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Analysis of the effectiveness of DSTATCOM for Voltage Sag Reduction

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ABSTRACT- Quality of power has always been an area of interest and needs continuous improvement for transmission and distribution system. In this paper the power quality issues viz. sag and swell are being analyzed for a distribution network. The effectiveness of DSTATCOM has been explored so that these above said power quality issues are mitigated up to a considerable extent. The performance of the device is examined when connected in shunt to a power distribution system. The results obtained validate a good performance of the model developed and high usefulness of the device to mitigate problems introduced. All simulations have been performed using MATLAB. Further the same system is analyzed for voltage sag conditions with and without DSTATCOM.

Keywords- Power quality improvement, voltage sag, voltage swell, DSTATCOM

I. INTRODUCTION

Shunt connected controllers at distribution and transmission levels usually fall under two categories - Static Synchronous Generators (SSG) and Static VAr Compensators (SVC).

A Static Synchronous Generator (SSG) is defined by IEEE as a self-commutated switching power converter supplied from an appropriate electric energy source and operated to produce a set of adjustable multiphase voltages, which may be coupled to an AC power system for the purpose of exchanging independently controllable real and reactive power. When the active energy source (usually Battery Bank, Superconducting Magnetic Energy Storage etc.) is dispensed with and replaced by a DC capacitor which cannot absorb or deliver real power except for short durations, the SVC becomes a Static Synchronous Compensator (STATCOM). STATCOM has no long term energy support in the DC Side and cannot exchange real power with the ac system; however it can exchange reactive power. Also, in principle, it can exchange harmonic power too. But when a STATCOM is designed to handle reactive power and harmonic currents together it gets a new name – Shunt Active Power Filter. So a STATCOM handles only fundamental reactive power exchange with the ac system.

STATCOMs are employed at distribution and transmission levels – though for different purposes. When a STATCOM is employed at the distribution

Level or at the load end for power factor improvement and voltage regulation alone it is called DSTATCOM. When it is used to do harmonic filtering in addition or exclusively it is called Active Power Filter. In the transmission system STATCOMs handle only fundamental reactive power and provide voltage support to buses. In addition STATCOMs in transmission system are also used to modulate bus voltages during transient and dynamic disturbances in order to improve transient stability margins and to damp dynamic oscillations.

II. DEFINITION OF SHUNT CONNECTED CONTROLLERS

IEEE defines the second kind of Shunt Connected Controller called Static VAr Compensator (SVC) as a shunt connected static VAr generator or absorber whose output is adjusted to exchange capacitive or inductive current so as to maintain or control specific parameters of the electrical power system (typically bus voltage). Thyristor-switched or thyristor- controlled capacitors/ inductors and combinations of such equipment with fixed capacitors and inductors come under this.

III. STATCOM AS CONTROLLERS

STATCOMs are fast responding generators of reactive power with leading VAr/ lagging VAr capability which can provide steady state reactive compensation as well as dynamic compensation during power system transients, sags, swells, flicker etc. Thereby they can contribute significantly to enhancement of Power Quality. High Power STATCOMs in the transmission system are usually made with devices of low switching frequency capability (GTO's) and hence need special PWM patterns to optimize switching behavior. Such STATCOMs use Synchronous Link principle in the control blocks. DSTATCOMs use high speed switching levels, simple inverter structures and high frequency PWM or Hysteresis Control to function as Current Regulated Sources whereas transmission system STATCOMs use multi-pulse or multi-level inverters using GTO's and function as controlled voltage sources with controllable phase and use Synchronous Link Control principle.

IV. DEVELOPMENT OF VAr CONTROLLERS

It became clear in the early eighties that apart from the mundane job of pumping lagging/leading VAr into the power system at chosen points, VAr generators can assist in enhancing stability of the power system during large signal and small signal disturbances if only they were faster in the time domain. Also, they can provide reactive support against a fluctuating load to maintain the bus voltage regulation and to reduce flicker problems, provide reactive support to control bus voltages against sag and swell conditions and provide reactive support to correct the voltage unbalance in the source – if only they were fast enough. PWM STATCOMs were capable of delivering lagging/leading VArs to a load or to a bus in the power system in a rapidly controlled manner.

High Power STATCOMs of this type essentially consist of a three phase PWM Inverter using GTOs, Thyristors or IGBTs, a DC side capacitor which provides the DC voltage required by the inverter, filter components to filter out the high frequency components of inverter output voltage, a link inductor which links the inverter output to the AC supply side, interface magnetics (if required) and the related control blocks. The Inverter generates a three-phase voltage which is synchronized with the AC Supply from the DC side capacitor and the link inductance links up this voltage to the AC source. The current drawn by the Inverter from the AC supply was controlled to be mainly reactive (leading or lagging as per requirement) with a small active component needed to supply the losses in the Inverter and Link Inductor (and in the magnetics, if any).The DC side capacitor voltage was maintained constant (or allowed to vary with a definite relationship maintained between its value and the reactive power to be delivered by the Inverter) by controlling this small active current component. The currents were controlled indirectly by controlling the phase angle of Inverter output Voltage with respect to the A.C. side source voltage in the "Synchronous Link Based Control Scheme" whereas they were controlled directly by current feedback in the case of "Current Controlled Scheme". In the latter case the Inverter will be a Current Regulated one, i.e. its switches were controlled in such a way that the Inverter delivers a commanded current at its output rather than a commanded voltage (the voltage required to see that the commanded current flows out of Inverter will automatically be synthesized by the Inverter). Current Control Scheme results in a very fast STATCOM which can adjust its reactive output within tens of microseconds of a sudden change in the reactive demand.

V. IMPORTANCE OF POWER QUALITY

The ultimate reason that we are interested in power quality is economic value. There are economic impacts on utilities, their customers, and suppliers of load equipment. The quality of power can have a direct economic impact on many industrial consumers. There has recently been a great emphasis on revitalizing industry with more automation and more modern equipment. This usually means electronically controlled, energy-efficient equipment that is often much more sensitive to deviations in the supply voltage than were its electromechanical predecessors. Thus, like the blinking clock in residences, industrial customers are now more acutely aware of minor disturbances in the power system. There is big money associated with these disturbances. It is not uncommon for a single, common place, momentary utility breaker operation to result in a $10,000 loss to an average-sized industrial concern by shutting down a production line that requires 4 hours to restart In the semiconductor manufacturing industry, the economic impacts associated with equipment sensitivity to momentary voltage sags resulted in the development of a whole new standard for equipment ride-through (SEMI Standard F-47, Specification for Semiconductor Process Equipment Voltage Sag Immunity).

VI. POWER QUALITY ISSUES

A sag is a decrease to between 0.1 and 0.9 pu in rms voltage or current at the power frequency for durations from 0.5 cycle to 1 min. The power quality community has used the term sag for many years to describe a short-duration voltage decrease. Although the term has not been formally defined, it has been increasingly accepted and used by utilities, manufacturers, and end users. The IEC definition for this phenomenon is dip. The two terms are considered interchangeable, with sag being the preferred synonym in the U.S. power quality community. Terminology used to describe the magnitude of a voltage sag is often confusing. A "20 percent sag" can refer to a sag which results in a voltage of 0.8 or 0.2 pu. The preferred terminology would be one that leaves no doubt as to the resulting voltage level: "a sag to 0.8 pu" or "a sag whose magnitude was 20 percent." When not specified otherwise, a 20 percent sag will be considered an event during which the rms voltage decreased by 20 percent to 0.8 pu.

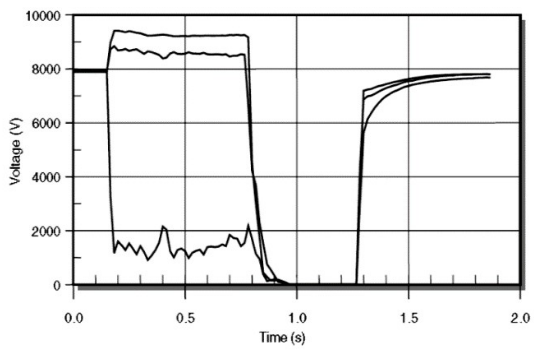

Figure 1. Three-phase RMS voltages for a momentary interruption due to a fault and subsequent re-closer operation

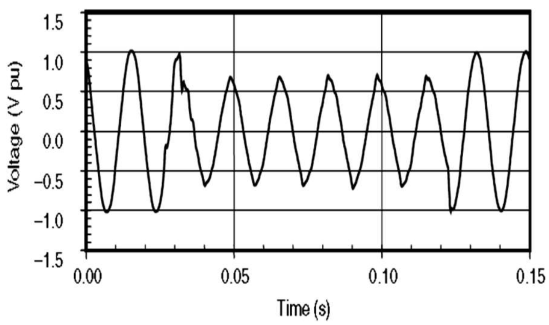

Figure 2. Voltage sag caused by an SLG fault - Voltage sag waveform

VII. CONFIGURATION OF DSTATCOM

A Distribution Static Synchronous Compensator (D-STATCOM) is used to regulate voltage on a 25-kV distribution network. Two feeders (21 km and 2 km) transmit power to loads connected at buses B2 and B3. A shunt capacitor is used for power factor correction at bus B2. The 600-V load connected to bus B3 through a 25kV/600V transformer represents a plant absorbing continuously changing currents, similar to an arc furnace, thus producing voltage flicker. The variable load current magnitude is modulated at a frequency of 5 Hz so that its apparent power varies approximately between 1 MVA and 5.2 MVA, while keeping a 0.9 lagging power factor. This load variation will allow you to observe the ability of the D-STATCOM to mitigate voltage flicker.

The D-STATCOM regulates bus B3 voltage by absorbing or generating reactive power. This reactive power transfer is done through the leakage reactance of the coupling transformer by generating a secondary voltage in phase with the primary voltage (network side). This voltage is provided by a voltage-sourced PWM inverter.

When the secondary voltage is lower than the bus voltage, the D-STATCOM acts like an inductance absorbing reactive power. When the secondary voltage is higher than the bus voltage, the D-STATCOM acts like a capacitor generating reactive power.

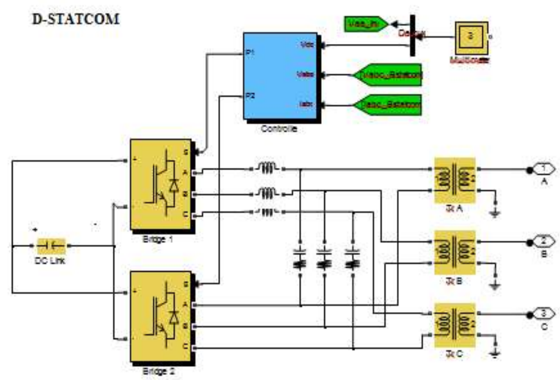

Figure 3. Block Diagram of DSTATCOM

VIII. DISTRIBUTION SYSTEM CONNNECTED WITH DSTATCOM - PERFORMANCE REVIEW USING MATLAB SIMULINK MODELS

The simulation model for creating voltage sag is shown in Fig. The same model is now connected with the same loads but a 10MW load is connected through a 3-phase circuit breaker which is normally open. This breaker connects the load to the system at 0.1sec. and is opened at 0.4 sec. thus, creating voltage sag due to sudden loading in the system. While voltage sag, the voltage falls below 1 pu and ranges between 0.75pu to 1 pu. The simulation result as a voltage waveform is shown also. This voltage waveform is a result of scope 8 connected to bus B2 in the system.

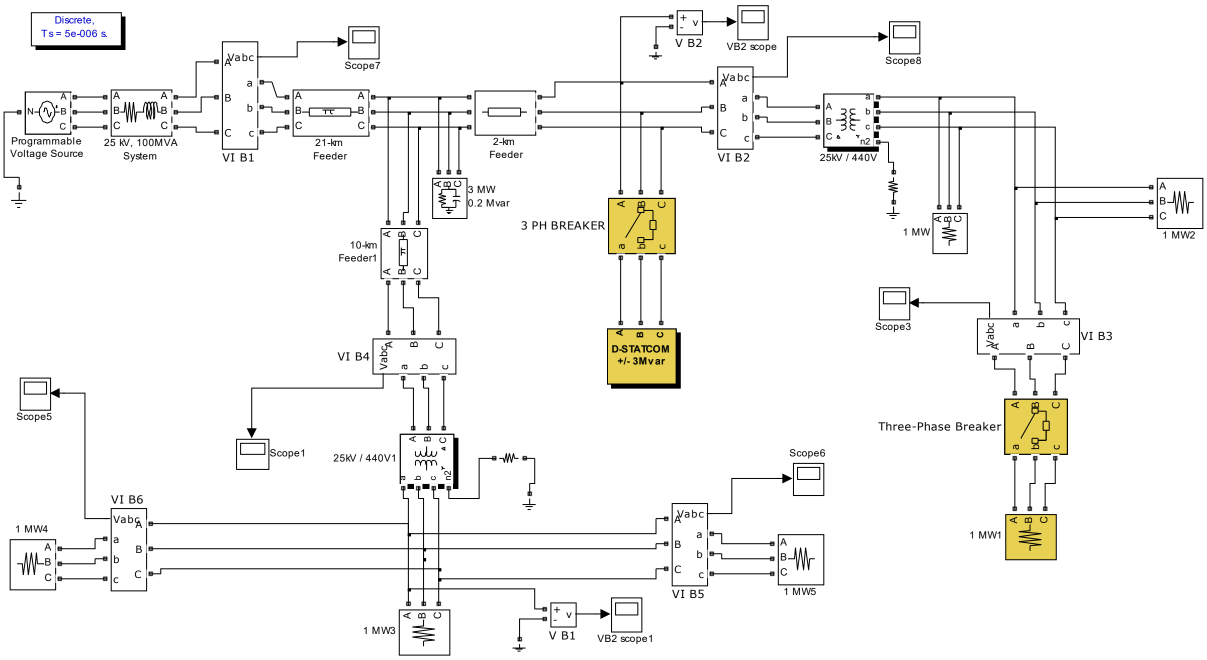

Figure 4. Simulation model of a distribution system for voltage SAG reduction

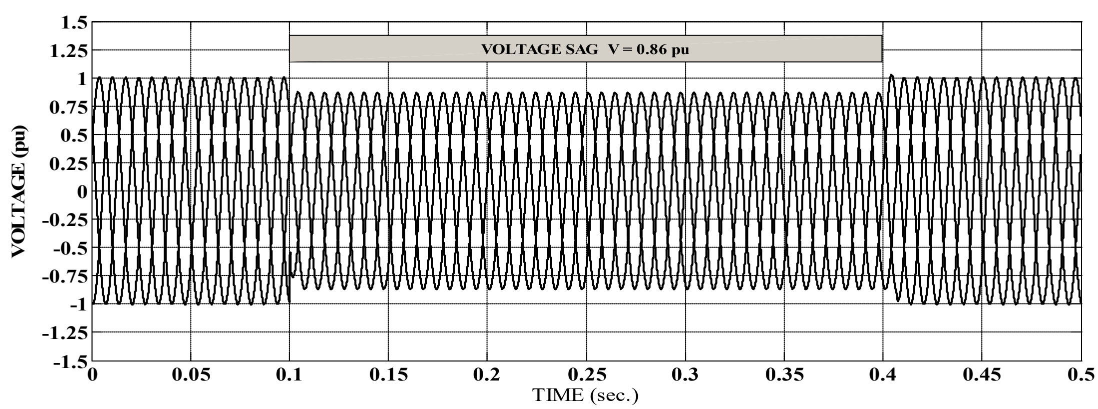

Figure 5. Voltage waveform for a distribution system showing voltage SAG

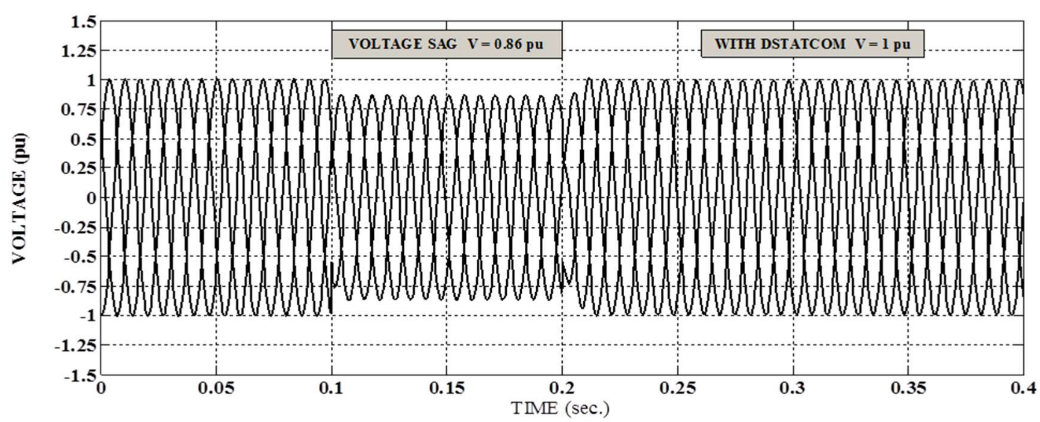

Figure 6. Voltage waveform of distribution system with a DSTATCOM (voltage SAG mitigation)

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