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Analysis of Existing Losses of 220 kV Substation With Possible Suggestions Of Reduction

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Abstract— Every Power System consists of basic electrical assembly and end to end protection zone. But during the long lifetime operation of a GSS possibility of faults and disoperation do exists. Majority of problems existing in these working stations remains same basic difference lies in the suitability of preventive actions taken to cope up with those critical situations. Thus following research paper carries practical case study for the existing losses of a real time 220 kV GSS. In the Indian Power System shunt capacitor banks have been installed at 33 kV voltage level at EHV substations to compensate load reactive power demand. But the capacity of installed shunt capacitors does not match with load reactive power demand which results in excessive reactive power flow on lines and transformers. Reflectively it results higher transmission losses, increased loading and poor voltage profile of the network. In this research paper case study of Rajasthan power system has been studied to evaluate the losses existing at 33 kV voltage level on transmission and other assemblies deployed. 220 kV GSS Sri Dungargarh located in Churu district has been selected to carry out the detail studies. Actual system condition of 220 kV GSS Sri Dungargarh existing in September 2016 has been simulated in Software. Impact of optimal reactive management at 33 kV voltage level has been analyzed on transmission losses, lines and transformers loading and network voltage profile. From simulation studies it is found out that significant transmission loss at 33 kV voltage level are obtained. Along with that various assemblies not in proper usages and dead conditions have been marked out along with their contribution in losses. These measures could be taken as guideline for the utilities to prepare a manageable guidebook over preventive measures for loss reduction at transmission level GSS.

Keywords— *Reactive Power losses, Transformer Taps; Load flow studies; transmission loss reduction; voltage profile improvement.*

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I. INTRODUCTION

Power system is anendless energy dissipating system in the form of electrical resistance [1]. India has one of the highest levels of electricity losses in the world. These losses imply electricity that is generated but does not reachingto customers. India's T&D losses are almost 25% of generation, i.e more than twice the world average [2].

Utilities are unaware of skillful ways to handle the operating of grids. The naïve behavior towards reactive power management is aging the system equipment’s by making them to work under capability. Thus promoting unskilled operation and laying way to increase in power losses of the system.

In this research work the existing losses of 220 kV has been identified and its effect on subsidiary 132 kV grid sub-stations, at 33 kV voltage level has been presented.

Rajasthan State Power system has been considered for research studies [4]. As observed from the past literature works shunt capacitor banks deployment can effectively reduce the power loss and provide additional benefits for system operation. Practice laid by, Yan Xu Zhao in 2013 [5] the power loss on transformers can account for a considerable portion of the overall loss. This work had proposed a method for optimal placement of capacitor banks to the transformers to reduce power loss. The capacitor bank locations are considered at the low-side of transformers. In 2013 by Young Jin Kim et al. [6] researched techniques to control steady-state voltage of test network by using reactive power ancillary service. The reactive power was managed in coordination with on-load tap changer (OLTC) and shunt capacitors (SCs) to reduce distribution line power losses. Mixed-integer nonlinear optimization problem was formulated & solved by using a particle swarm optimization (PSO) algorithm. Simulation case studies were performed to exhibit the coordinated reactive power support of the OLTC, and SCs which resulted in improved voltage quality.

The importance of OLTC operation was also discussed by Z. Hu in 2003 [7] where by determining the optimum dispatch schedules for on-load tap changer (OLTC) at substations operations were decided. The shunt capacitor switching depends on day-ahead load forecast. Switching operations modified for OLTC at substations, and time-interval based control strategy was adopted with genetic algorithm to ensure less switching operations than maximum allowed once to obtain a better voltage profile was continued. The proposed strategy minimized the power loss and improved the voltage profile by maintaining proper volt/var control of the system. Load carrying capability of the line also enhanced by controlling the reactive power flow of capacitor banks. Shunt capacitors compensation power loss reduction by maintain system voltage profile and reducing the lines and transformer loading were briefed by A.A. Sallam et al. in 2002 [8]. Similarly a better smart grid technology work was showed by G. Vamsi Krishna Kartheek [9] by suggesting options for reactive power management with coordinated voltage control at generators tap changers and switched shunt capacitors for enhanced voltage stability was put forwarded as a possible recommendation for coordinated operation of grid with pronounced skillful operation of utilities.

The location of generation and load pockets is large, the centralized monitoring and control of Thermal Power Stations from substations, becomes difficult. Also limited functionality is available for transmission infrastructures that are outside of substations. It has been observed that in Rajasthan Power System work is not carried towards optimum reactive power

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management [10]. As a result underutilization of power system equipment's causes unnecessary burden over the power generating assemblies of the system. Consequently increasing system losses, operation and maintenance cost of the grid therefore system requirements of reactive power must be fulfilled timely[11].

II. Objectives Of Case Study Of Real Time 220 Kv GSS

Rajasthan Power System is a vast system the test network considered is directly obtaining its power from 400 kV substations. Thus objectives fulfilled will directly improvise the whole grid. Thepurposes intended are briefed below.

1. To simulate the actual load flow of 220 KV GSS Sri Dungargarh as per actual data collection.
2. To identify the losses of 220 KV and subsidiary connected 132 KV GSS with identification of out of service capacitor banks.
3. Ways of loss reduction of Test System suitable for 220 KV voltage level.

III. Test system Data

Rajasthan State Power System has an area of 1,32,147 Square miles and had a population of 6.86 Crores [6]. The highest transmission voltage in Rajasthan is 765 kV. There are two 765 kV GSS, twenty one 400 kV GSS, one hundred eleven 220 KV GSS, three hundred ninety three 132 kV GSS as on 31st march 2016. Power map of Rajasthan power system is placed at Fig. 1.

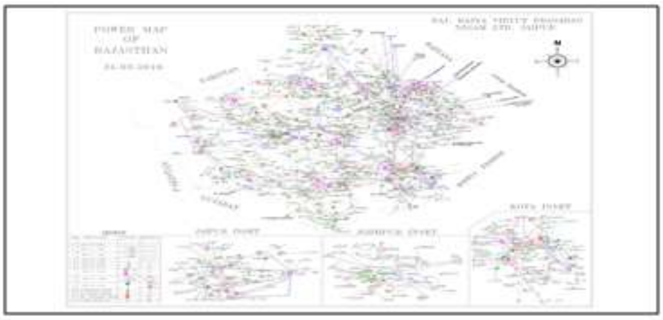

Fig.1 Rajasthan Power Map

220 kV GSS Sri Dungargarh is located in the Churu district and feed load of 132 kV GSS at Dulchasar,Sri Dungargarh, Riri and Upani through 132 kV lines. It is connected from 400 kV GSS Bikaner through 59 kM long 220 kV S/C line and also connected from 400 kV GSS Ratangarh through 62 kM long 220 kV S/C line. A generator has been connected to 220 kV bus of 220 kV GSS Sri Dungargarh and treated as a swing bus.Rajasthan Discoms 33 kV feeders are emanating from 33 kV bus of 220 kV and 132 kV substations and aggregated load of these 33 kV feeders has been represented at respective substations at 33 kV voltage level. Single line diagram of test system is placed at Fig-2 and details are abstracted here under.

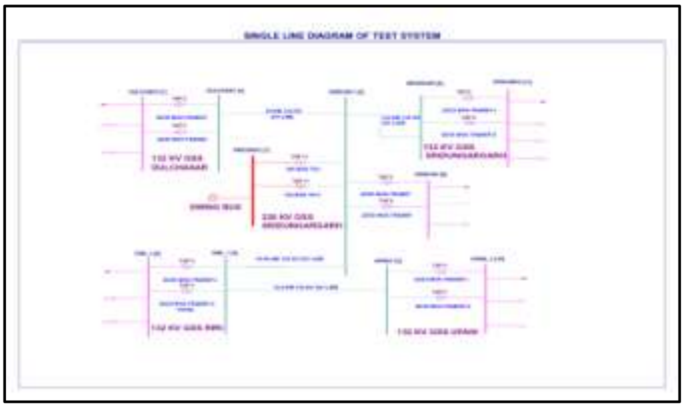

Fig.2 Single Line Diagram of Test System

TABLE I TRANSFORMERS DATA

Name of GSS	Transformers Details			
	Voltage Ratio	**MVA Capacity**	**% Impedance**	**X/R Ratio**
220 kV Sri Dungargarh	220/132 kV	100	12.39	67.7
	220/132 kV	100	12.39	67.7
	132/33 kV	40/50	11.93	37.74
	132/33 kV	20/25	10.09	28.98
132 kV Sri Dungargarh	132/33 kV	20/25	10.43	28.02
	132/33 kV	20/25	9.80	29.86
132 kV Dulchasar	132/33 kV	40/50	11.93	37.74
	132/33 kV	20/25	10.09	28.98
132 kV Riri	132/33 kV	20/25	9.80	29.86
	132/33 kV	20/25	9.91	29.86
132 kV Upani	132/33 kV	20/25	9.66	29.44
	132/33 kV	20/25	10.05	30.63

TABLE II TRANSMISSION LINES DATA

From GSS	To GSS	Line Voltage (kV)	Type of Circuit	Length (km)	Type of Conductor
220 kV Sri Dungargarh	132 kV Sri Dungargarh	132	S/C	2.6	Panther
220 kV Sri Dungargarh	132 kV Dulchasar	132	S/C	35	Panther
220 kV Sri Dungargarh	132 kV Riri	132	S/C	16.5	Panther
132 kV Riri	132 kV Upani	132	S/C	12.5	Panther

TABLE III PANTHER CONDUCTOR POSITIVE SEQUENCE PARAMETERS

System Particulars	Resistance(R) (Ohm/kM)	Reactance (X) (Ohm/kM)	Susceptance (B/2) (mho/km)
Values	0.1622174	0.3861158	1.46349e-006

IV. Actual System Data

To simulate the actual system condition, bus voltage, power flow on lines and transformers, actual tap setting of transformers, load, and status of capacitor banks of 220 kV GSS Sri Dungargarh and connected 132 kV substations have been gathered on 10 Sep 2016 at 1.0 PM and discussed in the following paragraphs:

a) Load Data

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As per information gathered on 10-9-2016 at 1 PM the recorded load of 33 kV feeders at the substations is provided in Table IV.

TABLE IV LOAD DATA

S.No.	Name of GSS	Recorded Load	
		MW	Power Factor
1	220 kV GSS Sri Dungargarh	29	0.85
2	132 kV GSS Sri Dungargarh	36	0.85
3	132 kV GSS Dulchasar	30	0.85
4	132 kV GSS Riri	26	0.85
5	132 kV GSS Upani	28	0.85
	Total	**149**	**0.85**

b) Shunt Capacitor Bank Data

Shunt Capacitor Banks are connected to 33 kV buses of substations. Net capacity capacitors connected at various substations on 10.9.2016 at 1 PM are provided in Table V.

TABLE V SHUNT CAPACITOR BANKS DATA

Name of GSS	Capacity of Shunt Capacitors (MVAR)	
	Installed (MVAR)	"ON" capacitors
220 kV GSS Sri Dungargarh	2x5.43	1x5.43
132 kV GSS Sri Dungargarh	3x5.43	3x5.43
132 kV GSS Dulchasar	2x5.43	2x5.43
132 kV GSS Riri	2x5.43	2x5.43
132 kV GSS Upani	2x5.43	2x5.43
Total	**59.73**	**54.30**

One 5.43 MVAR capacity shunt capacitor bank is out of service at 220 kV GSS Sri Dungargarh due to damage of circuit breaker and RVT.

c) Transformer TapPosition

Substation operators vary the tap position of transformers to control the LV bus voltage. Tap position of transformers at various substations on 10.9.2016 at 1 PM is abstracted in the followingtable:-

TABLE VI TRANSFORMERS TAP POSITION DETAILS

Name of GSS	Transformers Tap Details				
	MVA Capacity	Min.Tap / Min.Tap Voltage (kV)	Max.Tap / Max.Tap Voltage (kV)	Nomi.Tap / Nomi.Tap Voltage (kV)	Actual Tap Position
220 kV Sri Dungargarh	100	1/187	21/242	9/220	11
	100	1/187	21/242	9/220	11
	40/50	1/138	17/112	5/132	9
	20/25	1/138	17/112	5/132	9
132 kV Sri Dungargarh	40/50	1/138	17/112	5/132	8
	20/25	1/138	17/112	5/132	8
132 kV Dulchasar	20/25	1/138	17/112	5/132	9
	20/25	1/138	17/112	5/132	9
132 kV Riri	20/25	1/138	17/112	5/132	9
	20/25	1/138	17/112	5/132	9
132 kV Upani	20/25	1/138	17/112	5/132	8
	20/25	1/138	17/112	5/132	8

Table VI also denotes the actual transformer tap setting.

d) Bus Voltage

220 kV GSS and 132 kV GSS bus voltages were obtained and provided in Table VII.

TABLE VII BUS VOLTAGE

Name of GSS	Bus Voltage (kV)		
	220 kV Bus	132 kV Bus	33 kV Bus
220 kV Sri Dungargarh	224	131	35
132 kV Sri Dungargarh	Nil	133	34
132 kV Dulchasar		128	33
132 kV Riri		131	34
132 kV Upani		130	34

e) Line Power flow

Transmission Line power flows details to model the system as per actual recorded data is provided in Table VIII.

TABLE VIII TRANSMISSION LINE POWER FLOWS

Name of Line	Power flow	
	MW	MVAR
132 kV S/C Sridungargarh-Riri-Upani Line	55.69	16.11
132 kV S/C Sridungargarh-Dulchasar Line	30.1	7.97
132 kV S/C Sridungargarh (132 kV GSS)-Sridungargarh (220 kV GSS) Line	37.09	8.31
132 kV S/C Riri-Upani Line	28.3	4.029

Due to some errors in the measurement and also some time difference of measurement, some deviations may be observed in measured values.

f) Substation Power flow

Substation power flows of MW and Mvar as per database recorded by system engineer is provided in Table IX.

TABLE IX SUB-STATION POWER FLOWS

Name of GSS	Particulars	Power flow	
		MW	MVAR
220 kV Sri Dungargarh	132 kV side	144.08	44.22
	33 kV side	28.81	14.12
132 kV Sri Dungargarh	33 kV side	36.06	5.537
132 kV Dulchasar	33 kV side	29.67	8.65
132 kV Riri	33 kV side	25.9	3.86
132 kV Upani	33 kV side	28.27	5.7

g) Swing Bus Data

220 kV bus of 220 kV GSS Sridungargarh is represented as swing bus. Actual bus voltage and power drawal from Rajasthan grid by 220 kV GSS Sridungargarh on 10.9.2016 at 1 PM is tabulated here under

TABLE X SWING BUS DATA

Particulars	Swing Bus Voltage (kV)	MW flow	MVAR flow
	224	145	57

V. Simulation Of Actual System Condition

Test system has been modeled in the MiPower software and system condition of 10.9.2016 at 1.0 PM has been simulated.This case is identified as Case-I. IEEE data format of test system is placed at Appendix-1. Load flow study has been carried out using Newton Raphson method. Results of load flow study of Case-I are plotted at Fig-3. Results of load flow study are near to actual values.

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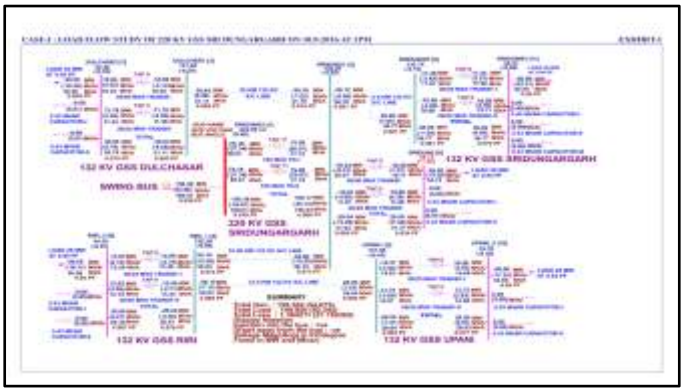

Fig.3 Load Flow Study of Case I

In Case-I, reactive power loading on swing bus is 54.68 MVAR. Therefore, new shunt capacitor banks have been identified at EHV substations to reduce the reactive flow and losses in the network. Additional shunt capacitor banks have been identified considering following factors :

- Load MVAR requirement
- Installed ShuntCapacitors
- Improvement of power factor
- Available capacity of shunt capacitors

Shunt capacitors are available of capacity 5.43 MVAR &can be operated either full capacity or half capacity i.e. 2.715 MVAr. Transmission system is capacitive and generators are stable in lagging power factor mode, therefore, substation power factor is maintained lagging.

VI. RESULT ANALYSIS

I. Effect on MVARs flow on Lines and Transformers

MVAR flow on lines and transformers of Test System in Case-I and Case-III have been tabulated at Table XIII.

TABLE XI MVAR FLOW ON LINES AND TRANSFORMERS

Particulars	**MVAR flow**
	Case-I
220/132 kV Transformers at 220 kV Sri Dungargarh	40.13
132/33 KV Transformers	
Sri Dungargarh(220 kV GSS)	11.96
Sri Dungargarh(132 kV GSS)	4.60
Dulchasar (132 kV GSS)	6.78
Riri (132 kV GSS)	4.21
Upani (132 kV GSS)	5.97
132 kV S/C Transmission Lines	
Sri Dungargarh (220 kV GSS)- Sri Dungargarh(132 kV GSS) Line	6.99
Sri Dungargarh-Dulchasar Line	7.02
Sri Dungargarh-Riri Line	12.56
Riri -Upani Line	7.11

From the simulation study it is observed that reactive power loading on all four transmission lines and substation transformers have been reduced in Case-III as compared to Case-I.

II. Effect on loading on Lines and Transformers

Loading of substation transformers and lines in Case-I and Case-III have been tabulated at Table XIV.

TABLE XII LOADING OF TRANSFORMERS AND LINES

Particulars	**MVA Loading**
	Case-I
220/132 kV Transformers at 220 kV Sri Dungargarh	155.44
132/33 kV Transformers at 220 kV Sri Dungargarh	31.37
132/33 kV Transformers at 132 kV Sri Dungargarh	36.77
132/33 kV Transformers at 132 kV Dulchasar	30.76
132/33 kV Transformers at 132 kV Riri	26.34
132/33 kV Transformers at 132 kV Upani	28.63
132 kV S/C Sri Dungargarh(220 kV GSS)- Sri Dungargarh(132 kV GSS) Line	36.77
132 kV S/C Sri Dungargarh-Dulchasar Line	31.11
132 kV S/C Sri Dungargarh-Riri Line	55.63
132 kV S/C Riri -Upani Line	29.04

From Table XIV it is observed loading on transmission lines and transformers have been decreased in Case-III as compared to Case-I which is due to reduction of MVAR flow. This spare capacity can be used to meet the increasing demand of respective areas and avoid the augmentation of system.

III. Effect on Voltage

Bus voltage in Test System for Case I and III are tabulated at table XV.

TABLE XIII EFFECT ON VOLTAGE

Name of GSS	**Bus Voltage (kV)**					
	Case-I			**Case-III**		
	220 kV	**132 kV**	**33 kV**	**220 KV**	**132 kV**	**33 kV**
220 kV Sri Dungargarh	224	133.91	34.72	224	136.39	34.59
132 kV Sri Dungargarh	-	133.74	34.41	-	136.26	33.18
132 kV Dulchasar	-	131.85	34.42	-	134.95	34.16
132 kV Riri	-	132.20	34.55	-	135.12	34.14
132 kV Upani	-	131.50	33.79	-	134.64	33.65

It is observed that network voltage profile in Case-III is better than Case-I.

IV. Effect on losses

Total losses of 220 kV GSS Sri Dungargarh which includes transformers losses at all five EHV substations and line losses of all four 132 kV lines for Case-I and Case-III are tabulated in table XVI.

TABLE XIVTRANSMISSION LOSS IN CASE-I AND CASE-III

Particulars	**Case I**
MW loss	1.3842

The MW loss of existing test system is1.3842 MW. Transmission losses are needed to be reduced. As per studies carried out in the complete Rajasthan network, total network saving could be doubled by providing savings in 132 kV network. Therefore, total saving may be raised by adding various power system improvement devices.Therefore, cost of additional shunt capacitor banks will be recovered in the first deployment year.

VII. CONCLUSION

In this paper, case study of Rajasthan power system has been presented and studied to evaluate the losses existing at 33 kV voltage level in transmission network and other system assemblies.

Studies have been carried for available versus proposed optimal reactive power management (Case-III). Following are the conclusions of studies :

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1. Reactive power loading on transmission lines and transformers have been reduced in Case-III as compared to Case-I.
2. The loading on transmission lines and transformers have been decreased in Case-III as compared to Case-I which is due to reduction MVAR flow on lines and transformers. This spare capacity can be used to meet the increasing demand of respective areas and avoid the augmentation of system.
3. It is seen that network voltage profile in Case-III is better than Case-I.
4. MW losses are significantly reduced in Case III as compare to Case I.
5. Cost of additional shunt capacitor banks have been recovered in one year due to energy saving.

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