Determination of Reactive Power Compensation and Transmission Line Power Transfer Capability Improvement of the Kenyan Power System

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ABSTRACT

To supply power, utilities usually sign a supply agreement with the consumer that states details of power supply to be connected. This allows the consumers to specify the voltage rating of any electrical equipment procured for use in their premises. Once the supply is connected, the consumer expects the voltage and frequency to be maintained nearly constant within the statutory tolerances and to experience minimum interruptions.

For a utility to effectively meet the requirements of the consumers, the power system must be properly controlled, where the main parameters to be controlled are voltage and frequency. To supply the system loads, a number of generating stations are interconnected through transmission lines and distribution network. The frequency of the system is controlled by ensuring real power balance of supply and demand; frequency is controlled centrally. However, the transmission and distribution systems need voltage control at various points in the system to maintain the voltage at the consumer premises within permissible limits(±6%).

When aggregated, loads have two power components; the active and reactive power. In addition to the consumer loads, the lines also require reactive power to establish the electric and magnetic fields. This reactive power used by the line is referred to as the reactive power losses and affect the voltage profile in a power system. Transmission lines absorb and inject reactive power and the net effect depends on line length and loading. For a heavily loaded line, reactive power loss (absorption) is more dominant. Because of reactive power losses increasing with the length of transmission lines, reactive power should not be transmitted over long distances. Unlike real power

which requires suitable sites for generation and therefore has to be transmitted to load centres, reactive power can be generated at load connections. This study assessed the reactive power requirement of the Kenyan transmission network so as to enable the transmission of all available power from Seven Forks hydro stations to the load centres. To enable power system simulation, a single line diagram model of the transmission network was prepared using data collected from the utility. Four scenarios were investigated by load flow analysis. Case one was the base case where the system was running with an emergency generator in service at a peak load of 989 MW. In case two, the system was running at the same peak load with emergency plant generation replaced with generation from Seven Forks hydro complex. In case three reactive power compensation assessment was done using the synchronous condenser reactive power injection method. The synchronous condensers were introduced in the network model at nine identified buses. In case four, the system load demand was raised to 1047 MW which is a hypothetical demand created to study the evacuation of the full capacity of the Seven Forks hydro complex.

The results of power flow analysis show that the emergency plant can only be retired and replaced with 56.4 MW supply from the Seven Forks if 331 MVAr is installed at nine locations identified in the transmission network. In addition, the results show that to evacuate 603 MW which is the full capacity of the Seven Forks hydro complex, 341 MVAr needs to be installed in the transission system for voltage support.

A financial analysis carried out at discount rates of 12%, 10% and 8% using the Net Present Worth criterion indicate the project is feasible at interest rates of 12%, 8% and 5% with a positive value of over 12.5 billion shillings and a Payback Period of less than one year in all the cases.

It is recommended that reactive power compensation be implemented in the transmission network of the Kenyan power system. Further, there is a need to carry out optimal capacitor and reactor placement in the Kenyan transmission and distribution networks and also study the reactive power requirement in the distribution system in order to improve voltage regulation in distribution substations.