The Optimum Location of Capacitor to Improve the Voltage of 220/66 kV Substation Using ETAP Software

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***Abstract*- The power system planning, design and operation study require load flow analysis to know the now day loads and generation also plan for future load demand in the network. Moreover, to know the voltages at every bus to connect suitable devices that can support the voltage stability. In this paper the study has been done on real network of 220/66 kV substation (Houn substation, Libyan network). Electrical Transient Analyzer Program (ETAP), is used to model and analysis the network. The switchgears, transformers and lines in the substation had modeled to do the power flow analysis. The power flow analysis determine the buses that suffer from under voltage and that need reactive power injected to maintain system voltages within specified limits. The results showed that the optimum location of capacitors connection to the network could improve the system voltage.**

Keywords: under voltage, Load Flow Analysis, ETAP software.

I. INTRODUCTION

Electrical power until reach to the customer pass through three stages, generation, transmission and distribution. The voltage at the generation is usually 11Kv, using power transformers, this voltage is stepped up to high voltage (220kv, 400kv or more) during transmission stage and stepped down to 30 kv or 11kv at distribution stage and reduced to 0.4kv at customer side (load). The loads are increase and decrees depending on the load demand. Transfer the power from region to other depending on the needs of power, which performed by control center. Thus, the steady state of load flow study is done used digital programs. The power flow study evaluate the bus bars voltages (magnitude and angle) and real and reactive powers flow for at each bus during steady state operating conditions [1]. Therefore, it is necessary to model all the networks components to do the power flow study [2].

However, the purpose of load flow study is to make sure the voltages at every bus in the network within the certain region (95-1.05% of nominal voltage). If the bus voltage less than 95% the bus suffer from under voltage problem. To solve this problem the reactive power have be injected at this bus, because the reactive power could not be transfer at a long distance especially under heavy load conditions [3]. In contrast, the overvoltage problem because surplus of reactive power, both cases under voltage and overvoltage can cause damage to certain devices like motors [4]. Some other works deal with this issue using ETAP software like the paper [5] that use the NEPAL power system.

However this paper use ETAP to carry out the load flow analysis of 220/66/11 kV substation. ETAP is an analysis software used to test the power systems using the real data [6]. The power transformers, current transformers, voltage transformers, circuit breakers and isolating switches have modeled in ETAP. This 220/66/11 kV substation is located near the city of Houn in Libya. The goal of this study to choose the optimum location of capacitor connection to improve the system voltage.

II. HOUN SUBSTATION

Table 1 shows Houn substation components and their ratings such as power transformers, circuit breakers, feeders, bus bars and isolating switches.

TABLE 1: HOUN SUBSTATION COMPONENTS

COMPONENT	QUANTITY	RATINGS
POWER TRANSFORMER (MVA)	3	63
	6	10
	8	20
CIRCUIT BREAKER	17	25kV / 1200A
FEEDERS (MVA)	3	6
	3	3
	1	5.5
	1	3.5
	2	2
	2	5
	1	7
	1	11
BUSES (KV)	1	220
	2	66
	14	11
ISOLATING SWITCHES	1	220kV/1000A
	6	66kV/1500A

III. Simulation of 220kV Substation Using ETAP

As shown in Figure 1 main grid supply power to the 220 kV network at bus1 that called swing bus, where the voltage (magnitude and angle) has defined. 220kV/66kV transformers (Transformer 1 and transformer 3) supply power to Bus 2 and Bus 3 respectively, while Bus2 and Bus3 supply fourteen feeders. Bus 2 and bus 3 called PV buses, where the real power and voltage magnitude have defined. On the other side transformers (from number 4 to number 17) are 66kV/11kV transformers supply power to buses (from number 4 to number 17). From bus4 to bus17 are called PQ buses, where real and reactive powers are defined [7] [8].

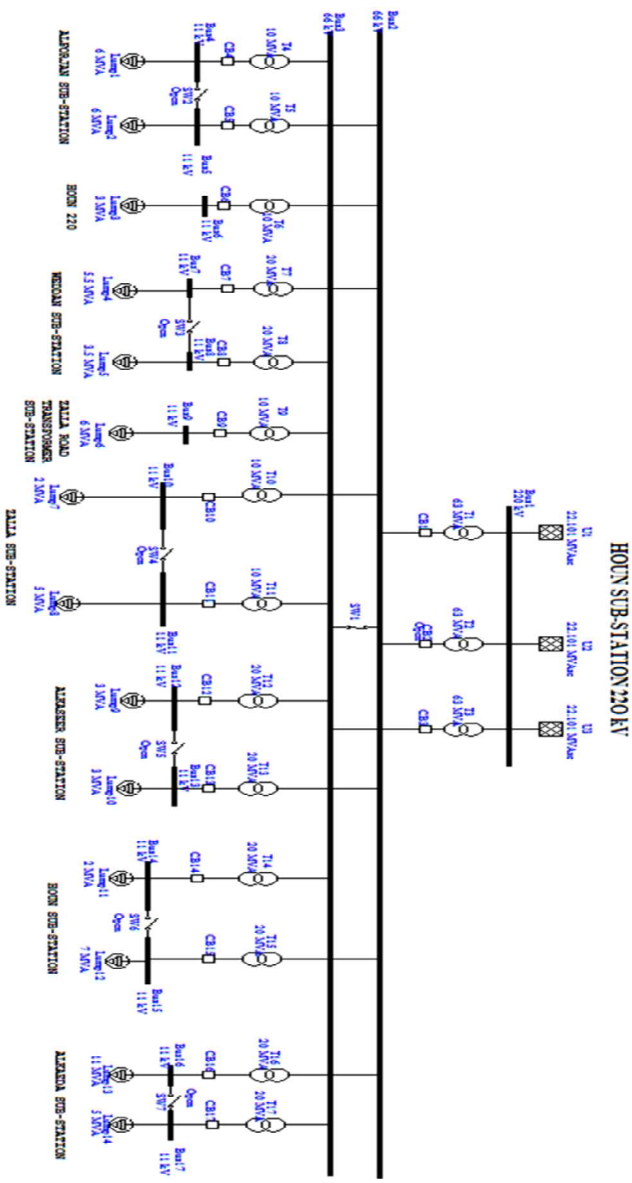

Fig. 1. Single line of 220 kV substation

IV. Load Flow Analysis using ETAP

In the load-flow study the voltage (magnitude and angle) at all buses are determined. Also according to Kirchhoff's law, the power demand plus the losses must be equal to the generated power to satisfy the power balance at each bus in the electrical network.

As shown in Figure 2 a load flow calculation is performed using ETAP software. The ETAP solve the system equations using Newton-Raphson method. The results show there is under voltage at bus 6 while at bus 2 and 3 the voltage within the nominal range.

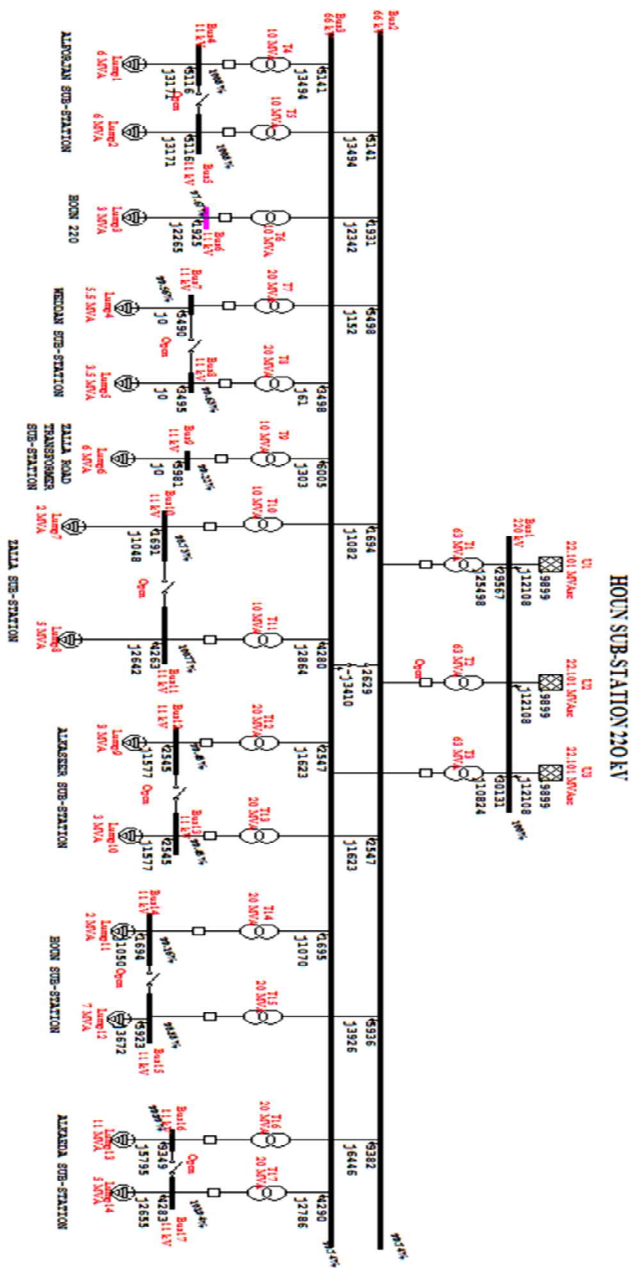

Fig. 2. Load flow of the Substation

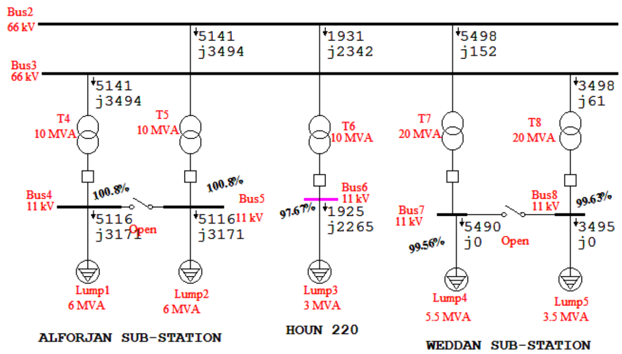

Fig. 3. Sectional view of Substation with simulation

As shown in Table 2 the real power on swing bus (Bus 1)is 59.567 MW and the reactive power is 36.323 MVAr and the power factor is 85.43 %..

TABLE 2: LOAD FLOW REPORT

Monitoring Points	kV	MW	MVAr	PF %
Bus 1* (Swing Bus)	220	59.698	36.323	85.43
Bus 2	66	30.131	-22.475	79.5
Bus 3	66	-30.086	-8.791	96.0
Bus 4	11	-5.116	-3.171	85.0
Bus 5	11	-5.116	-3.171	85.0
Bus 6	11	-1.925	-2.265	64.8
Bus 7	11	-5.490	0.000	100.0
Bus 8	11	-3.495	0.000	100.0
Bus 9	11	-5.981	0.000	100.0
Bus 10	11	-1.691	-1.048	85.0
Bus 11	11	-4.263	-2.642	85.0
Bus 12	11	-2.545	-1.577	85.0
Bus 13	11	-2.545	-1.577	85.0
Bus 14	11	-1.694	-1.050	85.0
Bus 15	11	-5.923	-3.672	85.0
Bus 16	11	-9.349	-5.795	85.0
Bus 17	11	-4.283	-2.655	85.0

V. SUMMARY REPORT DURING LOAD FLOW SIMULATION

Table 3 explain ETAP summary report after carrying out load flow analysis. The report show that the Bus 6 is operating at under voltage. This under voltage needs immediate attention or the system go unstable thus the load will be effected.

TABLE 3: ALERT REPORT

Device no.	Condition	Rating (kV)	Operating(KV)	Operating %
Bus6	Under Voltage	11.00	10.74	97.7

Table 4 give summary report about the total load demand and losses in the network.

TABLE 4: TOTAL GENERATION, LOAD AND DEMAND

Type	MW	MVAr	MVA	PF %
Swing- bus	59.698	36.323	69.880	85.43 Lagging
Total demand	59.698	36.323	69.880	85.43 Lagging
Total motor load	47.554	22.901	52.781	90.10 Lagging
Total static load	11.865	5.721	13.172	90.07 Lagging
Apparent losses	0.279	7.701		

VI. NETWORK IMPROVEMENT

Figure 4 shows the simulation results of the 220 kV substation carried out in ETAP after improvement of the network by connect the capacitor banks in shunt with the feeders. The rating of capacitor bank is 2.25 MVAr.

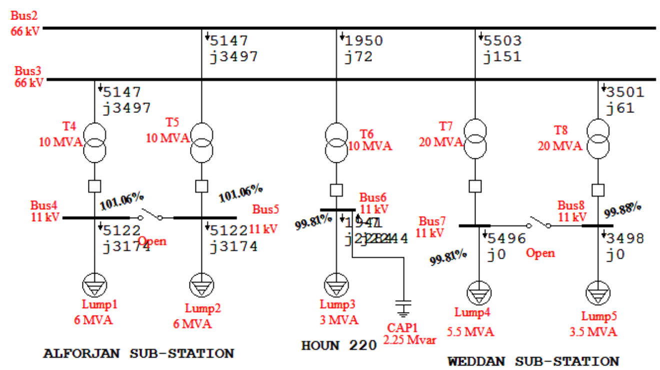

Fig. 4. Sectional view of Substation

As shown in Figure 4, the operating voltage of Bus 6 increase 97.67% to 99.81%this mean the system voltage is improved.

Table 5 shows that the real power, reactive power and power factor on swing (Bus1) is 59.772 MW, 33.915 MVAr, and the 86.97 % respectively.

TABLE 5: LOAD FLOW REPORT AFTER IMPROVEMENT

Monitoring Points	kV	MW	MVAr	PF %
Bus 1* (Swing Bus)	220	59.772	33.915	86.97
Bus 2	66	-29.539	-21.402	81.0
Bus 3	66	-30.124	-7.614	97.0
Bus 4	11	-5.122	-3.174	85.0
Bus 5	11	-5.122	-3.174	85.0
Bus 6	11	-1.948	-0.040	100.0
Bus 7	11	-5.496	0.000	100.0
Bus 8	11	-3.498	0.000	100.0
Bus 9	11	-5.987	0.000	100.0
Bus 10	11	-1.693	-1.049	85.0
Bus 11	11	-4.268	-2.645	85.0
Bus 12	11	-2.547	-1.579	85.0
Bus 13	11	-2.547	-1.579	85.0
Bus 14	11	-1.696	-1.051	85.0
Bus 15	11	-5.929	-3.675	85.0
Bus 16	11	-9.359	-5.801	85.0
Bus 17	11	-4.288	-2.658	85.0

Table 6 shows the summary report of load demand and losses. The losses after connection the capacitor are less than the losses when the system before the capacitor has connected shown in table 4.

TABLE 6: GENERATION, LOAD AND LOSSES AFTER IMPROVEMENT

Type	MW	MVAr	MVA	PF %
Swing Bus	59.772	33.915	68.724	86.97 Lagging
Total Demand	59.772	33.915	68.724	86.97 Lagging
Total Motor Load	47.554	22.901	52.781	90.10 Lagging
Total Static Load	11.947	3.524	12.456	95.91 Lagging
Apparent Losses	0.272	7.489		

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

TABLE 7: ALERT REPORT AFTER IMPROVEMENT

Device ID	Condition	Rating	Operating	Operating %
Bus 6	Normal Voltage	11.00 kV	10.87	99.81

VII. CONCLUSION

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 project design analysis of real network in Libya, 220/66/11 kV substation using ETAP software is carried out with an approach to overcome the problem of an under voltage. A number of operating conditions has done such as the loss of generator, a transmission line, a transformer or a load. These were used to determine the optimum size and location of capacitors to solve the problem of an under voltage. Connection of capacitor in shunt with optimum location the network improve the voltage. Thus using this software the system voltage stability can maintain by chose the operate capacitor location.

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