

# Analysis and Monitoring of 500 KV Grid; Innovation in Power, Control, and Optimization, using ETAP Software

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Received: 06 November, Revised: 17 November, Accepted: 20 November

**Abstract**—In this research work, we have modeled and analyzed an existing 500 KV power station located at Shiekh Muhammadi, Peshawar in ETAP, using the actual real time data taken carefully for simulation in order to improve the voltage profile of the system using different techniques. It was revealed that voltage profiles of most of the buses are far below the nominal values with high losses causing considerable voltage drop at the bus. The optimization was very carefully performed by analyzing each simulation results in light of classical Newton Raphson technique in order to get the best possible optimized value without going through tedious iterations. Reactive power compensation using Static Capacitor Banks was used for voltage profile improvement of the power system. After performing optimization through above techniques, the voltages of all the buses including those with previously critical under voltage conditions, experienced boost in voltage to the nominal value with increased in real power supplied, thus improving the overall efficiency of the system.

**Keywords**—Newton Raphson Technique, Voltage Profile, ETAP-Electrical Transient and Analyzer Program, Static Capacitor Banks, Distributed Generator.

## I. INTRODUCTION

Energy plays vital role in economics development of a country. Though energy may be required in different forms but amongst all, electrical energy has dominance mainly due to ease in its conversion into any form of energy. Besides, it can be easily regulated, has superior flexibility, cleanliness and high transmission efficiency. These characteristics of electrical energy make it essential for the overall advancement and prosperity of the modern world [1].

The aim of this project is to derive a mechanism to analyze a complex power grid using Electrical transient analyzer program (ETAP). Power system analysis is the process of assessing the magnitude of line current and voltages during different types of disturbances. The magnitude of these parameters mainly depends on the internal impedances of generators and intervening circuits. The magnitude of fault current which are usually to the tune of tens of thousands of Amperes, must be precisely calculated in order to estimate the impact of mechanical and thermal stresses on operational equipments.

These estimations are also helpful while selecting appropriate protective equipments i.e. circuit breakers, relays and isolators etc. and other allied devices of switchgears.

The process of determining the line voltages and currents in case of fault conditions is a tedious task; requires multifaceted mathematical calculations. These calculations get more and more complex as the number of busses in a grid increases. Thus mathematical calculations are only possible for simpler power system with lesser number of busses. However, dealing with large number of busses requires programming software to perform complex calculations.

It has always been a challenge for electrical engineers to first generate electrical energy and then transport it to the end users without compromising the efficiency, reliability and safety. Modern age electrical power system consist of complex integrated network where electrical energy is collected from generating units mostly located at remote areas and then transported through transmission and distribution system for ultimate utilization by consumers. The power demand of these consumers varies with time so as the load on power station thus the different parameters i.e. voltage and currents of different segments do not remain constant, rather varies from time to time[2].

Power system in its normal operating condition is analyzed and investigated by load flow studies. A typical electric power grid has a large number of buses and that can only be analyzed with computational tools. A variety of computational tools are available for load flow analysis.

In recent past, Pakistan Electric Power Company (PEPCO) has gone through frequent black outs in different part of the country due to power shortages. One of the reasons of these energy crises is the lack of technological capabilities in the field of power system analysis and monitoring as the existing power distribution system is mainly analyzed by FDR-ANA(Feeder Analysis) software [3].

Whereas, ETAP (Electrical Transient Analyzer Program) offers a state of the art Electrical Engineering programming arrangements with the help of which offline monitoring i.e. current flowing in every branch, power factor, active and reactive power flow of a power system, voltage drops, can be effectively performed.

ETAP can also be helpful in performing monitoring and real time simulation for energy management system. ETAP is fully equipped with the software solutions; required in an electrical system i.e. load flow, transient stability, relay coordination, open circuit and short circuit analysis, arc flash, conductor and cable ampacity and many more, by simply creating and editing one line diagram.

The above characteristics of ETAP make it suitable for any electrical power company [4,11,12].

## II. PROBLEM STATEMENT

The power system selected for this study is 500 KV grid station located at Shiekh Muhammadi, Peshawar. It is being feed from Terbella through 500 KV transmission line. It consists of 9 Nos. of power transformers, 11 feeders, 22 circuit breakers, 26 current transformers, 12 potential transformers and total 16 Nos. of buses. The total load connected to all the 11 kV feeders is 21.614 MVA.

If a power system comprises of N Nos. of buses and R Nos. of Generators, than the total Nos. of unknown variables during power system analysis are  $2(N - 1) - (R - 1)$  which requires  $2(N - 1) - (R - 1)$  Nos. of equations to be calculated [5].

Keeping in view the foregoing, the unknown variables in case of power system under study are 30 Nos. which requires 30 Nos. of equations to be solved simultaneously, in order to calculate all the elements for analysis.

## III. NEWTON RAPHSON METHOD

Newton Raphson method is one of the famous tools that can be used to solve these non linear equations. However, Newton Raphson method involved series of iterations starting with a suitable guess of unknown variables i.e. voltage magnitude, angle, active and reactive power etc. and then the process is again repeated by taking the most recent values found. The process of iteration continues until the values converge on a stopping limit [6].

After reviewing the literature, it has been revealed that carefully guessing the initial value and then properly analyzing the results can ease the process of iteration. It has been noted that a multiplying factor can also be used to speed up the process.

The above technique of analyzing the results and suggesting the new input value has been used in this research for optimization.

## IV. METHODS OF VOLTAGE PROFILE IMPROVEMENT

Load flow study provides different elements of power system but the most important of all is the voltage profile i.e. the voltage value of each bus. If the voltage profile of the system varies greatly, it will results in undue reactive power, causing real power losses to increase and in most of the cases there is an excessive voltage drop leading to the under-voltage condition [6].

Literature review indicates that different methods have been devised to improve the voltage profile of the system each having its own benefit and constrains. The method adopted in this research work is static capacitor.

## V. STATIC CAPACITOR PLACEMENT

The power system under study is in radial scheme. In such scheme, all the load are connected to single feeding unit mainly due to simplicity and low cost [7,9,10,13]. But the major drawback in this type of scheme is the fluctuation in system voltage that cause huge disturbance in voltage profile. As most of the load in distribution system are inductive in nature, thus causing deficiency of reactive power available to the load locally. Resultantly, the flow of current increases in distribution lines which reduces the voltage.

Capacitor on other hand is a reactive device with theoretically no power loss. Placing capacitor in the system balances the reactive power requirement causing reduction in reactive power supplied by the system which in turn reduces the current and ultimately improve the voltage profile of the system. It is important to place the capacitor at right location and to identify the optimum size of the capacitor.

## VI. PROBLEM METHADODOLOGY

The power system under case study is 500kV Sheikh Muhammadi Grid station, which is located at Indus Highway near Badhaber, Peshawar. It consists of 9 Nos. of power transformers, 11 feeders, 22 circuit breakers, 26 current transformers, 12 potential transformers and 500kV incoming Transmission line from Tarbella power station. The total load connected to all the 11 kV feeders is 21.614 MVA. ETAP has been used for simulation purpose in this research work.

The SLD using actual real time data of 500kV Shiekh Muhammadi grid station constructed in ETAP for our research work is shown in figure 1.

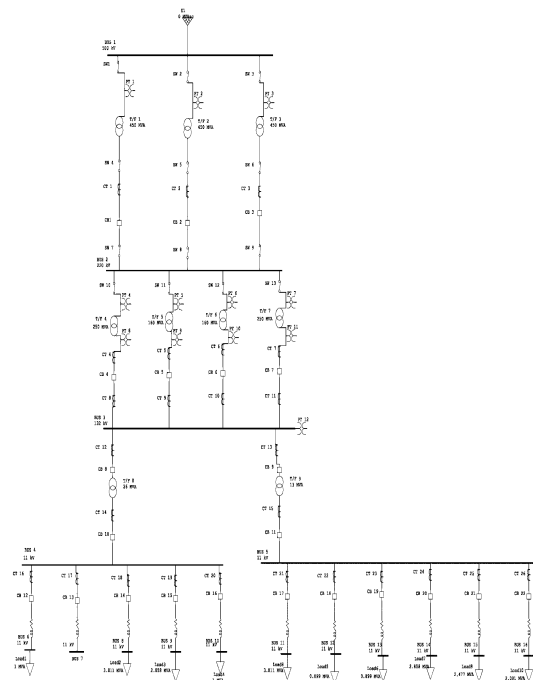


Figure 1: Single Line Diagram of Power System

## VII. SIMULATION RESULTS

The simulation results reveal that some of the load buses are in under voltage condition as depicted in Table 1. The under voltage condition is defined as “a condition in which an electrical equipment is receiving less than the required voltages”. The under voltage condition occurs when the voltage level goes 90% of the nominal voltage.

TABLE 1: BUS VOLTAGE CONDITIONS

BUS ID	Nominal Kv	Type	Voltage kV	Under Voltage Condition
BUS 1	500	SWING	500	Not
BUS 2	220	Load	219.932	Not
BUS 3	132	Load	131.892	Not
BUS 4	11	Load	10.905	Not
BUS 5	11	Load	10.767	Marginal
BUS 6	11	Load	10.593	Marginal
BUS 7	11	Load	10.909	Not
BUS 8	11	Load	9.738	Critical
BUS 9	11	Load	8.751	Critical
BUS 10	11	Load	10.302	Critical
BUS 11	11	Load	9.933	Critical
BUS 12	11	Load	10.619	Marginal
BUS 13	11	Load	10.619	Marginal
BUS 14	11	Load	10.183	Critical
BUS 15	11	Load	10.277	Critical
BUS 16	11	Load	10.389	Critical

### A. Load Flow Report

The power flows in different buses are given in Table 2.

TABLE 2: POWER FLOW STUDY OF EXISTING POWER SYSTEM

Bus ID	Voltage	kW Loading	kvar Loading	Amp Loading
BUS 1	500	18754	5015	22.42
BUS 2	219.232	18754	4993	50.95
BUS 3	131.892	18753	4958	84.91
BUS 4	10.905	7115	1861	389.4
BUS 5	10.767	11588	1919	629.8
BUS 6	10.593	927	0	50.54
BUS 7	10.909	0	0	0
BUS 8	9.738	2987	0	177.1
BUS 9	8.751	1664	709	119.3
BUS 10	10.302	877	0	49.16
BUS 11	9.933	3107	0	180.6
BUS 12	10.619	838	0	45.55
BUS 13	10.619	838	0	45.55
BUS 14	10.183	2449	0	138.9
BUS 15	10.277	2162	0	121.5
BUS 16	10.389	1785	0	99.19

### B. Voltage Profile

Voltage profile is the graph showing the buses and its voltage levels. As discussed earlier in Table:1, the BUS 1, BUS 2, BUS 3 are not in under voltage condition therefore the graph of voltage profile consists of only BUS 4 to BUS 16 as shown in Figure 2.

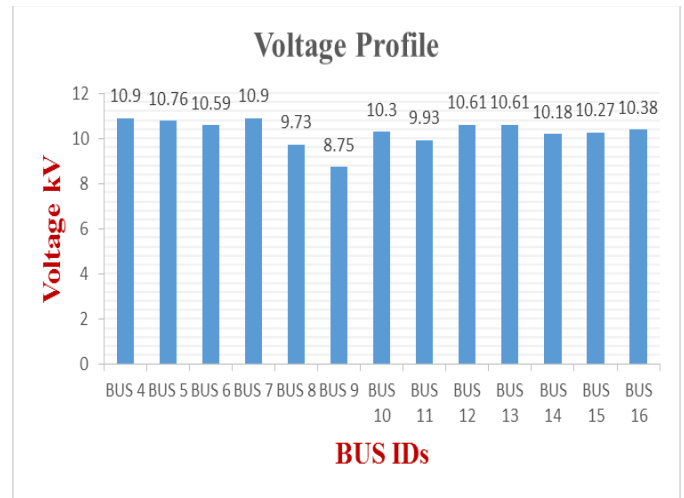


Figure 2: Voltage Profile of Existing Power System

### C. Optimal Capacitor Placement

The main process involved in achieving the desired voltage level at all the buses without compromising the power delivered, is the determination of optimum size of the capacitor and location [8,14,15,16]. Using the ETAP optimal capacitor placement (OCP) tool, the optimal size and place of the capacitor bank is selected as shown in Table 3.

TABLE 3: POSITION AND SIZE OF CAPACITOR BANKS

BUS IDs	Capacitor IDs	No of Banks	kVAR	kVAR/Bank
BUS 5	CAP 1	4	1200	300
BUS 6	CAP 2	2	600	300
BUS 7	Spare	Spare	Spare	Spare
BUS 8	CAP 3	8	2400	300
BUS 9	CAP 4	11	3300	300
BUS 10	CAP 5	2	600	300
BUS 11	CAP 6	4	1200	300
BUS 12	CAP 7	1	300	300
BUS 13	CAP 8	1	300	300
BUS 14	CAP 9	2	600	300
BUS 15	CAP 10	2	600	300
BUS 16	CAP 11	2	600	300

#### D. Voltage Profile of the System After Capacitor Placement

Table 4 clearly illustrates that the under voltage conditions of all the buses have been improved after placement of capacitors and so does the voltage profile as shown in Figure 3.

TABLE 4: BUS VOLTAGES AFTER CAPACITOR PLACEMENT

BUS ID	Nominal kV	Voltage kV	Under Voltage Condition
BUS 5	11	11.09	Improved
BUS 6	11	11.17	Improved
BUS 7	11	11.12	Improved
BUS 8	11	11.07	Improved
BUS 9	11	10.83	Improved
BUS 10	11	10.97	Improved
BUS 11	11	10.98	Improved
BUS 12	11	11.16	Improved
BUS 13	11	11.13	Improved
BUS 14	11	10.88	Improved
BUS 15	11	10.99	Improved
BUS 16	11	11.12	Improved

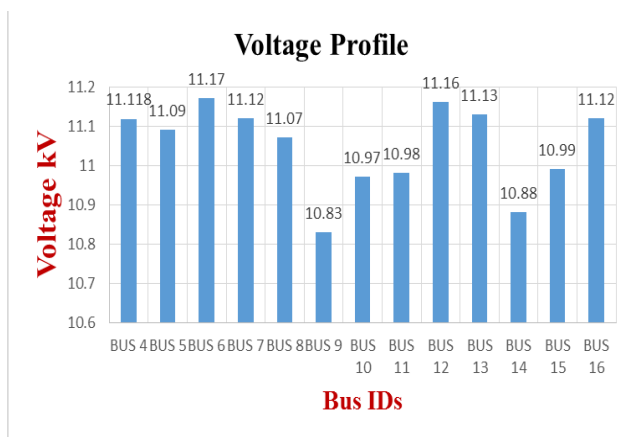


Figure 3: Voltage Profile After Capacitor Bank Placement

#### E. Comparison of Active Power Delivered

The comparison of active power delivered by the system before and after placement of capacitor banks is shown in Table 5. It is evident from the results that placing of capacitor banks on more than one buses simultaneously is not only helpful in improving the voltage profile of the system but the overall active power delivered by the system will also be increased, thus improving the overall efficiency of the power system.

TABLE 5: COMPARISON OF ACTIVE POWER DELIVERED BEFORE AND AFTER CAPACITOR PLACEMENT

Bus ID	Active Power KW Without Capacitor Banks	Active Power KW With Capacitor Banks
BUS 1	18754	23297
BUS 2	18754	23297
BUS 3	18753	23296
BUS 4	7115	9731
BUS 5	11588	13496
BUS 6	927	1032
BUS 7	0	0
BUS 8	2987	3865
BUS 9	1664	2553
BUS 10	877	995
BUS 11	3107	3803
BUS 12	838	926
BUS 13	838	926
BUS 14	2449	2800
BUS 15	2162	2475
BUS 16	1785	2047
<b>Total</b>	<b>92598</b>	<b>114539</b>
<b>Average</b>	<b>5787</b>	<b>7159</b>

#### CONCLUSION

In this research work, ETAP software was used to analyze the 500 KV, Shiekh Muhammadi grid station for voltage profile improvement. It was observed that using capacitor banks on more than one bus simultaneously in a power system, has eased the process of optimization in order to achieving the desired voltage profile and to increase the overall active power delivered by the system. The following conclusions have been drawn from this research:

- The reactive power plays important part in system reliability as it directly affects the voltage that has to be controlled.
- Under voltage condition can be improved by absorbing or injecting the reactive power to the system, depending upon the nature of the load.
- Using capacitor bank on more than one bus simultaneously has improved the voltage profile in addition to the increase in total active power delivered by the system, thus improving the overall efficiency of the power system.
- In order to get accurate and absolute results, the optimal value and best location for the capacitors to

be placed, can be easily found from ETAP software simulation.

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