Impact of SVC on Rajasthan Power System

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Abstract— **Requirement of electricity is increasing day by day, to fulfil the demand more power plants either they are conventional or renewable are also growing in numbers consequently. Extracting the power from power plants and to supply the load more transmission and distribution lines are needed, this makes the power system more bulky and sensitive to disturbances. Moreover the installation of new lines is not an easy task as there are some limitations due to financial and right of way aspects, so the growth of such lines is slower than expected. More and more power flowing through the existing lines touching there maximum thermal limit or the stability limits of generators. A small disturbance (series / shunt faults, outage of generators etc.) in power system can cause complete grid failure. FACTS devices are the best solution of such problems as they can maintain reactive power level in power system either by supplying or absorbing it. In this paper impact of Static VAr Compensator (SVC) on Rajasthan Power System is presented using Mipower simulation tool.**

***Keywords*—**Stability, SVC, Rajasthan Power System, 3 phase fault, outage of line, outage of generator.

1. INTRODUCTION

In last years voltage stability is painstaking as an vital concern to electric power industry. Voltage instability and voltage collapse portend power system reliability and security. The voltage glitches are often allied with contingencies like sudden line and generator outage, inadequate local reactive power supply and augmented loading of transmission lines. Voltage collapse is generally categorised by an preliminary gradual and progressive reduction and a ultimate quick drop in voltage magnitude at different buses.

To confirm continuous and worth power supply to the consumers the power system should be stable under contingency conditions. The introduction of Flexible AC Transmission System (FACTS) controllers [2] are progressively used to offer voltage and power flow controls. Addition of FACTS devices is initiate to be extremely effective in avoiding voltage instability [3].Though, the pay backs and performance of FACTS controllers are determined by their location and size [4].

Owing to extraordinary cost, the number of FACTS devices to be used should be diminished and their welfares may be maximized through efficient optimization techniques [5].Static VAR Compensator (SVC) is a shunt connected regulator proficient of all probable assistances of FACTS devices. It was proven that it is so easy to combine SVC in load flow solution and extremely appropriate for VAr support.

Through the earlier years there has been a constantly increasing courtesy to voltage stability calculation utilizing numerous analysis methods. Liu and Vu [6] offered a dynamic explanation of voltage collapse by distinguishing the voltage stability regions in terms of continuous tap changer model. Lee et al [7] presented a principle for static voltage stability improvement and used precise models for excitation systems, tap changer and other device for investigation of dynamic voltage stability. Voltage stability study using static and dynamic approaches in small radial network was executed by Morison et al [8]. Few advantages of dynamic simulation of this phenomenon were revealed by Deuse et al [9]. Taylor [10] and Kundur [11] suggested different static technique an dynamic simulation with suitable models for voltage stability equation.

2. MODELLING OF RAJASTHAN POWER SYSTEM

Simulation model of Rajasthan Power System is made up of its exact replica which has 748 buses encompassing 765 kV (2 nos.), 400 kV (35 nos.), 220 kV (145 nos.), 132kV (503 nos.) and generator buses (63 nos.). Total load of Rajasthan Power System is expected to be 10,000 MW [13].Three thermal power plants of nearly 3500 MW capacity are located in southern part of Rajasthan. Power of Kawai Super Critical Thermal Power Plant (2x660 MW), Chhabra Super Thermal Power Plant (4x250 MW) and Kalisindh Super Thermal Power Plant (2x600 MW) is combined at 400 kV voltage level at 765 kV GSS Anta and after that, it is being transmitted to 765 kV GSS Jaipur through 765 kV (2 nos.) single circuit lines as shown in APPENDIX 2.

3. LOCATION OF SVC

The location of SVC is significant in determining its usefulness. Preferably, it should be positioned at the electrical centre of the system or centre of a transmission line[9].

In this research SVC is connected to 400 kV bus through 400/33 kV transformer at 765 kV GSS Jaipur. Such location is selected because a large amount of generation is concentrated to southern part of Rajasthan and it is beneficial to transmit this power to higher voltage level to reduce the losses.

For a transmission line joining two systems, the best location for VAr compensator is at the middle, while for a radial feed to a load the best location is at the load end [10].

4. SIZE OF SVC

In order to choose SVC rating, the extreme conditions of the system are considered. The SVC has together capacitive as well as inductive rating. For the assortment of capacitive rating of SVC, the supreme load condition of the Rajasthan power system (i.e. 10,000 MW) has been fixed.

A. CAPACITIVE RATING OF SVC

Endurance of the capacitive rating of SVC, the maximum load of Rajasthan has been considered (i.e. 10,000MW) in the load flow study. Results of load flow study are shown in Fig 1. As per load flow study, virtual generator injects 245 MVAr, therefore, it should be suitable to fix the capacitive rating of SVC as 250 MVAr.

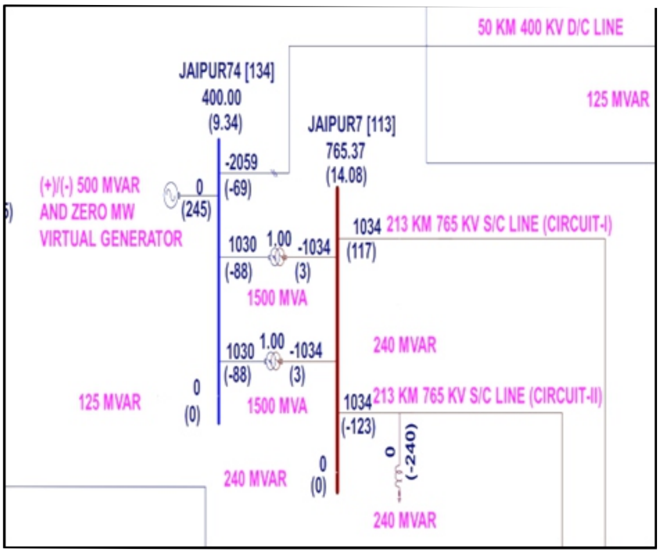

Fig. 1.Determining the Capacitive Rating of SVC

B. INDUCTIVE RATING OF SVC

To calculate the inductive rating of SVC, the minimum load of Rajasthan has been considered (i.e. 8,000MW) in the load flow study. Results of load flow study are shown in Fig.2. As per load flow study, virtual generator draw 218 MVAr, therefore, inductive rating of SVC should be 250 MVAr.

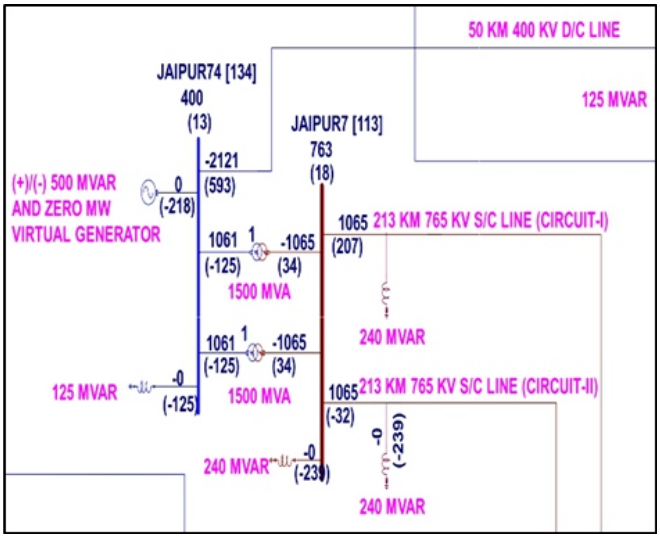

Fig. 2.Determining the Inductive Rating of SVC

5. IMPACT OF SVC ON RAJASTHAN POWER SYSTEM

To analyse the effect of SVC on load flow of large power system, load flow study is carried out for 10,000 MW load of Rajasthan Power System. Following two cases are considered for the load flow study:

Case-I: Load flow study of Rajasthan power system without SVC.

Case-II: Load flow study of Rajasthan power system with SVC connected at 765 kV GSS Jaipur.

Results of load flow study for above two cases are plotted at APPENDIX-2 andAPPENDIX-3 respectively.

6. RESULTS

A. Effect of SVC on Power System Voltage

The data shown in Table 1 demonstrates that the voltage of power system is improved with SVC.

TABLE 1
EFFECT OF SVC ON VOLTAGES OF DIFFERENT BUSES IN POWER SYSTEM

S. No.	Name of Bus	Nominal Bus voltage (kV)	Bus voltage (kV)	
			Without SVC	With SVC
1	Jaipur7	765	753.13	763.42
2	Anta7	765	754.26	761.24
3	Jaipur74	400	392.17	398.74
4	Anta74	400	394.62	396.62
5	Bassi4	400	392.54	396.93
6	Heerapura4	400	391.06	394.90
7	Kawai4	400	394.67	396.01
8	Kalisindh4	400	394.35	395.55
9	Chhabra4	400	394.88	396.14
10	Jodhpur4	400	397.04	398.26

Voltage of 400 kV GSS Jodhpur which is 300 km away from Jaipur has also improved. Therefore, it is observed that the effect of SVC installation is effective for large distance.

B. Effect of SVC on Generator Reactive Power Loading

Table 2 indicates that with SVC, reactive power loading on generators has been significantly reduced.

TABLE 2
EFFECT OF SVC ONGENERATOR REACTIVE POWER LOADING

S. No.	Name of Generator	Generators Reactive Power Loading (MVAr)	
		Without SVC	With SVC
1	Kawai_G1	82	63
2	Kawai_G2	82	63
3	Kalisindh_G1	79	63
4	Kalisindh_G2	79	63
5	Chhabra_G1	32	24
6	Chhabra_G2	32	24
7	Chhabra_G3	32	24
8	Chhabra_G4	32	24

Available reactive power margin on generators can be used to meet the requirements in steady condition and also in transient period.

C. Effect of SVC on Generator Active Power Output

Table 3 indicates that with SVC, there is no change in active power output of generators which clarify that there is no adverse effect on active power output while employing SVC.

TABLE 3
EFFECT OF SVC ON GENERATORS ACTIVE POWER OUTPUT

S. No.	Name of Generator	Generators Active power loading (MW)	
		Without SVC	With SVC
1	Kawai_G1	660	660
2	Kawai_G2	660	660
3	Kalisindh_G1	600	600
4	Kalisindh_G2	600	600
5	Chhabra_G1	250	250
6	Chhabra_G2	250	250
7	Chhabra_G3	250	250
8	Chhabra_G4	250	250

D. Effect of SVC on Active Power Flow through Power System Elements

With SVC at 765 kV substation Jaipur, power flow on 765 kV S/C Anta-Jaipur line has increased from 1032 MW to 1037 MW on each circuit. In Case-I, 765 kV S/C Anta-Jaipur lines are under loaded whereas 400 kV S/C Chhabra-Hindaun line is over loaded.

TABLE 4
EFFECT OF SVC ON ACTIVE POWER FLOW OF TRANSMISSION SYSTEM ELEMENTS

S. No.	Name of Generator	Power flow (MW)	
		Without SVC	With SVC
1	765 kV S/C Anta-Jaipur line (circuit-I)	1032	1037
2	765 kV S/C Anta-Jaipur line (circuit-II)	1032	1037
3	400 kV S/C Chhabra-Hindaun line	570	568
4	400 kV S/C Chhabra-Bhilwara line	395	391
5	1x315 MVA, 400/220 kV Transformer at Chhabra TPS	205	203
6	1x315 MVA, 400/220 kV Transformer at Kalisindh TPS	228	226

In Case-II, power flow on 765 kV S/C Anta-Jaipur line has increased and decreased on 400 kV S/C Chhabra-Hindaun line. As per load flow study, SVC increased the power flow on transmission lines which are directly connected to the substation as shown in Table 4.

E. Effect of SVC on Losses

In Case II total system losses are reduced as compared to Case I. System losses are reduced from 423.47 MW to 419.45 MW. The losses are reduced by 4.02 MW as shown in Table 5

TABLE 5
RAJASTHAN POWER SYSTEM LOSSES
WITHOUT & WITH SVC

S. No.	Active Power Loss (MW)	
	Without SVC	**With SVC**
1	423.47	419.45

7. CONCLUSION

In this paper, effect of SVC on Rajasthan Power System under steady state is analysed by using Mipower simulation software. As per load flow studies, with the application of SVC in normal operating conditions, voltage profile of power system is improved and reactive power loading on generators is reduced which increased the operating reserve of reactive power in the power system. The transmission losses are also reduced, real power flow on transmission lines increased and power angle of generators also reduced due to the presence of SVC. By considering the real time problems the compatibility of SVC for Rajasthan Power system has been checked out.

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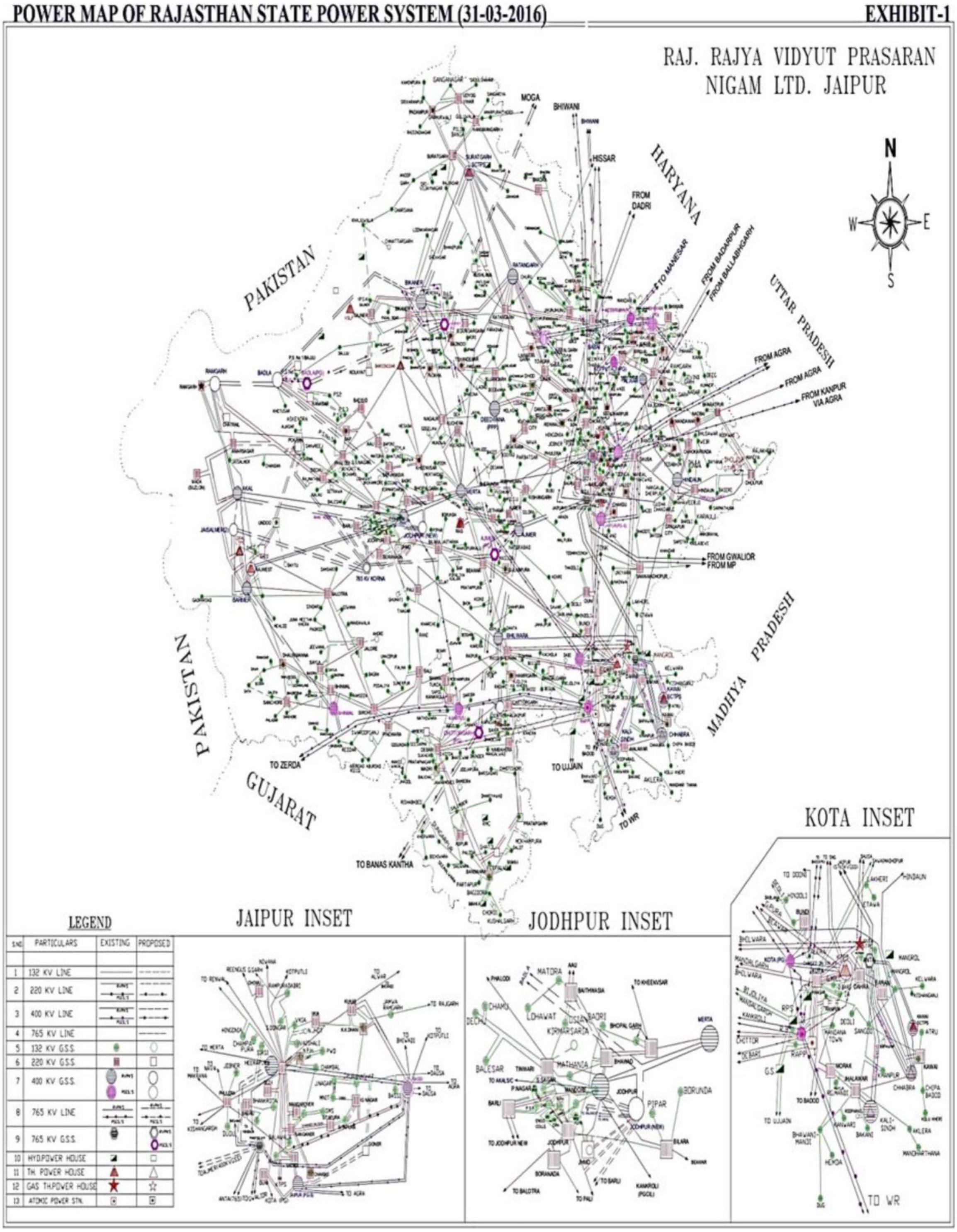
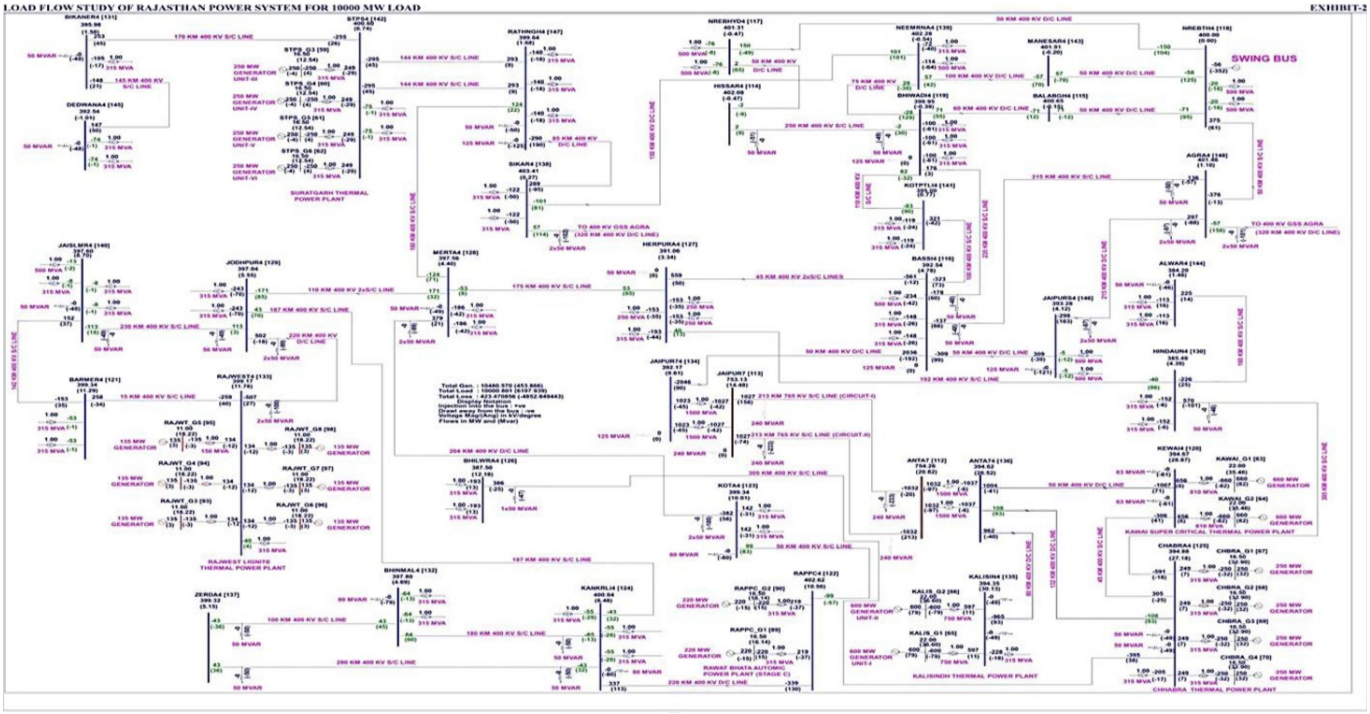
APPENDIX-1


POWER MAP OF RAJASTHAN STATE POWER SYSTEM (31-03-2016)
EXHIBIT-1
RAJ. RAJYA VIDYUT PRASARAN
NIGAM LTD. JAIPUR
N
W
E
S
PAKISTAN
HARYANA
UTTAR PRADESH
MADHYA PRADESH
GUJARAT
PAKISTAN
KOTA INSET
JAIPUR INSET
JODHPUR INSET
LEGEND
TO ZERDA
TO BANAS KANTHA
TO UJJAIN
TO WR
FROM AGRA
FROM GWALIOR
FROM MP

APPENDIX-2

Load Flow Results when SVC was Not Connected



APPENDIX-3

Load Flow Results when SVC was Connected