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Design Analysis of 220/132 KV Substation Using ETAP

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Abstract – *Electrical power system provides a vital service to the society. For healthy operation of electrical power generation, transmission and distribution, it is important that system should be balanced. This research paper deals with the simulation of 220/132 kV substation. The analysis is done by using advance software Electrical Transient Analyzer Program (ETAP) with detailed load flow analysis. All the data used for analysis is real time and collected from 220/132 KV substation under M.S.E.T.C.L.*

Key Words: *ETAP, Design analysis using ETAP, Load flow studies using ETAP, under voltage overcome, Reactive power compensation.*

1. INTRODUCTION

Electrical power system is back bone of the development of a nation. There is big issue of power quality for developed nations but the developing countries like India the load is increasing rapidly but generation is not up to the level of demand. Hence there is need of load flow management. Load flow analysis using software is accurate and gives highly reliable results. This research makes effective use of Electrical Transient Analyzer Program (ETAP) to carry out load flow analysis of 220 kV substation. The actual ratings of Power Transformers, Circuit Breakers, Current Transformers, Potential Transformers and Isolating switches are taken and modeled accordingly in ETAP. This 220 kV substation is located in Maharashtra State Electricity Transmission Corporation Limited (MSETCL) which comprises of 4 Power Transformers, 25 Circuit Breakers, 21 Current Transformers, 4 Potential Transformers and 55 Isolating switches.

The major cause of almost all the major power system disturbance is under voltage. Reactive power (VAr's) cannot be transmitted very far especially under heavy load conditions so it must be generated close to the point of consumption. This is because the difference in voltage causes reactive power (VAr's) to flow and voltages on a power system are only +/- 5 percent of nominal and this small voltage difference does not cause substantial reactive power (VArs) to flow over long distances. So if that reactive power (VArs) is not available at the load centre, the voltage level goes down. Chronic under voltages can cause excess wear and tear on certain devices like motor as they will tend to run overly hot if the voltage is low. The single line diagram of the substation is simulated in ETAP based upon actual data and it is seen that at both the 33 kV feeder buses and 132 kV buses there is under voltage. To overcome the under voltage at both the 33 kV feeder buses and 132 kV buses capacitor bank of suitable ratings are placed in shunt.

Section 1.1 is introduction of ETAP software. Section 2 is the details of the components. Section 3 is the simulation of single line diagram of 220 kV substation in ETAP based upon practical data. Section 4 is the Load Flow Analysis of the substation. Section 5 contains the Alert summary report generated after load flow analysis. Section 6 is the load flow analysis of the substation with an improvement to surmount the problem of under voltage. Section 6.1 rating of capacitor bank. Section 7 is the conclusion of this research work.

1.1 About ETAP

ETAP is Electrical Transient Analyzer Program. This software provides engineers, operators, and managers a platform for continuous functionality from modeling to operation. ETAP's model-driven architecture enables 'Faster than Real-Time' operations - where data and analytics meet to provide predictive behavior, preemptive action, and situational intelligence to the owner-operator.

ETAP offers a suite of fully integrated electrical engineering software solutions including arc flash, load flow, short circuit, transient stability, relay coordination, cable capacity, optimal power flow, and more. Its modular functionality can be customized to fit the needs of any company, from small to large power systems. Here we are focusing on load flow studies of 220 kV/132 kV/33 kV substation.

2 DETAILS OF COMPONENTS

Table -1

COMPONENT	TYPE	RATINGS	
Power Transformer	Transformer 1	50 MVA	
	Transformer 2	25 MVA	
	Transformer 3	150 MVA	
	Transformer 4	100 MVA	
Circuit Breaker	CB 1-11	30kV/1600A	
	CB 12-19	145kV/3150A	
	CB 20-25	245kV/3150A	
Current Transformer		Primary	Secondary
	CT 1-3	800A	1A
	CT 4-11	200A	1A
	CT 12-18	800A	1A
	CT 19-22	400A	1A
Potential Transformer	PT 1	220kV	120V
	PT 2,3	33kV	120V
	PT 4	132kv	120V
Isolating Switches	SW 1-20,45,47,49	33kV/1500A	
	SW 21-37,50	132kV/1250A	
	SW 38-44,46-48	220kV/1000A	
	SW 51-55	220kV/1000A	
Feeders	Load 1	175A	
	Load 2	262.4A	
	Load 3	175A	
	Load 4	140A	
	Load 5	209.9A	
	Load 6	122.5A	
	Load 7	157.5A	
	Load 8	140A	
	Load 9	349.9A	
	Load 10	306.2.A	
	Load 11	43.74	
	Load 12,13,14	0A (FUTURE)	

3. SIMULATION OF 220 kV SUBSTATION IN ETAP

Fig. 1 shows the Power Grid which supplies power to the 220 kV Bus 6 and Bus 7. Transformer 1 and Transformer 2 are 220kV/33kV supply power to Bus 1 and Bus 2 respectively. Four feeders are emanating from Bus 1 and four feeders are emanating from Bus 2. On the other side Transformer 3 and Transformer 4 is 220kV/132kV supply power to Bus 4 and Bus 5 respectively. Three feeders are emanating from Bus 4 and three feeders are emanating from Bus 5.

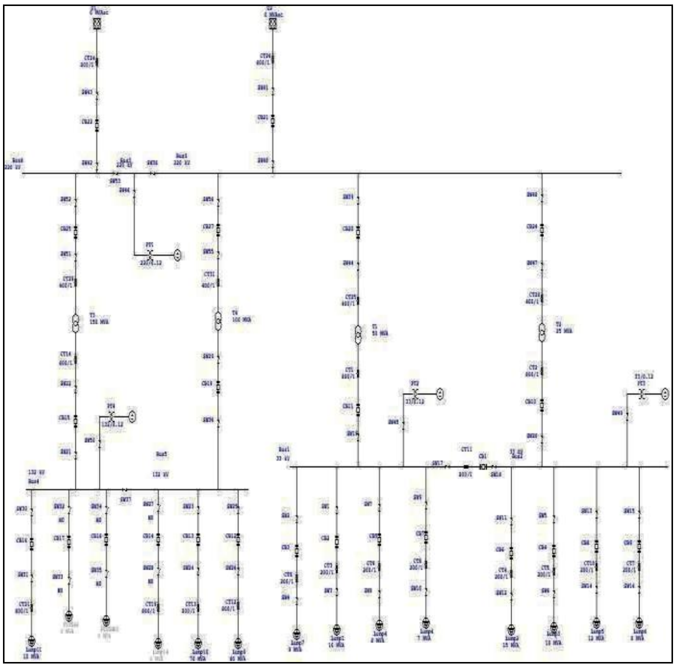

Fig.1. Simulated diagram of 220 kV substation using ETAP

4 LOAD FLOW ANALYSES

Fig. 2 shows the sectional view of load Flow Analysis of the 220kV substation carried out using ETAP in which Newton-Raphson method is used and it is observed that at the Bus 4 and Bus 5 there is under voltage which can be clearly seen from Fig. 2 (B) showing the sectional view of the feeders. At Bus 4 and Bus 5 the voltage level is 96%.

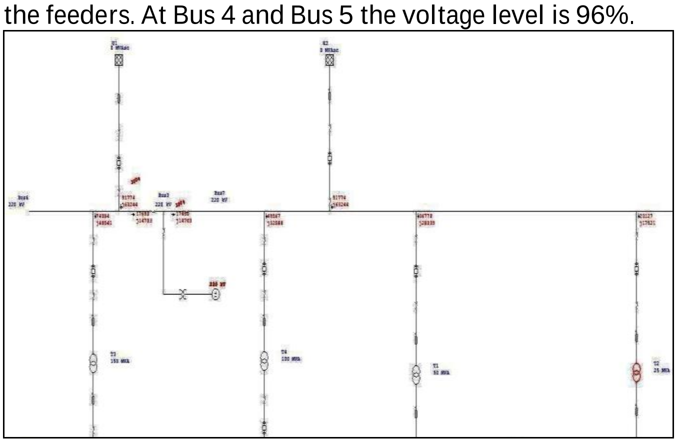

Fig -2(A): Sectional view of Substation

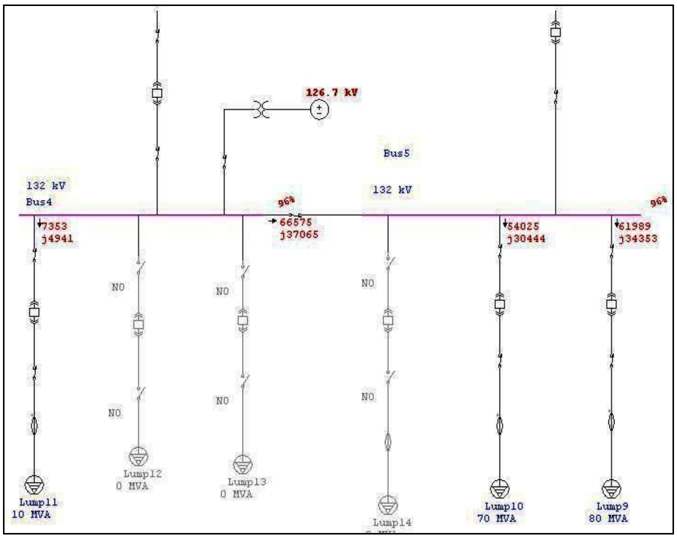

Fig -2(B): Sectional view of Substation with simulation

Similarly from fig 2(B) it is observed that at the Bus 1 and Bus 2 there is under voltage which can be clearly seen from the sectional view of the feeders. At Bus 1 and Bus 2 the voltage level shown in red color indicating the 93.04%.

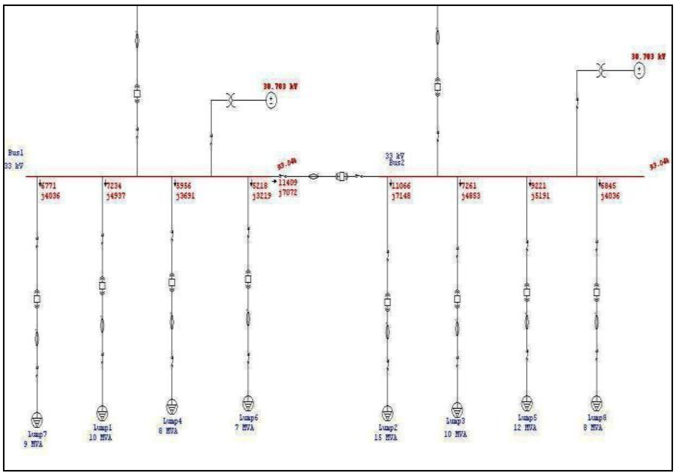

Fig -2(C) Sectional view of Substation with simulation

Table 2 shows that the real power on swing bus i.e. BUS 1 is 25.874 MW and the reactive power is 16.320 MVar and the power factor is 85% which is low.

Table -2

Monitoring Points	kV	MW	MVAr	%PF
BUS 1	33	25.874	16.320	85
BUS 2	33	35.125	21.688	85
BUS 4	132	7.470	5.020	83
BUS 5	132	117.862	65.828	87
BUS 6*,7*	220	91.774	63.244	82.35

* Swing Bus

Table 2 shows that the real power on swing bus i.e. BUS 1 is 25.874 MW and the reactive power is 16.320 M_{Var} and the power factor is 85% which is low.

5 ETAP ALERTS DURING LOAD FLOW ANALYSIS

Table 3 after carrying out load flow analysis using ETAP an alert summary report is generated which tells us which part of the system needs immediate attention and it can be clearly seen from the Table 3 that the Bus 1, Bus 2, Bus4 and Bus 5 are operating at an under voltage. Transformer 2 is also overloaded.

Table -3

Device ID	Condition	Rating	Operating	% Operating
Bus 1	Under Voltage	33 kV	30.703	93
Bus 2	Under Voltage	33 kV	30.703	93
Bus 4	Under Voltage	132 kV	126.722	96
Bus 5	Under Voltage	132 kV	126.722	96

Table 4 shows the Demand and Losses summary report which tells us about the total demand of the system and also about the losses that occurs in a system.

Table -4

Type	MW	MVAr	MVA	%PF
Swing Bus	234.902	138.788	272.839	83.05 (lag)
Total Demand	234.498	125.720	266.073	85.97 (lag)
Apparent Losses	0.404	13.067		

6 LOAD FLOW ANALYSES WITH AN IMPROVEMENT TO OVERCOME THE PROBLEM OF UNDER VOLTAGE

Fig. 3(A) the simulation of the 220 kV substation is carried out in ETAP by placing the capacitor banks in shunt with the feeders. The rating of capacitor bank 1 is 4.27 MVAr and that of capacitor bank 2 is 55 MVAr.

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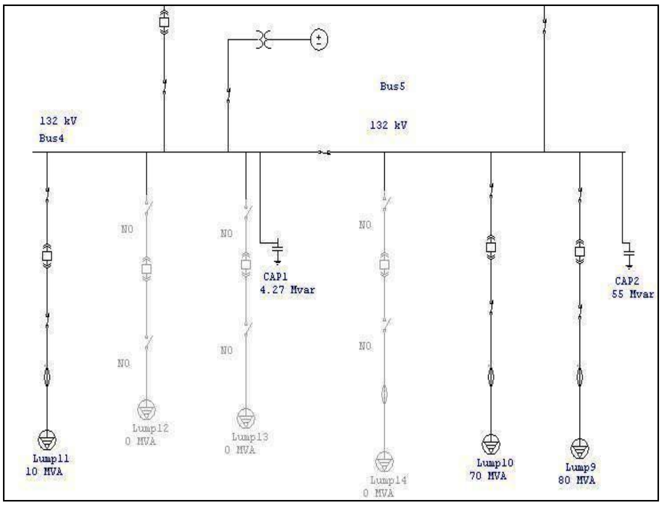

Fig -3(A) Sectional view of Substation

Similarly in Fig. 3(B) the capacitor bank is placed with the feeders in shunt and the rating of the capacitor bank 3 is 13.45 MVAr and capacitor bank 4 is 18.24 MVAr.

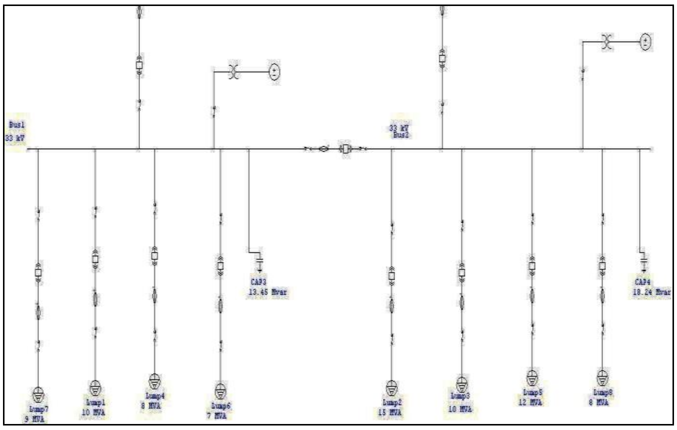

Fig -3(B) Sectional view of Substation

Fig. 3(C) shows the sectional view of load flow analysis of the feeders. From Fig. it can be clearly seen that the operating voltage of Bus 4 and Bus 5 has improved from 96% (Fig.2 (B)) to 99.01%.

6.1 RATING OF CAPACITOR

Rating of capacitor is calculated by using the following formula

Rating of Capacitor Bank (MVAr) = $MW * (\tan \phi_1 - \tan \phi_2)$

Where ϕ_1 and ϕ_2 can be calculated by follow

$\cos \phi_1$ = Existing Power Factor

$\cos \phi_2$ = Required Power Factor

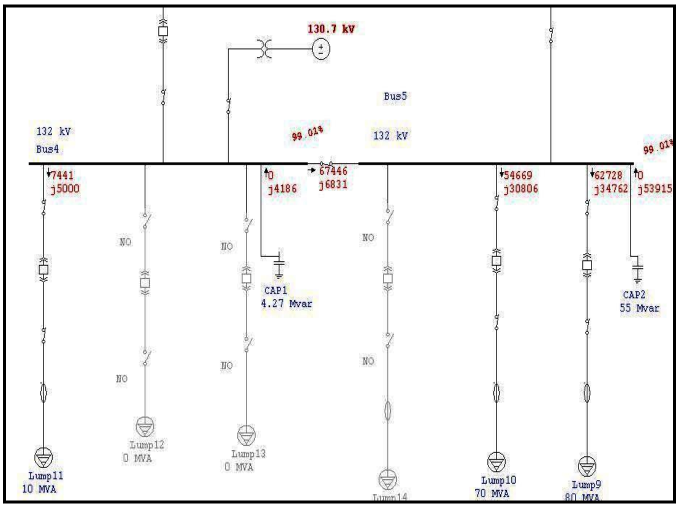

Fig -3(C) Sectional view of Substation with simulation

Similarly Fig. 3(D) shows the sectional view of load flow analysis of the feeders. From Fig. it can be clearly seen that the operating voltage of Bus 1 and Bus 2 has improved from 93.04% (Fig.2 (C)) to 98.06%.

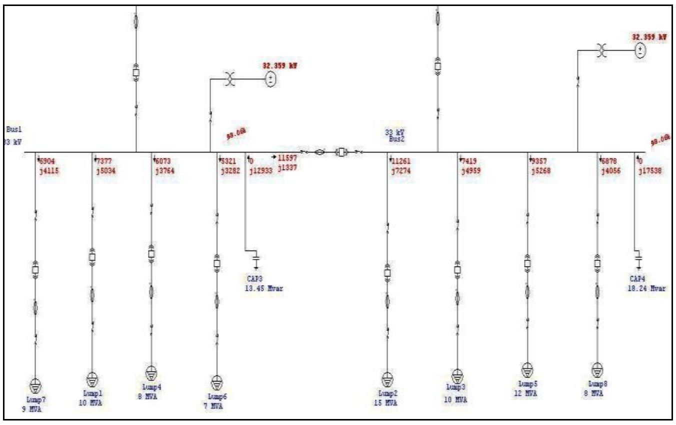

Fig -3(D) Sectional view of Substation with simulation

Table -5

Monitoring Points	kV	MW	MVAr	%PF
BUS 1	33	25.874	2.870	99
BUS 2	33	35.125	3.448	100
BUS 4	132	7.470	0.750	99
BUS 5	132	117.862	10.828	100
BUS 6*,7*	220	92.929	16.864	98.39

Table 6 shows the Demand and Losses summary report and the losses are far less as compared to the losses shown in table 4.

Table -5

Type	MW	MVar	MVA	%PF
Swing Bus	185.858	33.728	188.893	98.39 (lag)
Total Demand	185.858	33.728	188.893	98.39 (lag)
Apparent Losses	0.430	13.980		

By comparing table 7 to table 3 it can clearly be seen that the problem of an under voltage at both the buses is surmounted by the placement of capacitor banks in shunt to the feeders.

Device ID	Condition	Rating	Operating	% Operating
Bus 1	Normal Voltage	33 kV	32.359	98.058
Bus 2	Normal Voltage	33 kV	32.359	98.058
Bus 4	Normal Voltage	132 kV	130.692	99
Bus 5	Normal Voltage	132 kV	130.692	99

7 CONCLUSIONS

Power flow or load-flow studies are important for planning future expansion of power systems as well as in determining the best operation of existing systems. In this paper design analysis of 220/132 kV substation using ETAP software is carried out with an approach to overcome the problem of an under voltage. Load Flow Studies using ETAP software is an excellent tool for system planning. A number of operating procedures can be analyzed such as the loss of generator, a transmission line, a transformer or a load. This can be used to determine the optimum size and location of capacitors to surmount the problem of an under voltage. Also, they are useful in determining the system voltages under conditions of suddenly applied or disconnected loads. Load flow studies determine if system voltages remain within specified limits under various contingency conditions, and whether equipment such as transformers and conductors are overloaded. It was often used to identify the need for additional generation, capacitive, or inductive VAR support, or the placement of capacitors and/or reactors to maintain system voltages within specified limits.

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