Optimal Location of FACTS Device for Power Flow Control in Power System

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Abstract---The shunt connected compensation (STATCOM) based FACTS device for the control of voltage and the power flow in long distance transmission line. The proposed device is used in different locations such as sending end of the transmission line, middle and receiving end of the transmission line. The PWM control strategy is used to generate the firing pulses of the controller circuit. Simulations were carried out using MATLAB Simulink environment. The suitable location and the performance of the proposed model were examined. Based on a voltage-sourced converter, the STATCOM regulates system voltage by absorbing or generating reactive power. The simulation results reveals that the reactive power generated is better at the middle of the transmission line when compared with the other ends of the transmission line and also the voltage is controlled at the middle of the line. Henceforth the location of STATCOM is optimum when connected at the middle of the line.

Keywords: FACTS device, STATCOM, PWM technique, MATLAB Simulink.

I. INTRODUCTION

A Flexible AC Transmission System (FACTS) is an ac transmission system that provides better power flow control and dynamic stability by controlling ac transmission system parameters of voltage, phase angle. And impedance. The shunt device consists of Static variable compensator (SVC) and Static synchronous compensator (STATCOM). The FACTS devices are connected in the power system transmission for the reduction of the transmission line losses and also to increase the transfer capability. Shunt active compensation provided by a static synchronous compensator (STATCOM) connected at the center of the transmission line to minimize the effects of sub synchronous resonance (SSR). The STATCOM is VSC based controller to regulate the voltage by varying the reactive power in a distribution line.

Based on the type of compensation, we have three different categories of FACTS devices:
- Shunt device such as SVC and STATCOM.
- Series device such as TCSC, TCPST and TCVR.
- Combined shunt-series device such as UPFC.

Each of the above FACTS devices have its own properties and used for a specific goal.

II. OPERATING PRINCIPLE

The STATCOM consists of a coupling transformer, an inverter and a DC capacitor as shown in figure 1.

![Functional Model of STATCOM](image)

Fig. 1: Functional Model of STATCOM

Now the voltage-sourced converter that converts a dc voltage at its input terminals into a three-phase set of ac voltages. And the reactive current can be regulated by varying the magnitude of this output voltage.

The ac current magnitude can be calculated using the following equation:

\[ I_{ac} = \frac{V_{out} - V_{ac}}{X} \]

If the amplitude of the converter output voltage \( V_{out} \) is increased above \( V_{ac} \), then the ac current \( I_{ac} \) flows through the transformer reactance from the converter to the ac system generating reactive power. If the amplitude of the converter output voltage \( V_{out} \) is decrease below \( V_{ac} \), then the ac current \( I_{ac} \) flows through the transformer reactance from the ac system to converter. so, it absorb reactive power. The corresponding reactive power exchanged can be expressed as follows:

\[ Q = \frac{V_{out}^2 - V_{out} V_{ac} \cos \alpha}{X} \]

The real power exchange between the voltage-sourced converter and the ac system can be calculated using
where the angle $\alpha$ is the angle between the ac system bus voltage $V_{ac}$ and the converter output voltage $V_{out}$.

when $\alpha = 0$ then $P= 0$ So that by adjusting phase shift $\alpha$, we can exchange real power also.

III. OPERATING CHARACTERISTIC OF STATCOM
This characteristic shows the STATCOM ability to support a very low system voltage; down to about 0.15 per unit. STATCOM provide control of reactive power in both leading and lagging $\text{p.f.}$ range. The STATCOM increased transient ratings in both capacitive and inductive regions shown in figure 2.

The STATCOM has the ability to increase/decrease the voltage magnitude and consequently to increase/decrease power flows in the transmission line.

![Fig. 2: V-I characteristic of STATCOM](image)

IV. SIMULATION MODEL
Here we considered a three bus Power system which consists of two 500-KV equivalents generators, respectively 3000 MVA and 2500 MVA, connected by a 600-km long transmission line. When the STATCOM is not in operation, the "natural" power flow on the transmission line is 951.4 MW from bus B1 to B3. STATCOM has a rating of +/-100MVA. This STATCOM is a phasor model of a typical three-level PWM STATCOM.

Figure 3 explains about the circuit diagram without compensation. In this circuit the power is directly measured in the 600km long transmission line at the three stages like B1, B2 and B3 and also tabulated the result in table 1.

Figure 4 explains about the circuit diagram when STATCOM is connected at the Middle of the long transmission line. Similarly the connections are made when the STATCOM is connected at the sending end and receiving end of the long transmission line.

Simulations are also carried out on several power systems, like a 5-bus power system, 7-bus power system and an IEEE-14 bus power System. Use MATLAB SIMULINK for IEEE 3 bus system model for power flow Study.

Case 1: simulate model without FACTS device.
Case 2: simulate model with STATCOM.
V. SIMULATION RESULTS
To understand the effect of presence of STATCOM in system, on system parameters carried out by simulation analysis of the system. The results are generated by MATLAB outputs. Initially Vref is set to 1 pu at t = 0.2 s, Vref is decreased to 0.97 pu at t = 0.4 s and Vref is increased to 1.03 at 0.6 s shown in figure 5.

When Vm is low then STATCOM operate in inductive mode and absorb reactive power (+ve sign). When Vm is high then STATCOM operate in capacitive mode and generate reactive power (-ve sign) shown in figure 6.

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VI. CONCLUSION
The role of shunt FACTS devices, which are connected in long distance transmission lines, are to improve the power transfer capability and also to control the power flow in the power system network. In this proposed work STATCOM is employed as a shunt FACTS device. STATCOM is connected at the various locations such as sending end,
middle and receiving end of the transmission line. The results were obtained with and without compensation. The simulation results reveals that the reactive power generated is better at the middle of the transmission line when compared with the other ends of the transmission line and also the voltage is controlled at the middle of the line. So, the location of STATCOM is optimum when connected at the middle of the line.

REFERENCES


