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REINFORCING KENYA POWER NATIONAL GRID USING STATCOM DEVICES

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ABSTRACT

Modern power system is a complex network comprising of numerous distributed generators, transmission lines, switchgears, distribution network and variety of loads. However, the quality of the power supplied to the end users is deteriorating as network expand due to inherent system disturbances such as voltage dips, harmonic distortions and phase angle deviations caused mainly due to low voltage network faults. This has resulted to high level of customers' dissatisfaction and complains. Research has shown that over 60% of system perturbations are caused by natural events such as lightning strikes and system faults. There are various methods power utilities are employing to realize a robust and reliable power transmission system. Such methods include re-conducting of transmission lines, construction of new transmission lines and in recent time installation of Flexible AC transmission system (FACTs) devices. The FACTS are power electronic devices that have ability of controlling the network voltage condition both in steady and transient state of complex power system. The most common power electronic controllers are, Dynamic voltage stabilizer (DVS), Static Synchronous Compensators (STATCOM), shunt compensators and Unified power flow controller (UPFC). The STATCOM devices are the most widely installed power electronic controllers as they provide excellent performance in stabilizing the power system both in steady state and non-steady state (system disturbances) conditions. It is for this reason the author propose installation of STATCOMs to reinforce the Kenya Power national power grid to achieve a robust and resilience system which improves the power quality supplied to the end users.

Contribution/Originality: This study is one of very few studies which have investigated the impact of installing STATCOM devices to enhance the quality of power supplies and improve on power stability/ reliability in Kenya power grid. In recent time, the power grid has experienced several power disturbances in major load centers.

1. INTRODUCTION

Any power system has inherent transients that can originate from switching operations (circuit breaker operations, capacitor switching), system faults, lightning strokes, loading of a single large load/ loss of a single large load. The adverse effects of system disturbances are devastating. The major impacts on power system are voltage collapse, voltage dips/ swell or system transients (impulse or oscillatory). A weak system is very vulnerable to system disturbances because line faults usually results to wide spread power outage. This is very rampant occurrences in developing countries. To improve quality of power supplied to the power end users, most power utilities add transmission lines and interconnected them with existing installations. In some solemnly cases, they increase thermal generations at the load center. These mitigation measures are expensive in terms of cost of implementation and time. With advert of power electronic devices such as Thyristors, IGBT, MOS-FET, they have offered a cheaper and faster alternative in stabilizing the power system and making it more reliable and robust both in steady state and transient conditions [1].

The Kenya Power owns and maintains transmission lines and distribution network at the following nominal voltages: (i) Transmission 132kV, 220kV, and 400kV (ii) Sub Transmission- 66kV, (iii) Distribution - 33kV and 11kV and (iv) Low voltage network- 415V and 240V. With the ever increasing of load connected to the existing network as country economy grows, the needs to continually expand and enhance the power system is inevitable in order to meet the additional power demands. With additional 5,000MW expected to be brought on board into the grid by 2018, the existing system and upcoming new transmission lines needs to sustain the power flow with minimum interruptions even in the presence of system perturbations. Due to recently awareness of the customers regarding the requirements of a quality power supplies, it is pertinent for the power utility to meet the laid down statutory power supply requirements. This paper propose installation of STATCOM devices to ensure that the power utility supplies a quality power that is within the statutory requirements as defined by Kenya Bureaus of Standard (KBS) and power regulatory bodies.

The STATCOM is a dynamic shunt compensation device connected to the transmission network to provide dynamic reactive support, balanced as well as unbalanced, to control the voltage to a set point and also provide dynamic support during network contingencies [2]. A STATCOM consist of power electronic converters that damp the changes in transmission system and maintain steady state and transient margins. They are designed to enhance controllability and increase power transfer capability of transmission lines. The STATCOM is one of FACTS family. FACTS devices employ both passive and active elements. Passive element includes inductors and capacitors and on the other hand active elements include IGBT, Thyristors, MOSFET and GTO. The FACTS devices enhance transmission system control and increase line loading up-to the thermal limits without compromising it reliability. Further, it enables the power utility to delay constructing of new transmission facilities and instead maximizes on existing transmission assets [3, 4]. The FACTS devices can be thyristor switched or static controlled. Thyristor switched employ ON-OFF principle while static controlled employs static elements such as IGBT, MOSFET, or MOS-controlled thyristor (MCT).

The circuit below (fig. 1a) depicts elements of STATCOM while fig. 1b shows a photo of active element (MOSFET).

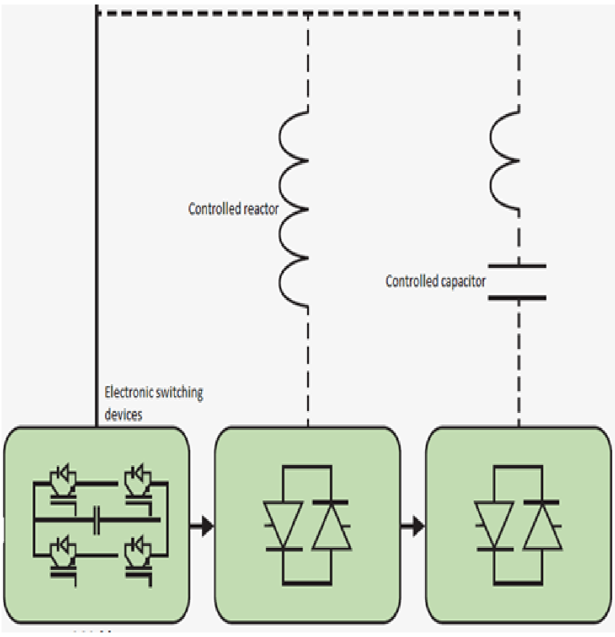

Fig-1a. Elements of the STATCOM
Source: ABB- An introduction to Facts-2006

Fig-1b. A photo of installed MOS-FET
Source: ABB- An introduction to Facts- 2006

1.1. Type of FACTS Devices

The table 1 hereunder presents various types of FACTs devices and their main applications

Table-1. FACTs type

	Load Flow Control	Voltage Control	Transient Stability	Dynamic Stability
SVC				
STATCOM				
TCSC				
UPFC				

Source: PSD: Power System Dynamics- April, 2016

Where;

SVC –Static Var compensator, STATCOM- Static Synchronous Compensator, TCSC –Thyristor Controlled Series Compensator, UPFC- Unified Power Flow Compensator

From table 1 above, STATCOM offers a wide range of solutions for perpetual challenges experienced by power system. It is imperative noting that UPFC is not often considered despite giving superior results because of high cost of implementing and maintenance costs. In additional, it requires a robust network which currently the Kenya utility is yet to establish.

2. MODERN POWER SYSTEM

Continued urbanization, electrification of railway transport and increased use of renewable energy sources such as wind power, place more stringent demands on new and existing infrastructures. It is worth noting in recent time that construction of new transmission lines is becoming difficult and time consuming due to the challenge of acquiring the rights of way and cost of construction. As result, the existing infrastructures are getting constrained day after day as more loads are added which were not factored during the design stage. For the power company to meet the statutory regulations of voltage variations limit as stated in IEEE 519-1992 IEEE Standard 519-1196 [5]; KS 2236-3 [6] and KS 2236-4 [7] two options are proposed;

i. Increase thermal generation at load center
ii. Install STATCOM devices at selected major primary substations

The first option requires ERC approvals and has ripple effects of increasing the price of electricity tariff which can slow down country's economic growth. In contrary, installation of STATCOM enables the power utility to comply with the statutory requirements without impacting negatively on price of the electricity.

2.1. The Advantages STATCOM Device

The STATCOM has numerous advantages. These include;

i. Control the power flow as system demand
ii. Increase the loading capability of lines to their thermal capacities
iii. Increase the system security through raising the transient stability, limit the short circuit currents and over-load
iv. Prevent cascading of black-outs by damping the system disturbances and oscillation
v. Reduce reactive power hence reducing power losses along transmission lines
vi. Increase utilization of lowest cost generation among the generation mix
vii. Strength a weak system by providing required voltage support during contingencies events thus stabilizes the voltage; eliminates voltage dips/ swell in the network
viii. Reduces frequent transformer tapping for voltage regulation and shunt capacitor frequent switching
ix. Allow system to operate over large range of loading profile without power and voltage oscillations (*as shown in figure 2 below*)

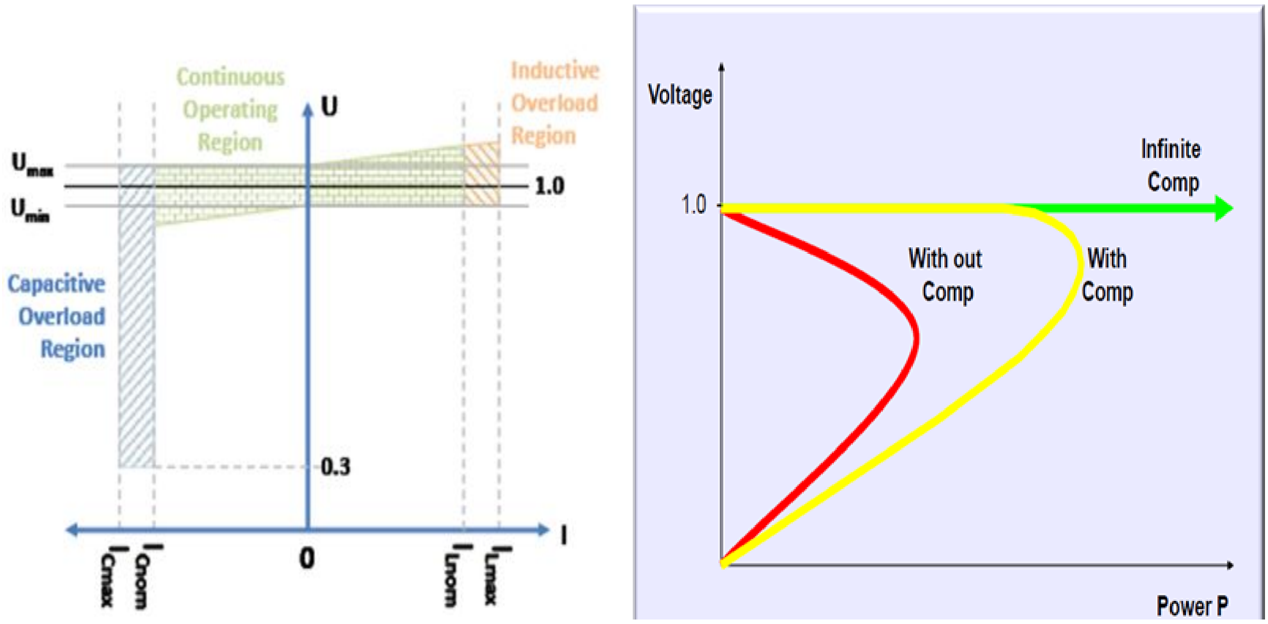

Fig-2. Operating range of STATCOM

Source: ABB- An introduction to Facts-2006

Where;

Comp implies presence of STATCOM in the system.

It is vivid from fig. 2 that installation of STATCOM improves the voltage profile under system transients and disturbance conditions.

From the above benefits of installing STATCOM in the power system, it is vivid that the STATCOM devices enhances quality of power supplied to the end power users (hence *less complains*).Further it enables the power utility to reduce technical losses and optimizes its existing infrastructures. As observed in one of the large power consumer with issue of poor power quality (*see the voltage profile as captured by the power quality equipment*), installing STATCOM will mitigate the voltage dips which adversely affects the production process of the manufacturing firms by smoothening the voltage profile as shown in figure 3 below.

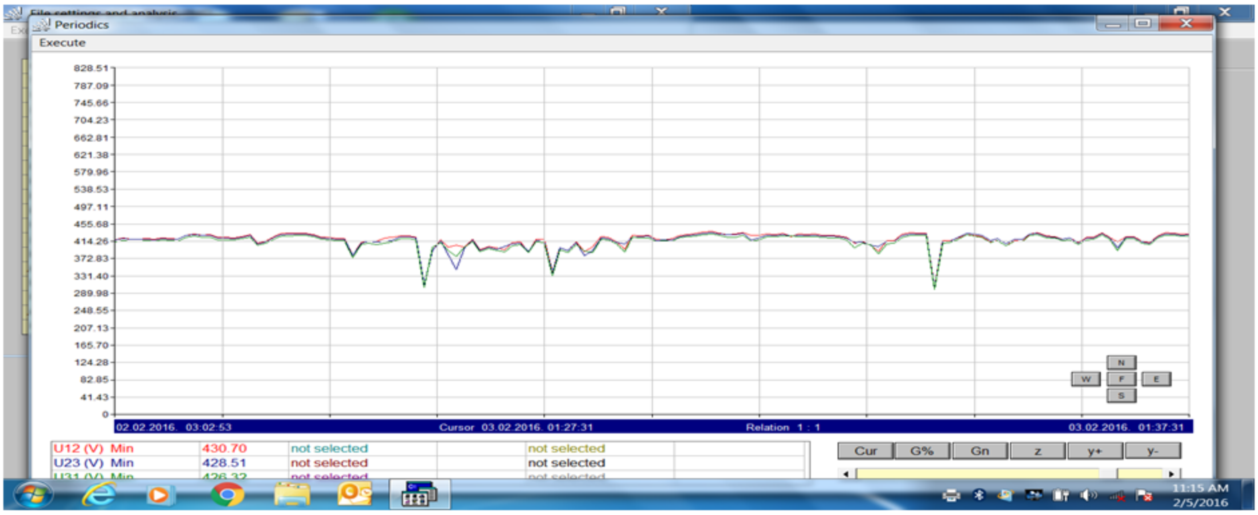

Fig-3. Power quality at Serena hotel –Mombasa

Source: Kenya power –power quality data at Serena Hotel on February, 2016

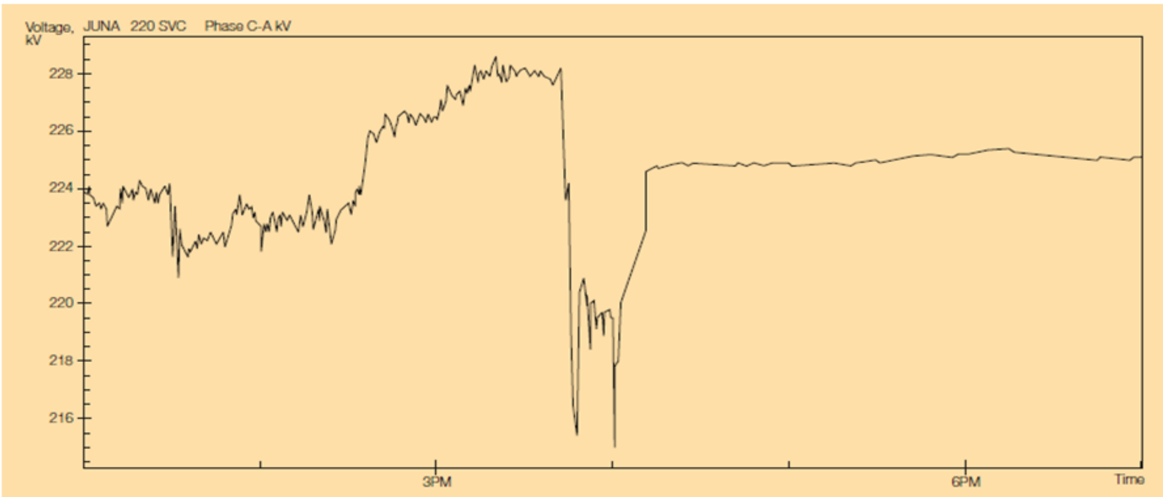

Fig-4. Voltage waveform before and after installing a compensator [2].

Source: ABB- SVC for voltage support of 220kV grid feeding mining loads in Western Austria

It is clear from Fig.4 that fast response of static compensator improves drastically the voltage profile of power grid and consequently the power quality supplied to the end power users. It can also be deduced that static compensator improve performance of the manufacturing firms by eliminating voltage dips which adversely affect operation of machines with variable speed drives and Switch Mode Power Supplies (SMPS).

3. KENYA POWER CASE STUDY

In recent time, the power quality supplied to the large power consumers have deteriorated considerably prompting the end power users perpetually keep on complaining to the power utility of poor power quality. This is mainly due to extensive expansion of the network and overloading of existing infrastructures beyond their designed capacity. Expansion of network has increased susceptibility of the system to earth faults and vandalism of the switchgears such as transformers and permanent earthing wire. On the other hand, overload has resulted to frequent operations of overload detecting devices such as auto-reclosers and fuses. Also noted is frequent phase failure due to line jumpers snapping and hotspots at primary and secondary substations. The other main cause of poor quality of power supplied to the end users is location of the generation stations and restriction of energy regulation body on use of the thermal generations which are strategically installed at load center. Geothermal and hydropower generations, which are the main power sources in Kenya, the power has to be transported using high voltage transmission lines to the load centers (Nairobi, Mombasa and Kisumu). As result, there is highly ohmic losses which contribute to low voltage at receiving end. It is this reason why regions such as coast region and western Kenya have frequently be experiencing voltage dips and low voltage at end users. It is worth noting that any major or minor perturbations along the transmission lines (*caused by lightning strikes, line fault*) usually results in a wide-spread power outages.

To mitigate susceptibility of power system to voltage collapsing and voltage dips, installation of STATCOM devices will result to a desired system performance even under the above stated conditions. This is because the STACOM will stabilizes the voltage and increase power transfer capability of transmission line evacuating power from Hydro and geothermal power generations. Moreover, the STATCOM will also improve voltage without necessary adding thermal generation in coast region. Worth noting is that there is 66kV STACOM available which does not need transformer to interface to the power system. This reduces the cost and installation time.

To install the STATCOM, the followings are prerequisite requirements that power utility need to undertake or contract;

i. Training of the implementing team.

It is pertinent to build human capacity by comprehensively conducting training on STATCOM specifications, procuring of contractor, system studies, installations, maintenance and servicing.

ii. Harmonic system analysis

It is paramount to conduct system harmonic analysis on existing power network to establish the dominant harmonic voltage frequencies presents as to achieve desired STATCOM specifications. It is worth noting that STATCOMs inherently generate harmonics and there is need to mitigate voltage series resonance due to magnification of harmonic frequencies with line parameters (*shunt capacitors and series inductors*).

iii. Power system power flow studies

Carrying-out power flow studies is a prerequisite requirement to enable designer to realizes optimal ratings of the STATCOM and ideal location for installation. This enable the power utility to spend less in initial capital investment and achieve the desired system performance as highlighted above.

4. CONCLUSION AND RECOMMENDATION

4.1. Conclusion

STATCOM is one of family of FACTs that consists of power electronic switches such as IGBT or MOSFET for improving power quality supplied to the end users. The STATCOM has been on the market from 1990s and is already installed globally by many countries. Example of some of countries embraced the STATCOM technologies are South Africa (ESKOM), India, Saudi Arabia (SEC), Mozambique (Edm), USA at Austin Taxas, and Chile at Cerro-Navia. After installation of STATCOM, the power utilities have benefited mainly on the voltage profile stabilization, improvement of utilization of existing transmission equipment and reduction of technical losses.

4.2. Recommendation

It has been noted that there is dire need of strengthening the grid network especially at Western, Coast and Nairobi regions. In recent time, power quality has attracted a lot of attention globally due to advent of sensitive equipment which are susceptible to power variations within a narrow bandwidth. In this regard, there is need for Kenya Power to employ the latest technologies to optimize the existing infrastructures and improve the power quality supplied to the end users.

Further, the country is gearing toward transmitting and distributing additional 5000 MW by 2018, hence there is need to establish a robust and resilience power network that can withstand inherent system contingencies. One economical and fast method is to install STATCOM devices, a technology which has already been implemented by other power utilities and has proven to improve power system stability and utilization of existing transmission assets to their thermal limit.

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