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Load Flow Studies with UPFC Power Injection Model

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ABSTRACT: the Flexible AC Transmission Systems (FACTS) is very popular and essential device in power systems. Several FACTS-devices have been introduced for various applications in power system. Among a variety of FACTS controllers, Unified Power Flow Controller (UPFC) is the most powerful and versatile device. This is focused on to improve the bus voltage and to reduce the active and reactive power losses in the transmission lines incorporating steady state model of UPFC in Newton-Raphson (NR) power flow algorithm. The steady state model of the UPFC, derived from two voltage source representation, is presented and analyzed in detail. A MATLAB program is executed to incorporate the UPFC model in NR Load flow algorithm.

KEYWORDS: UPFC, POWER FLOW.

I. INTRODUCTION

Power flow studies provide a systematic mathematical approach for determination of various bus voltages, there phase angle, active and reactive power flows through different lines, generators and loads at steady state condition. For the planning and operation of power distribution system, Power flow analysis is used. It is very important to control the power flow along the transmission line. These devices constitute an emerging technology called FACTS (flexible alternating current transmission systems) [2, 3]. The FACTS technology opens up new opportunities for controlling the both types of powers and enhancing the usable capacity of present transmission systems. This opportunity is arises through the ability of FACTS controllers to adjust the power system electrical parameters including series and shunt impedances, current, voltage, phase angle, and the damping oscillations etc. The implementation of such equipment requires the different power electronics-based compensators and controllers. The FACTS devices use various power electronics devices such as Thyristors , Gate turn offs(GTO), Insulated gate bipolar transistors(IGBT), Insulated Gate Commutated thyristors (IGCT),they can be controlled very fast as well as different control algorithms adapted to various situations. FACTS technology has a lots of benefits, such as greater power flow control ability, increased the loading of existing transmission circuits, damping of power system oscillations, has less bed impact on environmental and ,has the less cost than other alternative techniques of transmission system is used.

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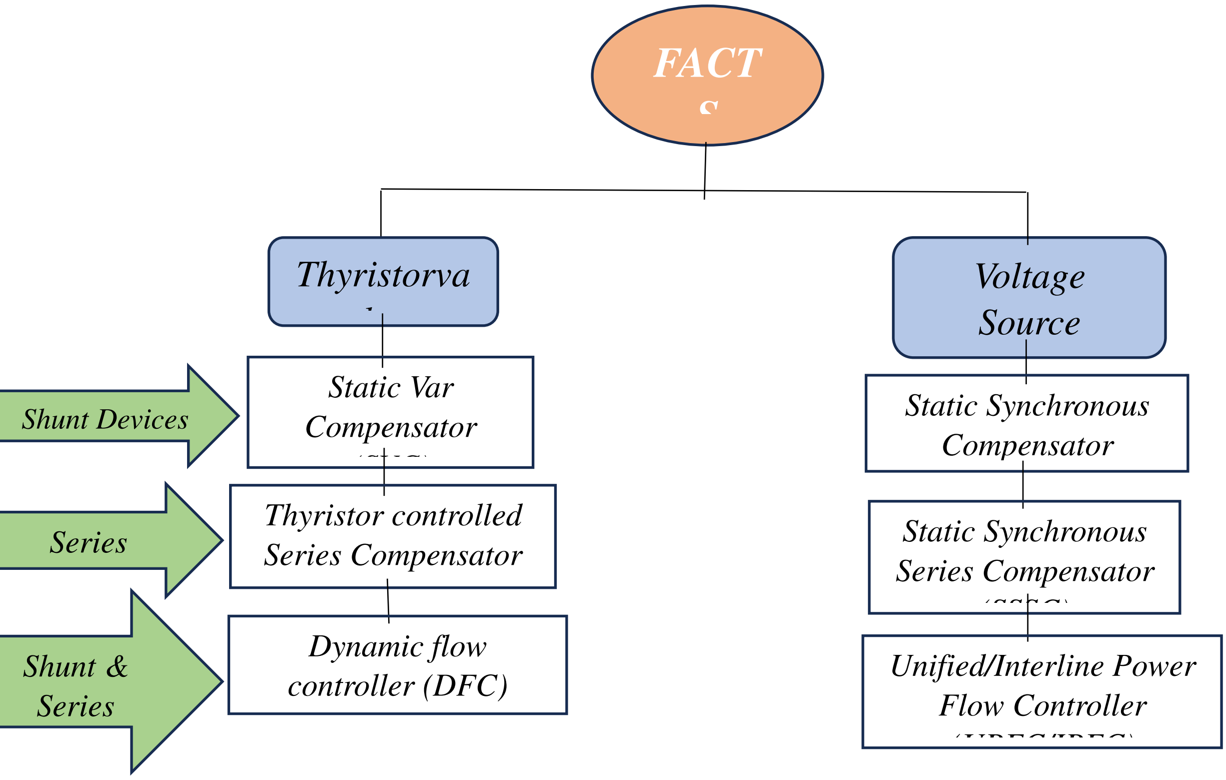

Fig. Overview of major FACTS Devices in terms of on power electronic devices.

The UPFC is one of the most versatile device. It cannot only perform the functions of the static synchronous compensator (STATCOM), thyristor switched capacitor (TSC)thyristor controlled reactor (TCR), and the phase angle regulator but also provides additional flexibility by combining some of the functions of the above controllers [1]. The main function of the UPFC is to control the flow of real and reactive power by injection of a voltage in series with the transmission line. Both the magnitude as well as the phase angle of the voltage can be varied independently. Real and reactive power flow control can allow for power flow in prescribed routes, transmission lines loading is closer to their thermal limits and can be utilized for improving transient and small signal stability of the power system.

II. LITERATURE REVIEW

This situation has necessitated a review of the traditional power system concepts and practices to achieve greater operating flexibility and better utilization of existing power systems. The various thyristor circuits used in to generate and control the reactive power .These technologies have been instrumental in the broad application of high voltage DC and AC transmissions. They have already made a significant impact on AC transmission via the increasing use of thyristor controlled static VAR compensators (SVCs). Various mathematical model of UPFC has been introduced depend upon various purpose of application. For the Power system stability studies the UPFC current injection model is used, which improve the dynamic performance of the system [11]. In this model the shunt compensation of UPFC is controlled to maintain the system bus voltage and the two components of UPFC series voltage, which are in phase voltage and quadrature voltage, are coordinated to respond to the power variations of the line. The active and reactive power loads in the PQ bus and the voltage magnitude at the PV bus are set at the values to be controlled by the UPFC. The active power injected into the PV bus has the same value as the active power extracted in the PQ bus since the UPFC and coupling transformers are assumed to be lossless. These powers are expressed as function of terminal, nodal voltages, and the output voltage of the series source which represents the UPFC series converter.

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FACTS Controller:

Flexible AC Transmission System (FACTS): Alternating current transmission systems incorporating power electronic-based and other static controllers to enhance controllability and increase power transfer capability.

The various basic applications of FACTS-devices are:

- power flow control
- increase of transmission capability
- voltage control
- reactive power compensation, stability improvement
- Power quality improvement
- Power conditioning.

FACTS-devices employs the use of thyristor valves or converters. This valves or converters are well known since several years. They have low switching frequency and low losses. The devices of the right hand side column of the fig has more advanced technology of voltage source converters based mainly on Insulated Gate Bipolar Transistors (IGBT) or Insulated Gate Commutated Thyristors (IGCT). Pulse width modulation technique is used to control the magnitude and phase of the voltage.

Theory of UPFC:

The Unified Power Flow Controller (UPFC) was proposed first time for real turn-off time control and dynamic compensation of ac transmission systems. These inverters, labelled "VSC1"and "VSC2" in the figure are operated with a common dc link provided by a dc storage capacitor. With this arrangement the ac power converter in which the real power can freely flow in either direction between the ac terminals of the two inverters and each inverter can independently generate as well as absorb the reactive power at its own ac output terminal. Thus the shunt branch is required for compensate (from the system for any real power drawn/supplied by the series branch and the losses. when the power balance is not maintained, at that situation the capacitor cannot remain at a constant voltage.

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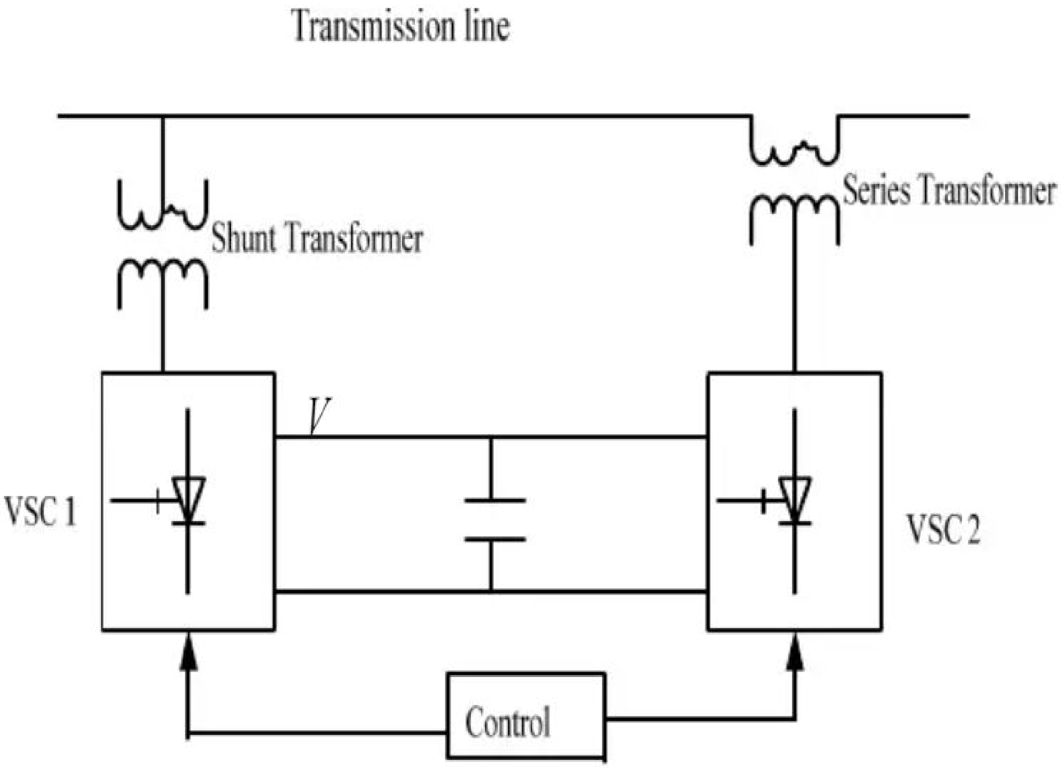

Fig. The Schematic diagram of UPFC

The power of the dc link is converted back to ac and coupled to the transmission line via a shunt-connected transformer. If reactive power is required then inverter 1 can also generate or absorb controllable reactive power. It is also important to note that whereas there is a closed "direct" path for the real power negotiated by the action of series voltage injection through Inverters 1 and 2 back to the line, corresponding the reactive power exchanged is supplied or absorbed locally by Inverter 2 and therefore the reactive power does not flow through the line. The Unified Power Flow Controller from the stand point of conventional power transmission based on reactive series compensation, shunt compensation, and phase shifting, the UPFC is the only device which can fulfil all these functions and thereby meet multiple control objectives by adding the injected voltage V, with appropriate amplitude and phase angle, to the terminal voltage V Using phasor representation.

Result: To observe the steady state performance of the UPFC in the power, three standard study systems are taken.

Bus System:

Base MVA=100;

Xs=0.025;

Total active power loss without UPFC=19.114MW;

Total reactive power loss without UPFC= 36.091MVA

After incorporating UPFC in the system the active and reactive power losses are given in table 2.When UPFC is incorporated in between two buses and for different value of ‘r’ and‘‘♈’ =120° the variation of active and reactive power losses are shown. From the table we observed that when UPFC is incorporated in the system the active and reactive power loss in the transmission line has reduced.

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Table: Active & reactive power losses for different value of 'r' and 'ϒ' in various buses.

When r=0.01 &$\gamma=120°$			When r=0.04 &$\gamma=120°$			When r=0.06&$\gamma=120°$		
Line	P_{loss}	Q_{loss}	Line	P_{loss}	Q_{loss}	Line	P_{loss}	Q_{loss}
6-7	19.034	35.051	6-7	18.902	31.740	6-7	18.99	31.688
3-4	19.076	35.954	3-4	18.834	33.801	3-4	18.715	32.65
4-6	19.108	36.068	4-6	19.111	36.079	4-6	19.00	34.932
12-14	19.116	36.101	12-14	19.112	36.081	12-14	18.898	34.367
12-15	19.114	36.093	12-15	19.119	36.120	12-15	19.102	36.05
12-16	19.081	35.908	12-16	N.C	N.C	12-16	N.C	N.C
14-15	19.046	35.742	14-15	210.836	647.015	14-15	N.C	N.C
16-17	19.059	35.829	16-17	203.055	1006.643	16-17	N.C	N.C

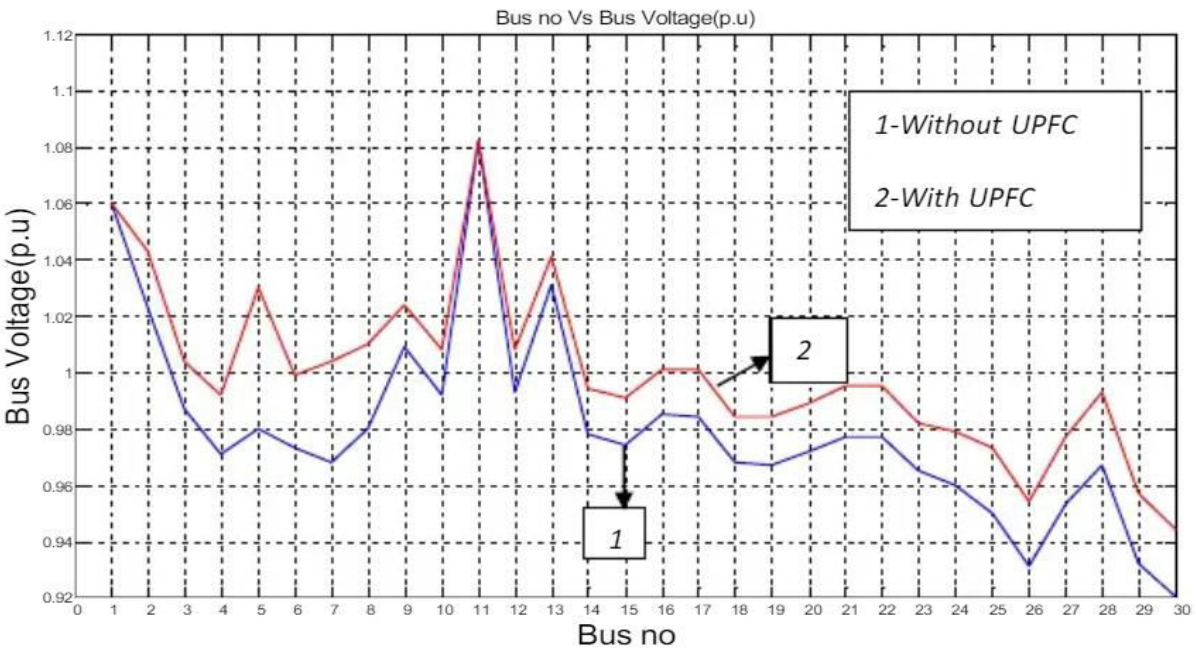

Fig. Bus voltage increase after incorporate UPFC in between buses 10-17

III. CONCLUSION

In this study, A MATLAB program has executed to incorporate the steady-state mathematical model of UPFC in the conventional NR power flow algorithm. The steady state effect of UPFC has shown in different system. It is shown that when UPFC is incorporated in between two buses in the system, for different value of 'r' and'∟' the active and reactive power loses are reduced. It is also shown that not only the power losses are reduced, the voltage profile of the every buses also improved after incorporate UPFC.

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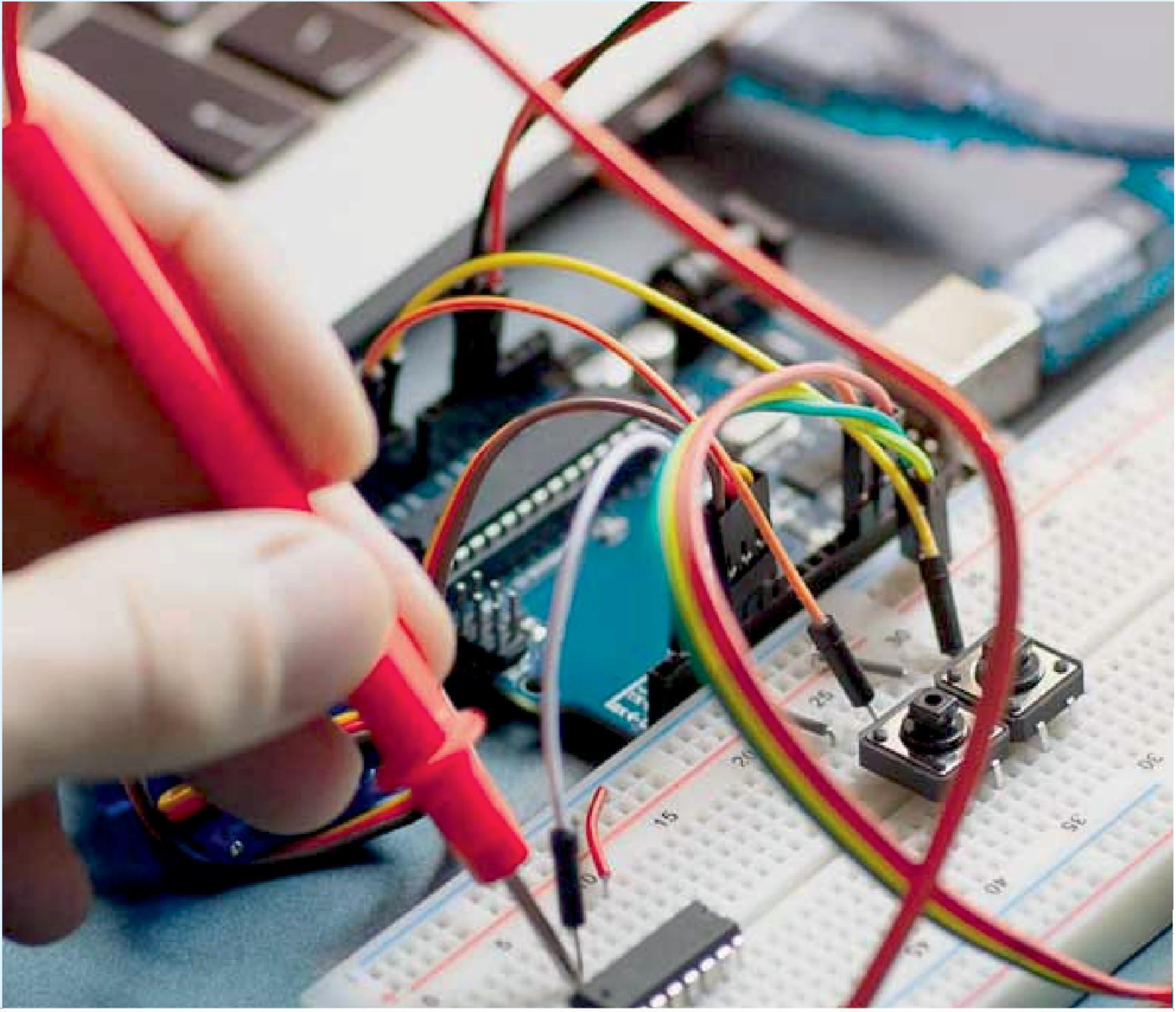

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