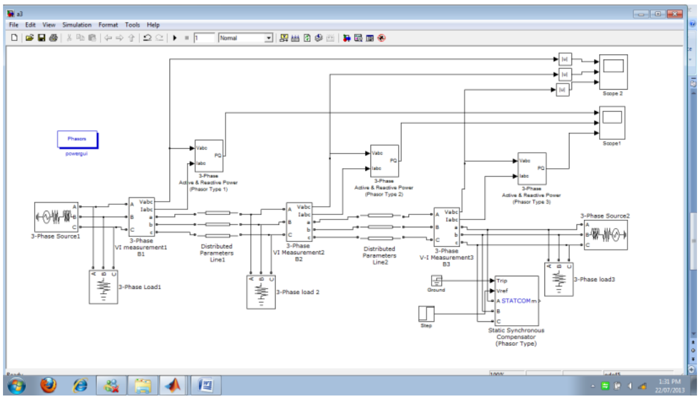


Fig.4 Simulation Model when STATCOM at Receiving End.

5. SIMULATION WAVEFORM

Simulation result P,Q & V in waveform shown in Fig5 to Fig11 with different STATCOM condition and 75 degree power angle only.In three axis scope Upper,Middle and Lower scope represent for Bus B1,B2 and B3 respectively.for P& Q graph Yellow line represents to Active power P and Red line represents to Reactive power Q. Graph at other power angle except 75 degree is not shown only result are given.

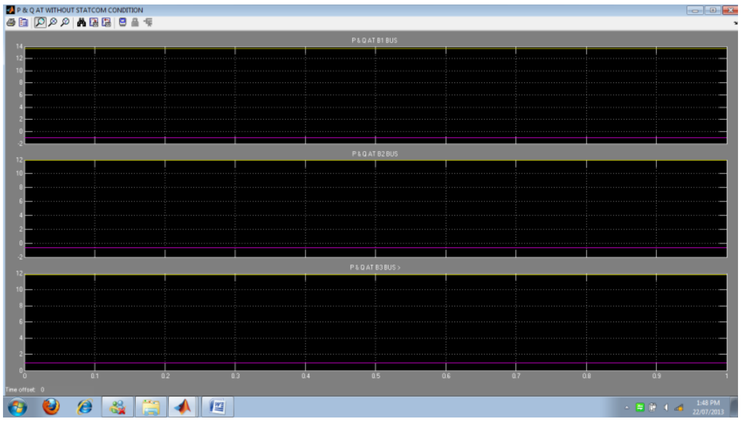


Fig. 5 P & Q When STATCOM is Not Connected

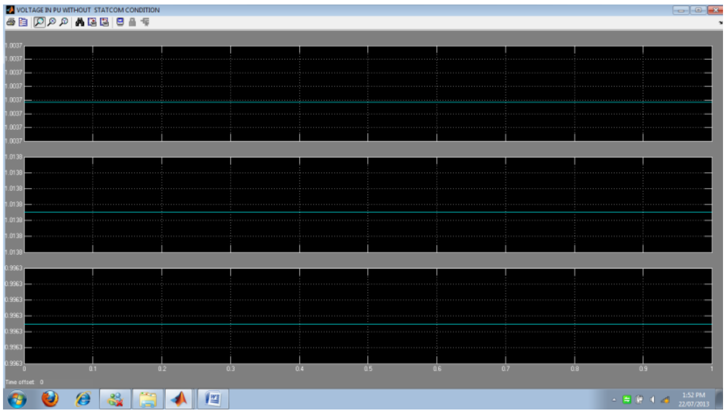


Fig.6 Bus Voltages When STATCOM is Not Connected

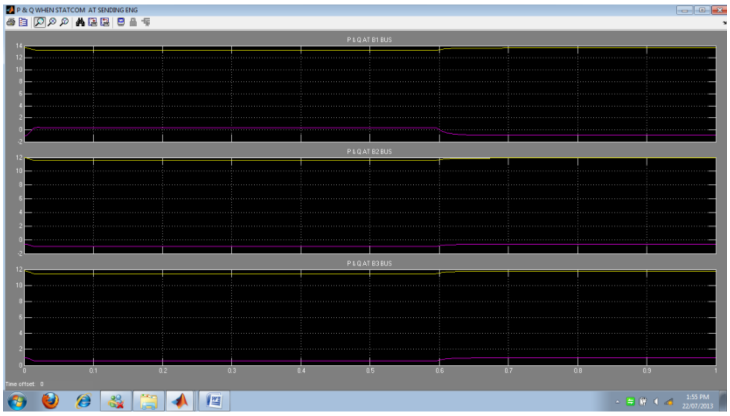


Fig.7 P & Q When STATCOM at Sending End.

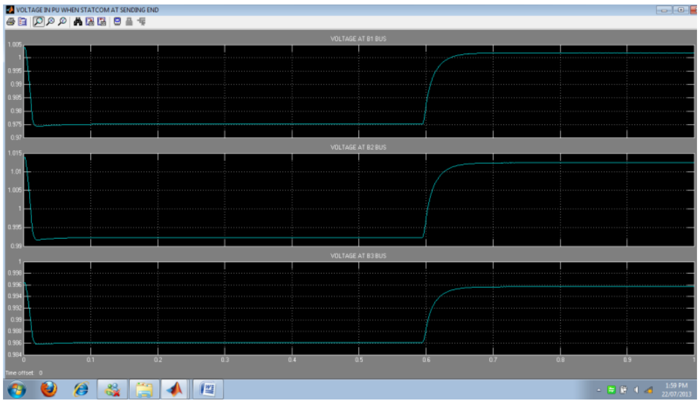


Fig.8 Voltage When STATCOM at Sending End

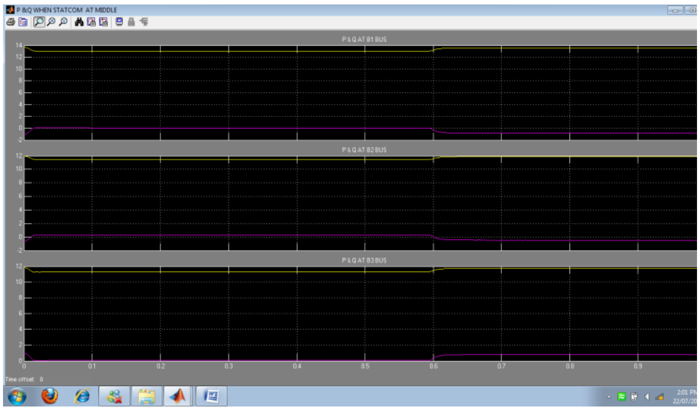


Fig. 9 P & Q When STATCOM at Middle

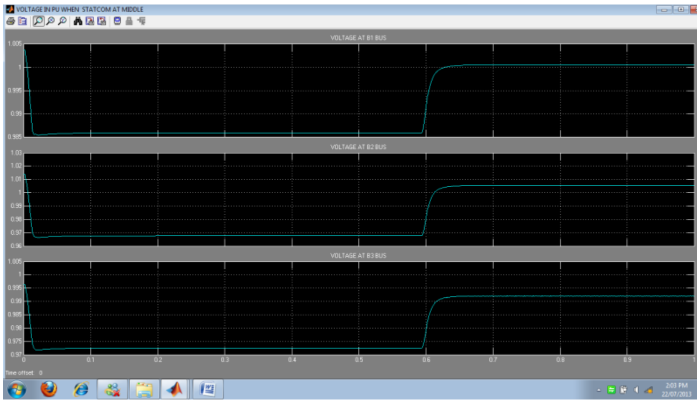


Fig.10 Simulation Result of Voltage When STATCOM at Middle

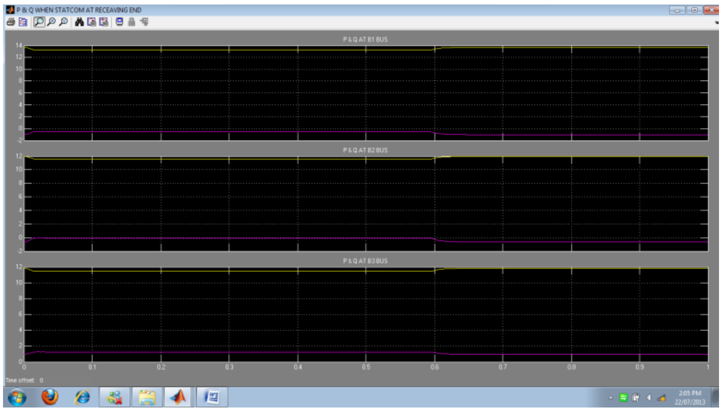


Fig.11 P & Q When STATCOM at Receaving End

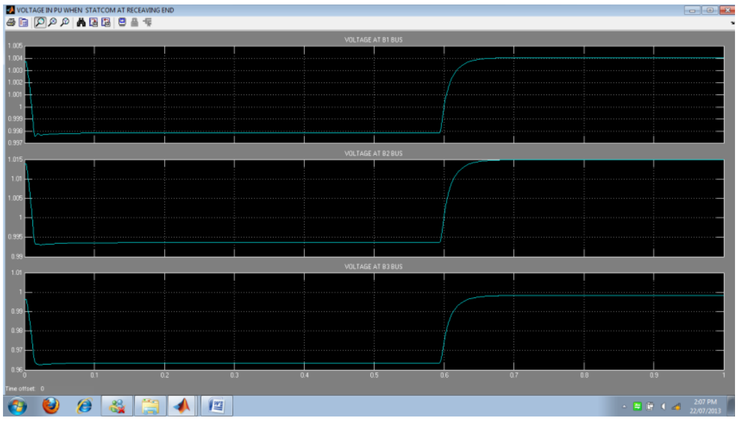


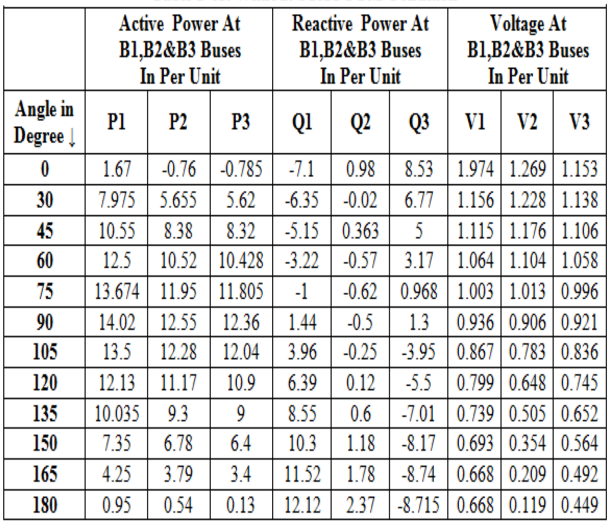
Fig.12 Simulation Result of Voltage When STATCOM at Receaving End

6. RESULTS

Simulation results at different location of SATACOM with different power angle 0 to 180 degree are give in table no 1 to 4.

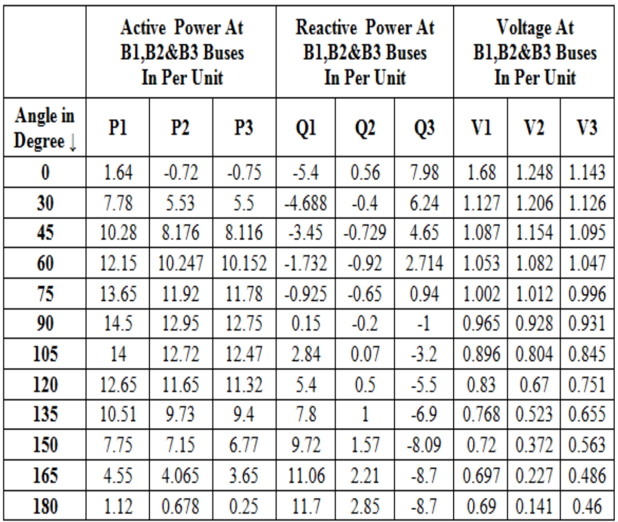
Table no 5 to 11 also shown the same parameter for simplicity of analytical point of view they are in order of power angle. At power angle 30, 60, 90,120,150 &180 the variation of P,Q&V at different location of STATCOM are shown. It is clear that angle till 60 degree active power will be approximately same at without and compensated condition but as angle increase active power after compensation is increasing and will become double approx. at angle 150 to 180 degree. Reactive power also deficit after compensation at middle STATCOM condition reactive power deficit more.

Table 1 At Without STATCOM Condition



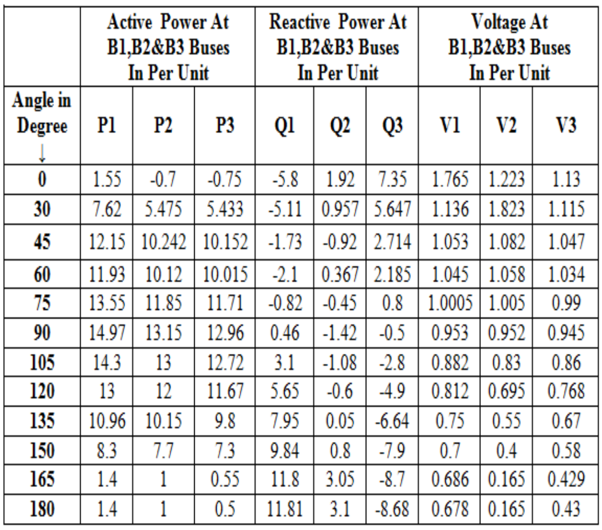
	Active Power At B1,B2&B3 Buses In Per Unit			Reactive Power At B1,B2&B3 Buses In Per Unit			Voltage At B1,B2&B3 Buses In Per Unit		
Angle in Degree ↓	**P1**	**P2**	**P3**	**Q1**	**Q2**	**Q3**	**V1**	**V2**	**V3**
0	1.67	-0.76	-0.785	-7.1	0.98	8.53	1.974	1.269	1.153
30	7.975	5.655	5.62	-6.35	-0.02	6.77	1.156	1.228	1.138
45	10.55	8.38	8.32	-5.15	0.363	5	1.115	1.176	1.106
60	12.5	10.52	10.428	-3.22	-0.57	3.17	1.064	1.104	1.058
75	13.674	11.95	11.805	-1	-0.62	0.968	1.003	1.013	0.996
90	14.02	12.55	12.36	1.44	-0.5	1.3	0.936	0.906	0.921
105	13.5	12.28	12.04	3.96	-0.25	-3.95	0.867	0.783	0.836
120	12.13	11.17	10.9	6.39	0.12	-5.5	0.799	0.648	0.745
135	10.035	9.3	9	8.55	0.6	-7.01	0.739	0.505	0.652
150	7.35	6.78	6.4	10.3	1.18	-8.17	0.693	0.354	0.564
165	4.25	3.79	3.4	11.52	1.78	-8.74	0.668	0.209	0.492
180	0.95	0.54	0.13	12.12	2.37	-8.715	0.668	0.119	0.449

Table 2 STATCOM At Sending End



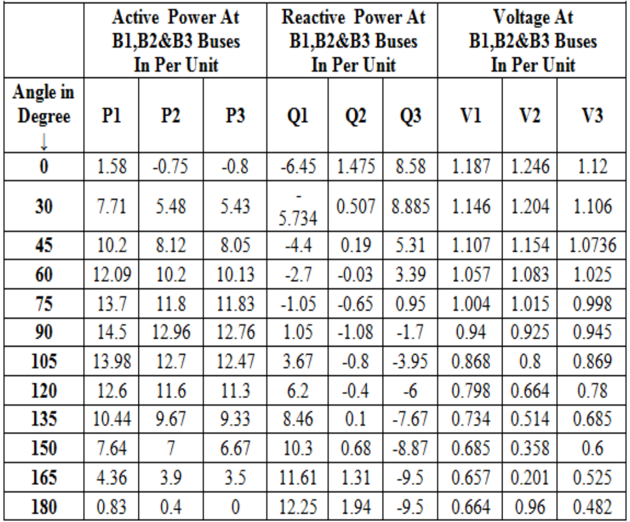
	Active Power At B1,B2&B3 Buses In Per Unit			Reactive Power At B1,B2&B3 Buses In Per Unit			Voltage At B1,B2&B3 Buses In Per Unit		
Angle in Degree ↓	**P1**	**P2**	**P3**	**Q1**	**Q2**	**Q3**	**V1**	**V2**	**V3**
0	1.64	-0.72	-0.75	-5.4	0.56	7.98	1.68	1.248	1.143
30	7.78	5.53	5.5	-4.688	-0.4	6.24	1.127	1.206	1.126
45	10.28	8.176	8.116	-3.45	-0.729	4.65	1.087	1.154	1.095
60	12.15	10.247	10.152	-1.732	-0.92	2.714	1.053	1.082	1.047
75	13.65	11.92	11.78	-0.925	-0.65	0.94	1.002	1.012	0.996
90	14.5	12.95	12.75	0.15	-0.2	-1	0.965	0.928	0.931
105	14	12.72	12.47	2.84	0.07	-3.2	0.896	0.804	0.845
120	12.65	11.65	11.32	5.4	0.5	-5.5	0.83	0.67	0.751
135	10.51	9.73	9.4	7.8	1	-6.9	0.768	0.523	0.655
150	7.75	7.15	6.77	9.72	1.57	-8.09	0.72	0.372	0.563
165	4.55	4.065	3.65	11.06	2.21	-8.7	0.697	0.227	0.486
180	1.12	0.678	0.25	11.7	2.85	-8.7	0.69	0.141	0.46

Table 3 STATCOM At Middle Condition



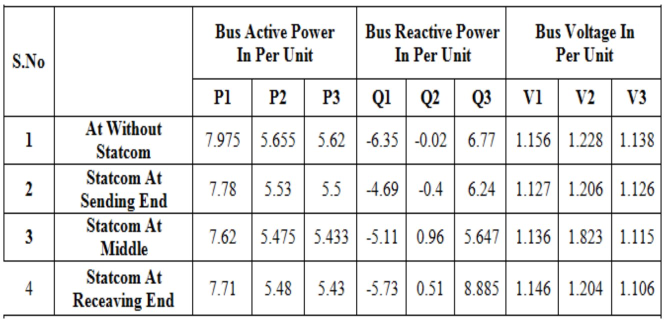
	Active Power At B1,B2&B3 Buses In Per Unit			Reactive Power At B1,B2&B3 Buses In Per Unit			Voltage At B1,B2&B3 Buses In Per Unit		
Angle in Degree ↓	**P1**	**P2**	**P3**	**Q1**	**Q2**	**Q3**	**V1**	**V2**	**V3**
0	1.55	-0.7	-0.75	-5.8	1.92	7.35	1.765	1.223	1.13
30	7.62	5.475	5.433	-5.11	0.957	5.647	1.136	1.823	1.115
45	12.15	10.242	10.152	-1.73	-0.92	2.714	1.053	1.082	1.047
60	11.93	10.12	10.015	-2.1	0.367	2.185	1.045	1.058	1.034
75	13.55	11.85	11.71	-0.82	-0.45	0.8	1.0005	1.005	0.99
90	14.97	13.15	12.96	0.46	-1.42	-0.5	0.953	0.952	0.945
105	14.3	13	12.72	3.1	-1.08	-2.8	0.882	0.83	0.86
120	13	12	11.67	5.65	-0.6	-4.9	0.812	0.695	0.768
135	10.96	10.15	9.8	7.95	0.05	-6.64	0.75	0.55	0.67
150	8.3	7.7	7.3	9.84	0.8	-7.9	0.7	0.4	0.58
165	1.4	1	0.55	11.8	3.05	-8.7	0.686	0.165	0.429
180	1.4	1	0.5	11.81	3.1	-8.68	0.678	0.165	0.43

Table 4 STATCOM At Receiving End



	Active Power At B1,B2&B3 Buses In Per Unit			Reactive Power At B1,B2&B3 Buses In Per Unit			Voltage At B1,B2&B3 Buses In Per Unit		
Angle in Degree ↓	**P1**	**P2**	**P3**	**Q1**	**Q2**	**Q3**	**V1**	**V2**	**V3**
0	1.58	-0.75	-0.8	-6.45	1.475	8.58	1.187	1.246	1.12
30	7.71	5.48	5.43	-5.734	0.507	8.885	1.146	1.204	1.106
45	10.2	8.12	8.05	-4.4	0.19	5.31	1.107	1.154	1.0736
60	12.09	10.2	10.13	-2.7	-0.03	3.39	1.057	1.083	1.025
75	13.7	11.8	11.83	-1.05	-0.65	0.95	1.004	1.015	0.998
90	14.5	12.96	12.76	1.05	-1.08	-1.7	0.94	0.925	0.945
105	13.98	12.7	12.47	3.67	-0.8	-3.95	0.868	0.8	0.869
120	12.6	11.6	11.3	6.2	-0.4	-6	0.798	0.664	0.78
135	10.44	9.67	9.33	8.46	0.1	-7.67	0.734	0.514	0.685
150	7.64	7	6.67	10.3	0.68	-8.87	0.685	0.358	0.6
165	4.36	3.9	3.5	11.61	1.31	-9.5	0.657	0.201	0.525
180	0.83	0.4	0	12.25	1.94	-9.5	0.664	0.96	0.482

Table 5 At power Angle 30 Degree



S.No		Bus Active Power In Per Unit			Bus Reactive Power In Per Unit			Bus Voltage In Per Unit		
		P1	**P2**	**P3**	**Q1**	**Q2**	**Q3**	**V1**	**V2**	**V3**
1	**At Without Statcom**	7.975	5.655	5.62	-6.35	-0.02	6.77	1.156	1.228	1.138
2	**Statcom At Sending End**	7.78	5.53	5.5	-4.69	-0.4	6.24	1.127	1.206	1.126
3	**Statcom At Middle**	7.62	5.475	5.433	-5.11	0.96	5.647	1.136	1.823	1.115
4	**Statcom At Receaving End**	7.71	5.48	5.43	-5.73	0.51	8.885	1.146	1.204	1.106

Table 6 At power Angle 60 Degree

S.No		P1	P2	P3	Q1	Q2	Q3	V1	V2	V3
1	At Without Statcom	12.5	10.52	10.43	-3.22	-0.57	3.17	1.064	1.104	1.058
2	Statcom At Sending End	12.15	10.25	10.15	-1.73	-0.92	2.714	1.053	1.082	1.047
3	Statcom At Middle	11.93	10.12	10.02	-2.1	0.37	2.185	1.045	1.058	1.034
4	Statcom At Receaving End	12.09	10.2	10.13	-2.7	-0.03	3.39	1.057	1.083	1.025

Table 7 At power Angle 75 Degree

S.No		P1	P2	P3	Q1	Q2	Q3	V1	V2	V3
1	At Without Statcom	13.67	11.95	11.81	-1	-0.62	0.968	1.003	1.013	0.996
2	Statcom At Sending End	13.65	11.92	11.78	-0.93	-0.65	0.94	1.002	1.012	0.996
3	Statcom At Middle	13.55	11.85	11.71	-0.82	-0.45	0.8	1.001	1.005	0.99
4	Statcom At Receaving End	13.7	11.8	11.83	-1.05	-0.65	0.95	1.004	1.015	0.998

Table 8 At power Angle 90 Degree

S.No		P1	P2	P3	Q1	Q2	Q3	V1	V2	V3
1	At Without Statcom	14.02	12.55	12.36	1.44	-0.5	1.3	0.936	0.906	0.921
2	Statcom At Sending End	14.5	12.95	12.75	0.15	-0.2	-1	0.965	0.928	0.931
3	Statcom At Middle	14.97	13.15	12.96	0.46	-1.42	-0.5	0.953	0.952	0.945
4	Statcom At Receaving End	14.5	12.96	12.76	1.05	-1.08	-1.7	0.94	0.925	0.945

Table 9 At power Angle 120 Degree

S.No.		Bus Active Power In Per Unit			Bus Reactive Power In Per Unit			Bus Voltage In Per Unit		
		P1	P2	P3	Q1	Q2	Q3	V1	V2	V3
1	At Without Statcom	12.13	11.17	10.9	6.39	0.12	-5.5	0.799	0.648	0.745
2	Statcom At Sending End	12.65	11.65	11.32	5.4	0.5	-5.5	0.83	0.67	0.751
3	Statcom At Middle	13	12	11.67	5.65	-0.6	-4.9	0.812	0.695	0.768
4	Statcom At Receaving End	12.6	11.6	11.3	6.2	-0.4	-6	0.798	0.664	0.78

Table 10 At power Angle 150 Degree

S.No		P1	P2	P3	Q1	Q2	Q3	V1	V2	V3
1	At Without Statcom	7.35	6.78	6.4	10.3	1.18	-8.17	0.693	0.354	0.564
2	Statcom At Sending End	7.75	7.15	6.77	9.72	1.57	-8.09	0.72	0.372	0.563
3	Statcom At Middle	8.3	7.7	7.3	9.84	0.8	-7.9	0.7	0.4	0.58
4	Statcom At Receaving End	7.64	7	6.67	10.3	0.68	-8.87	0.685	0.358	0.6

Table 11 At power Angle 180 Degree

S.No		P1	P2	P3	Q1	Q2	Q3	V1	V2	V3
1	At Without Statcom	0.95	0.54	0.13	12.12	2.37	-8.715	0.668	0.119	0.449
2	Statcom At Sending End	1.12	0.678	0.25	11.7	2.85	-8.7	0.69	0.141	0.46
3	Statcom At Middle	1.4	1	0.5	11.81	3.1	-8.68	0.678	0.165	0.43
4	Statcom At Receaving End	0.83	0.4	0	12.25	1.94	-9.5	0.664	0.96	0.482

6.1 VARIATION OF ACTIVE POWER

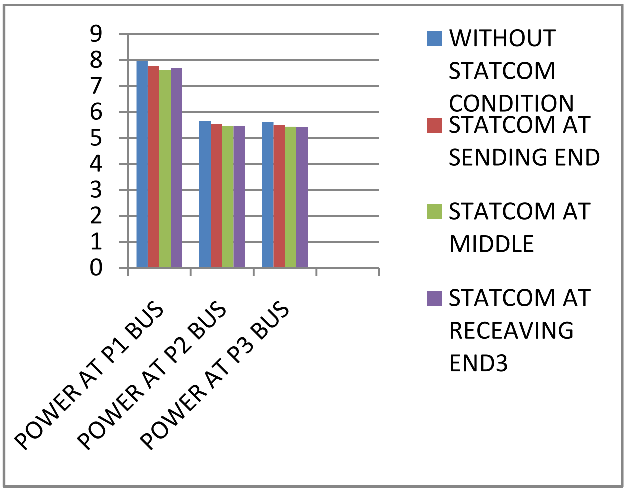


Fig.12 Active Power P of B1, B2, & B3 Buses at different Location of STATCOM at 30 Degree power angle

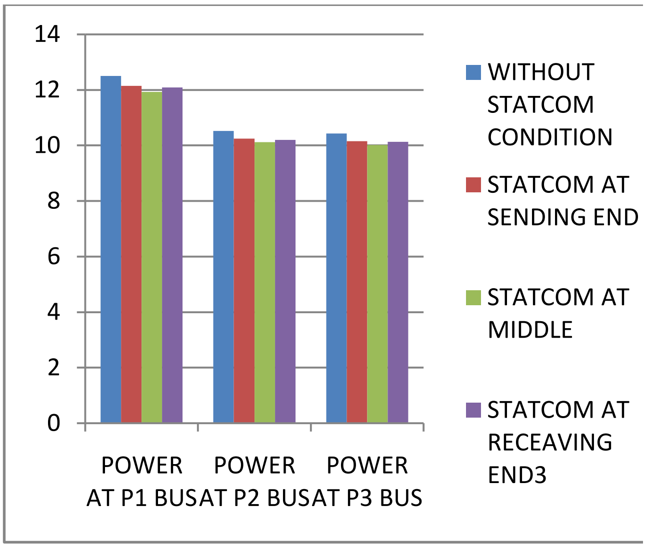


Fig.13 Active Power P of B1, B2, & B3 Buses at different Location of STATCOM at 60 Degree power angle.

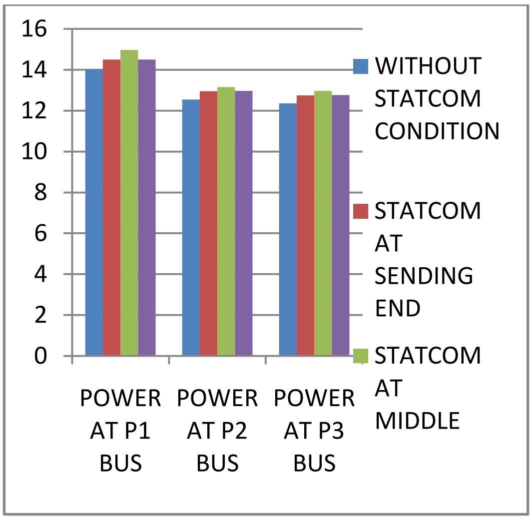


Fig.14 Active Power P of B1, B2, & B3 Buses at different Location of STATCOM at 90 Degree power angle.

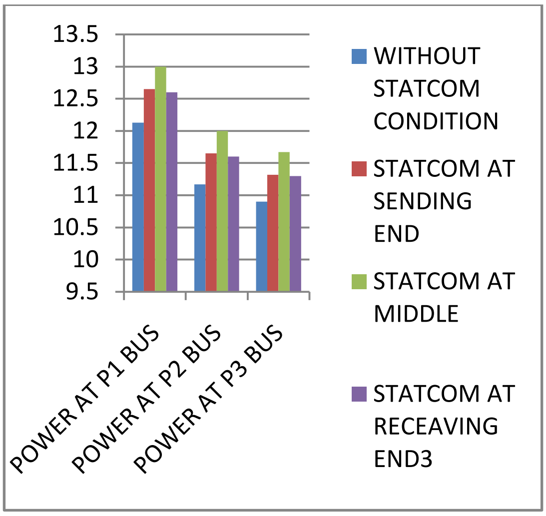


Fig.15 Active Power P of B1, B2, & B3 Buses at different Location of STATCOM at 120 Degree power angle.

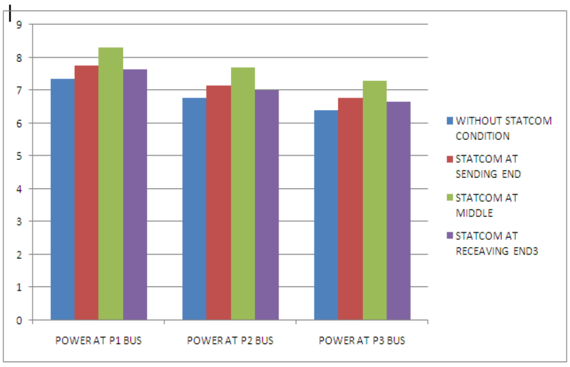


Fig.16 Active Power P of B1, B2, & B3 Buses at different Location of STATCOM at 150 Degree power angle

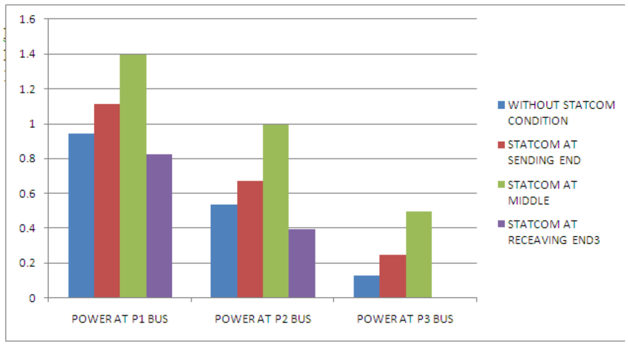


Fig.17 Active Power P of B1, B2, & B3 Buses at different Location of STATCOM at 180 Degree power angle

7. CONCLUSION

The vital role of shunt FACTS devices, which are connected in long distance transmission lines, are to improve the power transfer capability and also to control the power flow in the power system network. In this proposed work STATCOM is employed as a shunt FACTS device. STATCOM is connected at the various locations such as sending end, middle and receiving end of the transmission line. The results were obtained with and without compensation at different location of STATCOM with different power angle. The simulation results and Graph from Fig(3a) to Fig(3f) shows that the reactive power generated and voltage controlled is better at the middle of the transmission line when compared with the other ends of the transmission line and also this is analyzed that at mid point location of STATCOM power transfer increase with power angle increase but at steady state limit 90 degree is best for better power transfer. So, the location of STATCOM is optimum when connected at the middle of the line.

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