Voltage Sag Mitigation by Facts Devices

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***Abstract*—This paper investigates the effect of FACTS devices on the improvement of power quality problems. For this purpose 400 kv transmission system has been considered. In this paper we have taken power quality problem as a voltage sag and FACTS Device as a Unified Power Flow Controller. The whole system is simulated by using EMTC-PSCAD.**

***Keywords*- FACTS, EHV-AC, Voltage Sag, STATCOM, UPFC, PSCAD.**

I. INTRODUCTION

As we know that the demand of electricity is increasing day by day. Due to this day by day increasing demand of electricity power quality problems are introduced in the power system. Due to power quality problems the efficiency of power system is affected very much. It is becoming very necessary to mitigate these power quality problems. In this paper voltage sag as a power quality problem is mitigated. A Voltage Sag as defined by IEEE Standard 1159-1995, IEEE Recommended Practice for Monitoring Electric Power Quality, is a decrease in RMS voltage at the power frequency for durations from 0.5 cycles to 1 minute, reported as the remaining voltage. The measurement of a Voltage Sag is stated as a percentage of the nominal voltage, it is a measurement of the remaining voltage and is stated as a sag TO a percentage value. Thus a Voltage Sag to 60% is equivalent to 60% of nominal voltage, or 288 Volts for a nominal 480 Volt system. Voltage sags can occur on Utility systems both at distribution voltages and transmission voltages. Voltage sags which occur at higher voltages will normally spread through a utility system and will be transmitted to lower voltage systems via transformers. Voltage sags can be created within an industrial complex without any influence from the Utility system. These sags are typically caused by starting large motors or by electrical faults inside the facility.

II. POWER QUALITY PROBLEMS

Power Quality disturbances include all possible situations in which the waveforms of the supply voltage or load current deviate from the sinusoidal waveform at rated frequency with amplitude corresponding to the rated rms value for all three phases of a three-phase system. Power quality disturbance covers sudden, short duration deviation impulsive and oscillatory transients, voltage dips (or sags), short interruptions, as well as steady- state deviations, such as harmonics and flicker.

Power Quality Problems are:

1) Transients
   - (a) Impulsive
   - (b) Oscillatory
2) Short-duration variations
   - (a) Instantaneous
     - i. Interruption
     - ii. Sag (dip)
     - iii. Swell
   - (b) Momentary
     - i. Interruption
     - ii. Sag (dip)
     - iii. Swell
   - (c) Temporary
     - i. Interruption
     - ii. Sag (dip)
     - iii. Swell
3) Long-duration variations
   - (a) Interruption,
   - (b) Under-voltages
   - (c) Over-voltages
4) Voltage unbalance
5) Waveform distortion
   - (a) DC offset Steady state
   - (b) Harmonics
   - (c) Inter-harmonics
   - (d) Notching Steady state
   - (e) Noise
6) Voltage fluctuations
7) Power frequency variations

Flexible AC Transmission System (FACTS) controllers are the effective means to improve the power transfer capacity of the existing power systems. Available Transfer Capability (ATC) can be improved by by using FACTS controllers depends on its optimal location in the power system. Flexible AC Transmission Systems (FACTS) controllers are essentially used as an effective and promising alternative to enhance the power transfer capability. FACTS devices improve the stability of the network by regulating the bus voltages and redistribution of flow of line.[3]

III. Facts Devices

A. ***SVC.*** SVC is a shunt-connected static var absorber or generator . it'ssss 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). SVC is an important FACTS controller already widely in operation. Ratings range from 60 to 600 MVAR. SVC can be considered as a "first generation" FACTS controller and uses thyristor controllers. It is a shunt reactive compensation controller consisting of a combination of fixed capacitor or thyristor-switched capacitor in conjunction with thyristor-controlled reactor.

B. ***TCR.*** TCR is a shunt-connected thyristor-controlled inductor whose effective reactance is varied in a continuous manner by partial-conduction control of the thyristor valve. TCR has been used as one of the economical alternatives of FACTS controllers.

C. ***TSC.*** TSC is a shunt-connected thyristor-switched capacitor whose effective reactance is varied in a stepwise manner by full- or zero-conduction operation of the thyristor valve [1].

D. ***TSR.*** TSR is a shunt-connected thyristor-switched inductor whose effective reactance is varied in a stepwise manner by full- or zero-conduction operation of the thyristor valve [1].

E. ***TCSC.*** TCSC is a capacitive reactance compensator, which consists of a series capacitor bank shunted by a thyristor-controlled reactor in order to provide a smoothly variable series capacitive reactance. The description of the first TCSC installation is given in [1].

F. ***TSSC.*** TSSC is a capacitive reactance compensator, which consists of a series capacitor bank shunted by a thyristor-switched reactor to provide a stepwise control of series capacitive reactance.

G. ***TCSR.*** TCSR is an inductive reactance compensator, which consists of a series reactor shunted by a thyristor-controlled reactor to provide a smoothly variable series inductive reactance [1].

H. ***TSSR.*** TSSR is an inductive reactance compensator, which consists of a series reactor shunted by a thyristor-controlled reactor to provide a stepwise control of series inductive reactance [1].

I. ***TCPST.*** TCPST is a phase-shifting transformer adjusted by thyristor switches to provide a rapidly variable phase angle. This controller is also referred to as TCPAR. **TCVL.** TCVL is a thyristor-switched metal-oxide varistor used to limit the voltage across its terminals during transient conditions [9].

J. ***TCVR.*** TCVR is a thyristor-controlled transformer that can provide variable in-phase voltage with continuous control [1].

K. ***SSSC.*** SSSC is a static synchronous generator operated without an external electric energy source as a series compensator whose output voltage is in quadrature with, and controllable independently of, the line current for the purpose of increasing or decreasing the overall reactive voltage drop across the line and thereby controlling the transmitted electric power [3]. The SSSC may include transiently rated energy storage or energy absorbing devices to enhance the dynamic behavior of the power system by additional temporary real power compensation, to increase or decrease momentarily, the overall real (resistive) voltage drop across the line.

L. ***STATCOM.*** STATCOM is a static synchronous generator operated as a shunt-connected static var compensator whose capacitive or inductive output current can be controlled independent of the ac system voltage

M. ***UPFC.*** UPFC is a combination of STATCOM and a SSSC which are coupled via a common dc link to allow bidirectional flow of real power between the series output terminals of the SSSC and the shunt output terminals of the STATCOM and are controlled to provide concurrent real and reactive series line compensation without an external electric energy source. The UPFC, by means of angularly unconstrained series voltage injection, is able to control, concurrently or selectively, the transmission line voltage, impedance, and angle or, alternatively, the real and reactive power flow in the line. The UPFC may also provide independently controllable shunt reactive compensation. The UPFC proposed by Gyugyi [29] is the most versatile FACTS controller for the regulation of voltage and power flow in a transmission line.

N. ***GUPFC.*** GUPFC can effectively control the power system parameters such as bus voltage, and real and reactive power flows in the lines. A simple scheme of GUPFC consists of three converters, one connected in shunt and two connected in series with two transmission lines terminating at a common bus in a substation [2]. It can control five quantities, i.e., a bus voltage and independent active and reactive power flows in the two lines. The real power is exchanged among shunt and series converters via a common dc link.

O. ***IPC.*** IPC is a series-connected controller of active and reactive power consisting, in each phase, of inductive and capacitive branches subjected to separately phase-shifted voltages. The active and reactive power can be set independently by adjusting the phase shifts and/or the branch impedances, using mechanical or electronic switches. In the particular case where the inductive and capacitive impedance form a conjugate pair, each terminal of the IPC is a passive current source dependent on the voltage at the other terminal.

P. ***IPFC.*** IPFC is a combination of two or more SSSCs that are coupled via a common dc link to facilitate bi-directional flow of real power between the ac terminals of the SSSCs and are controlled to provide independent reactive compensation for the adjustment of real power flow in each line and maintain the desired distribution of reactive power flow among the lines [1]. The IPFC structure may also include a STATCOM, coupled to the IPFC common dc link, to provide shunt reactive compensation and supply or absorb the overall real power deficit of the combined SSSCs.[1]

IV. Simulation Tools Used

PSCAD was first conceptualized in 1988 and began its long evolution as a tool to generate data files for the EMTDC simulation program. PSCAD (Power Systems CAD) is a powerful and flexible graphical user interface to the world-renowned, EMTDC solution engine. PSCAD enables the user to schematically construct a circuit, run a simulation, analyze the results, and manage the data in a completely integrated, graphical environment. Online plotting functions, controls and meters are also included, so that the user can alter system parameters during a simulation run, and view the results directly. PSCAD is a fast, accurate, and easy-to-use power system simulation software for the design and verification of all types of power systems. PSCAD is also known as PSCAD/EMTDC because EMTDC is the simulation engine, which is now the integral part of PSCAD graphical user interface. PSCAD is most suitable for simulating time *domain instantaneous responses*, also known as *electromagnetic transients* or *instantaneous solutions*, in both electrical and control systems.

PSCAD/EMTDC is a powerful electromagnetic transient's simulation program. It is most suitable for time domain simulations of the systems. It is an industry standard simulation tool. The graphical interface of the software makes it very easy to build the circuit and observe the results in within a single integrated environment. Due to the presence of the graphical interface the time for the development of the program is drastically reduced. PSCAD/EMTDC uses subsystems, which breaks the whole job into smaller units and makes the understanding easy. In EMTDC there the user can write his own program, which best suits, his simulation and integrate it to the main program.

PSCAD comes complete with a library of pre-programmed and tested models, ranging from simple passive elements and control functions, to more complex models, such as electric machines FACTS devices, transmission lines and cables. If a particular model does not exist, PSCAD provides the flexibility of building custom models, either by assembling them graphically using existing models, or by utilizing an intuitively designed Design Editor.

The following are some common models found in systems studied using PSCAD:

- Resistors, inductors, capacitors
- Mutually coupled windings, such as transformers
- Frequency dependent transmission lines and cables (including the most accurate time domain line model in the world!)
- Current and voltage sources
- Switches and breakers
- Protection and relaying
- Diodes, thyristors and GTOs
- Analog and digital control functions
- AC and DC machines, exciters, governors, stabilizers and inertial models
- Meters and measuring functions
- Generic DC and AC controls
- HVDC, SVC, and other FACTS controllers
- Wind source, turbines and governors

PSCAD, and its simulation engine EMTDC, have enjoyed close to 30 years of development, inspired by ideas and suggestions by its ever strengthening, worldwide user base. This development philosophy has helped to establish PSCAD as one of the most powerful and intuitive CAD software packages available.[2]

V. RESULT AND GRAPH

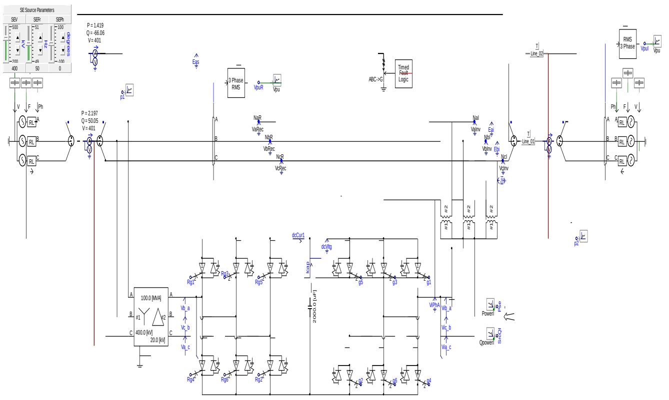

Figure 1 Simulation Model Of UPFC

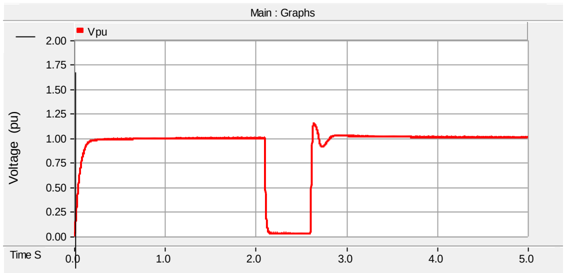

Figure 2 Voltage Sag Before Using UPFC

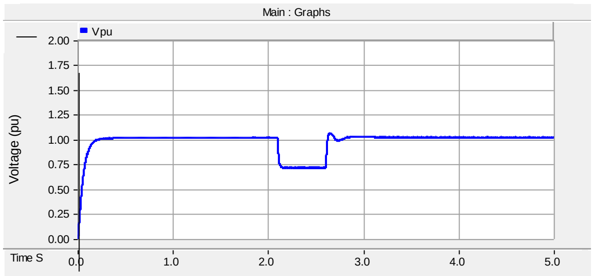

Figure 3 Voltage Sag after Using UPFC

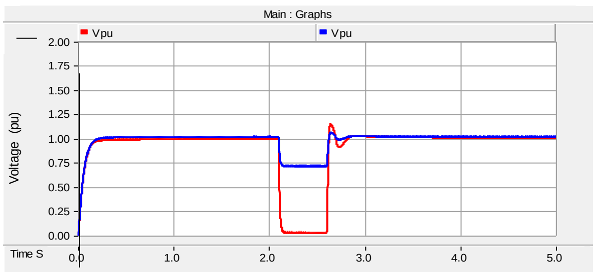

Figure 4 Comparisons between without and with UPFC

Figure 1 the simulated model used for the voltage sag mitigation is shown.figure 2 and 3 gives the voltage sag before and after using UPFC.From above observation we can conclude that voltage sag can be reduced to a considerable value by connecting UPFC between the 400KV transmission system.

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