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Comparative Study of UPFC & STATCOM by Using Detailed Simulation Model

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Abstract

This paper shows the application of the FACTS controllers used in power system for balancing the Reactive Power, Voltage Stability & Power Factor through-out the process of the transmission of the power. In this paper the simulation model of the UPFC & STATCOM Facts Controllers are taken for observation so that a complete comparison can be carried out so that the output result can be more useful for the further application. The Matlab Simulation is used here to carry out the whole process. In this paper the after the comparison of all three devices the best one is chosen among them for results.

Key Words: STATCOM, UPFC, VOLTAGE STABILITY, REACTIVE POWER, ACTIVE POWER

INTRODUCTION

A flexible alternating current transmission system (FACTS) is a system composed of static equipment used for the AC transmission of electrical energy. It is generally a power electronics-based system. FACTS are defined by the IEEE as "a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability."[1]The first FACTS installation was at the C. J. Slatt Substation in Northern region. This is a 500 kV, 3-phase 60 Hz substation, and was developed by EPRI, the Bonneville Power Administration and General Electric Company.[2]

Many devices contribute to reactive power compensation and voltage profile. A transmission line, due to its physical characteristics, supplies reactive power under light loading and consumes it under heavy loading conditions. Power system voltages are controlled through the supply and consumption of reactive power. In general terms, decreasing reactive power margin causes voltage fall, while increasing reactive power margin causes voltage rise. Voltage instability is basically caused by an unavailability of reactive power support in an area of the network, where the voltage drops uncontrollable. Lack of reactive power may essentially have two origins firstly, a gradual increase of power demands without the reactive part being met in some buses or secondly, a sudden change in the network topology redirecting the power flows in such a way that the required reactive power cannot be delivered to some buses. Introducing FACTS devices is the most effective way for utilities to improve the voltage profile and voltage stability margin of the system.[3]

STATCOM

A static synchronous compensator (STATCOM), also known as a "static-synchronous-condenser" is a regulating device used on alternating current electricity transmission networks. It is based on a power electronics voltage-source converter and can act as either a source or sink of reactive AC power to an electricity network. If connected to a source of power it can also provide active AC power. It is a member of the FACTS family of devices. Usually a STATCOM is installed to support electricity networks that have a poor power factor and often poor voltage regulation.

There are however, other uses, the most common use is for voltage stability. A STATCOM is a voltage source converter (VSC)-based device, with the voltage source behind a reactor. The voltage source is created from a DC capacitor and therefore a STATCOM has very little active power capability. However, its active power capability can be increased if a suitable energy storage device is connected across the DC capacitor.

UPFC

A Unified Power Flow Controller (or UPFC) is an electrical device for providing fast-acting reactive power compensation on high voltage electricity transmission networks. It uses a pair of three-phase controllable bridges to produce current that is injected into a transmission line using a series transformer. The controller can control active and reactive power flows in a transmission line.

The UPFC uses solid state devices, which provide functional flexibility, generally not attainable by conventional thyristor controlled systems. The UPFC is a combination of a static synchronous compensator (STATCOM) and a static synchronous series compensator (SSSC) coupled via a common DC voltage link. The UPFC concept was described in 1995 by L. Gyugyi of Westinghouse. [4]

SIMULATION

BLOCK DIAGRAM THEORY - A Unified Power Flow Controller (UPFC) is used to control the power flow in a 400 kv transmission system. The UPFC located at the left end of the 75-km line L2, between the 400 kv buses B1 and B2, is used to control the active and reactive powers flowing through bus B2 while controlling voltage at bus B1.

It consists of two 100-MVA, three-level, 48-pulse GTO-based converters, one connected in shunt at bus B1 and one connected in series between buses B1 and B2. The shunt and series converters can be exchange power through a DC bus. The series converter can inject a maximum of 10% of nominal line-to-ground voltage (28.87 kV) in series with line L2.

SECTIONS

Programmable Voltage Source
Vrms = 400e3*1.0491,
Phase Angle (deg) = 9.2,
Frequency (Hz) = 50

Three Phase Series RLC Circuit
Vrms = 400e3*1.00,
Frequency (Hz) = 50

Three Phase Parallel RLC Circuit
Vrms = 400e3,
Frequency (Hz) = 50

Three phase Source
Vrms = 400e3*1.00,
Frequency (Hz) = 50

Three Phase Series RLC Circuit
Vrms = 400e3,
Frequency (Hz) = 50

Three Phase Source
Vrms = 400e3*0.98,
Phase Angle (deg) = 9.2,
Frequency (Hz) = 50

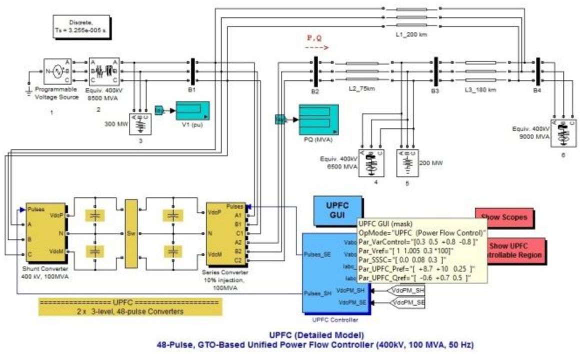

Fig 1. UPFC Detailed Model

This pair of converters can be operated in three modes:

Unified Power Flow Controller (UPFC) mode, when the shunt and series converters are inter-connected through the DC bus. When the disconnect switches between the DC buses of the shunt and series converter are opened, two additional modes are available Shunt converter operating as a Static Synchronous Compensator (STATCOM) controlling voltage at bus B1 Series converter operating as a controlling injected voltage, while keeping injected voltage in quadrature with current.

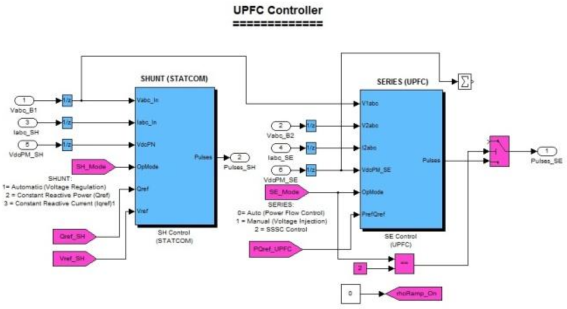

Fig 2. UPFC Controller

The mode of operation as well as the reference voltage and reference power values can be changed by means of the "UPFC GUI" block. The principle of operation of the harmonic neutralized converters is explained in another demo entitled "Three-phase 48-pulse GTO converter".

When the two converters are operated in UPFC mode, the shunt converter operates as a STATCOM. It controls the bus B1 voltage by controlling the absorbed or generated reactive power while also allowing active power transfer to the series converter through the DC bus. The reactive power variation is obtained by varying the DC bus voltage.

The four three-level shunt converters operate at a constant conduction angle (Sigma= 180-7.5 = 172.5 degrees), thus generating a quasi-sinusoidal 48-step voltage waveform. When operating in UPFC mode, the magnitude of the series injected voltage is varied by varying the Sigma conduction angle, therefore generating higher harmonic contents than the shunt converter.

The natural power flow through bus B2 when zero voltage is generated by the series converter (zero voltage on converter side of the four converter transformers) is P=+870 MW and Q=-70 Mvar. In UPFC mode, both the magnitude and phase angle and the series injected voltage can be varied, thus allowing control of P and Q. The UPFC controllable region is obtained by keeping the injected voltage to its maximum value (0.1 pu) and varying its phase angle from zero to 360 degrees. [5]

WORKING MODEL

Power control in UPFC mode

Open the UPFC GUI block menu. The GUI allows you to choose the operation mode (UPFC or STATCOM) as well as the Pref/Qref reference powers and/or V1 reference voltage settings . Also, in order to observe the dynamic response of the control system, the GUI allows you to specify a step change of any reference value at a specific time. Make sure that the operation mode is set to "UPFC (Power Flow Control)".

The reference active and reactive powers are specified in the last two lines of the GUI menu. Initially, Pref= +8.7 pu/100MVA (+870 MW) and Qref=-0.6 pu/100MVA (-60 Mvar). At t=0.25 sec Pref is changed to +10 pu (+1000MW). Then, at t=0.5 sec, Qref is changed to +0.7 pu (+70 Mvar). Run the simulation for 0.8 sec. Open the "Show Scopes" subsystem. Observe on traces 1 and 2 of the UPFC scope the variations of P and Q. After a transient period lasting approximately 0.15 sec, the steady state is reached (P=+8.7 pu; Q=-0.6 pu). Then P and Q are ramped to the new settings (P=+10 pu Q=+0.7 pu). Observe on traces 3 and 4 the resulting changes in P Q on the three transmission lines.

Var control in STATCOM mode

In the GUI block menu, change the operation mode to "STATCOM (Var Control)". Make sure that the STATCOM references values (1st line of parameters, [T1 T2 Q1 Q2]) are set to [0.3 0.5 +0.8 -0.8]. In this mode, the STATCOM is operated as a variable source of reactive power.

Initially, Q is set to zero, then at T1=0.3 sec Q is increased to +0.8 pu (STATCOM absorbing reactive power) and at T2=0.5 sec, Q is reversed to -0.8 pu (STATCOM generating reactive power).Run the simulation and observe on the STATCOM scope the dynamic response of the STATCOM.

Zoom on the first trace around t=0.5 sec when Q is changed from +0.8pu to -0.8pu. When Q=+0.8pu, the current flowing into the STATCOM (cyan trace) is lagging voltage (magenta trace), indicating that STATCOM is absorbing reactive power. When Qref is changed from +0.8 to -0.8, the current phase shift with respect to voltage changes from 90 degrees lagging to 90 degrees leading within one cycle.

This control of reactive power is obtained by varying the magnitude of the secondary voltage Vs generated by the shunt converter while keeping it in phase with the bus B1 voltage Vp. This change of Vs magnitude is performed by controlling the dc bus voltage. When Q is changing from +0.8 pu to -0.8 pu, Vdc (trace 3) increases from 17.5 kV to 21 kV.

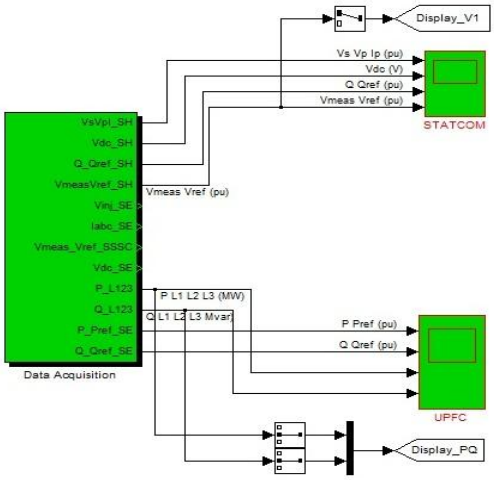

Fig 3. Simulation Circuit

RESULTS:

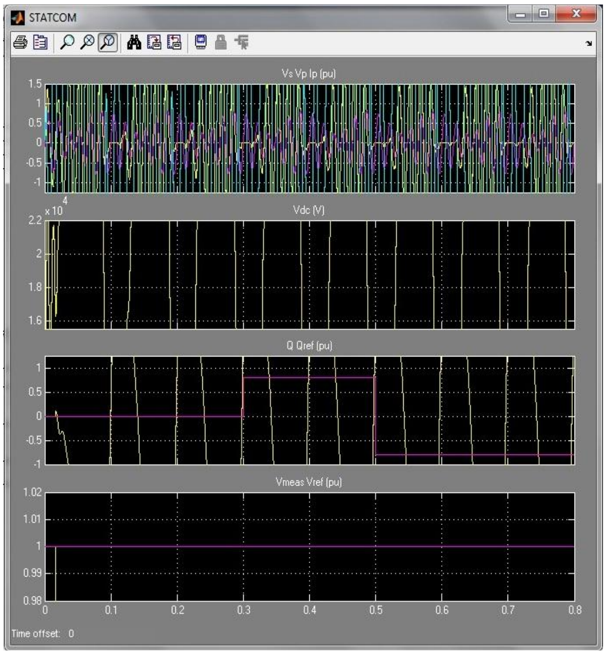

Fig 4. Output of STATCOM

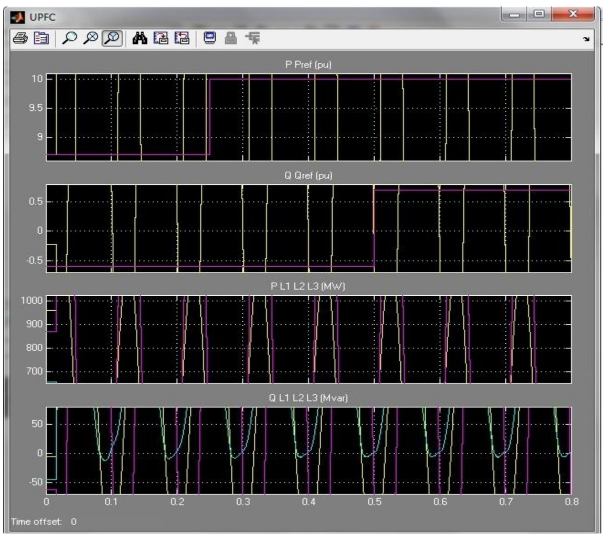

Fig 5. Output of UPFC

At the given values;
Vrms = 400 kv,
Frequency = 50 Hz
Active Power = 200e6
Results obtained by the simulation model of UPFC are as follows;
V1(rms) = 0.76,
P(MVA) = -896.32,
Q(MVA) = 62.47

CONCLUSION

The above simulation shows the complete results waveform of both the taken Facts Devices and also the values of **V1(rms), P(MVA) & Q(MVA)**. The results show that among both of them STATCOM & UPFC, the UPFC Controller is the best to give the output waveform in the stable and the desired manner at the **400 kv** , 100MVA on 48 cycle pulse GTO.

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