

Modulation and Control of Transformer less UPFC for Interconnecting Synchronous AC Grids

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Abstract:- In this paper, Modulation and control of transformer less unified power flow controller is presented. As is well known the traditional UPFC that exists two back-to-back inverters bulky and more complicated zig-zag transformer are completely eliminated. Now a day's FACTS devices are used to control the flow of power to increase the transmission capacity and to improve the stability of the power system. One of the most commonly used FACTS devices is Unified power flow controller (UPFC). It is well that UPFC (Unified Power flow controllers) are the most versatile FACTS device that can be used to active power flow and reactive power flow control between synchronous grids. The convention UPFC that consist two back-to-back inverters are connecting with series and shunt transformers used for real power and reactive power exchange between grids to UPFC. In Transformer less new FACTS device are used to overcome the problem of convention UPFC such as the bulky, large size, zig-zag transformer, having slow dynamic response, isolation. Although the new transformer less UPFC to remove series and shunt transformers to achieve desired voltage. In case of Transformer we use inductor and capacitor combination series and shunt with H Bridge power MOSFET Inverters. UPFC several advantages over the traditional technology ,such as Transformer less ,light weight, high efficiency, low cost and fast dynamic response.

Keywords— Flexible AC Transmission System (FACTS), PWM (Plus width modulation), UPFC, Transformer less UPFC, Power flow control, LC Coupler.)

I. INTRODUCTION

The concept of unified power flow control is that injects voltage of variable magnitude and phase angle. This provides control of power system parameters, such as terminal voltage, line impedance and phase angle, thereby providing necessary real and reactive power flow control [1-2]. UPFC is a combination of STATCOM and SSSC, which are coupled via a common DC link [3], to allow bi-directional flow of real power between the series output terminals of the SSSC and shunt output terminals of STATCOM [4], and are controlled to provide concurrent real and reactive series line compensation without an external electric energy source [5-6].

UPFC is the most comprehensive multivariable Flexible AC Transmission system (FACTS) controller [7-9], UPFC is one of the FACTS devices, which can control power system parameters, such as terminal voltage, line impedance and

phase angle [10]. Therefore it can be used not only for power flow control but also for power system stabilizing control UPFC capable of generating/absorbing both real and reactive power UPFC are capable of directing real and reactive power flow through a designated route [11]. Nowadays FACTS devices can be used to control the power flow and enhance system stability [12]. They enable a line to carry power closer to its thermal rating. The salient features of a FACTS device are its multiple control functions, such as power flow control, voltage control, transient stability enhancement and oscillation damping. Voltage sag compensation is necessary for secure system operation. A well designed FACTS Controller can not only increase the transmission capability but also improves the power system stability. UPFC is the most comprehensive multi variable flexible AC transmission systems controller (Menniti *et. Al.*2001 and Sen and Stacey 1999) [13].

II. TRANSFORMER LESS UPFC

Fig.1 shows transformer less UPFC which consist with the help of CMI cascade multilevel inverter concept we used power MOSFET as inverter function Combination of series inductor and parallel capacitor to generate high voltage level. Coupling inductor is in between series and shunt combination of inductor and capacitor. Each phase having own dc source and each phase control with help of PWM (Pulse width Modulation) pulse width modulation signal given to the POWER MOSFET with modified signal.

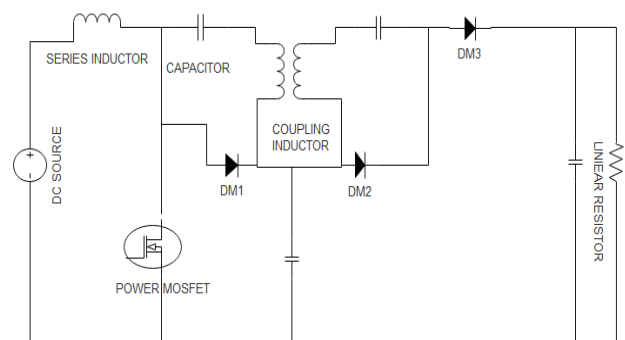


Fig.1. LC coupling inverter of transformer less Single phase UPFC

Each phase having own phase delay to maintain in transformer less UPFC with phase shifting between initial

state and final state the control phase shift we also control voltage , current, real and reactive power with help of phase angel. The voltage control to the Vdg of power MOSFET used in each single phase control. Inductor and capacitor are connected in series and parallel are connecting with coupling inductor. Inductor is use in circuit for over current absorption inductor used for current controlling device and over power absorb. Initial inductor used for backup current flow through the coupling inductor protection. Capacitors are uses for generation of voltage, coupling inductor having same ratio to transfer real and reactive power of series and shunt connection. Negative current absorption we the help of absorption diodes also these diodes are use compensation diode and in phase diodes only.

A. Transformer less UPFC Operating principle

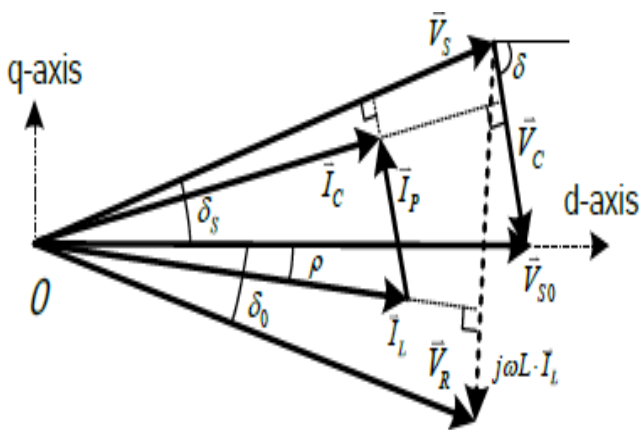


Fig.2. phasor diagram of transformer less UPFC

Fig.2 show a phase diagram example of the transformer less UPFC where V_{s0} and V_{r0} are the sending and receiving end voltages respectively. In transformer less UPFC generated voltage V_c for obtaining new sending end voltage V_s which in turn controls active and reactive power flows over the transmission line. Active power P and reactive power Q transmitted over the line with the UPFC can expressed Where δ_0 is the original phase angle difference between the sending end voltage V_{s0} and V_{r0} . The active power P_0 and reactive power Q_0 over the uncompensated system (without the UPFC) are:

$$P_0 = \frac{V_{s0} V_R \sin \delta_0}{X}$$

$$Q_0 = \frac{V_{s0} V_R \sin \delta_0}{X}$$

The active and reactive power P_c and Q_c of UPFC

$$P_c = \frac{V_c V_R \sin(\delta_0 + \delta)}{X}$$

$$Q_c = - \frac{V_c V_R \cos(\delta_0 - \delta)}{X}$$

Because both amplitude V_c and phase angle δ of the UPFC injected voltage phasor V_c can be any values command the new UPFC provide a full controllable range for both active and reactive power P_c and Q_c which are advantage independent of the original sending end voltage and phase angle therefore the theory proves that the new transformer less UPFC has the same functionally as the conventional UPFC.

III. MATLAB SIMULATION OF THREE PHASE TRANSFORMER LESS UPFC

Fig fig.3 shows UPFC is used to control the power flow in a 500 kV /230 kV transmission systems. The system, connected in a loop configuration, consists essentially of five buses (B1 to B5) interconnected through transmission lines (L1, L2, L3). Two power plants located on the 230-kV system generate a total of 1500 MW which is transmitted to a 500-kV 15000-MVA equivalent and to a 200-MW load connected at bus B3. The plant models include a speed regulator, an excitation system as well as a power system stabilizer (PSS). In normal operation, most of the 1200-MW generation capacity of power plant.

Using the load flow option of the powergui block, the model has been initialized with plants 1 and 2 generating respectively 500 MW and 1000 MW and the UPFC Out of service (Bypass breaker closed). The resulting power flow obtained at buses B1 to B5 is indicated by red numbers on the circuit diagram. The UPFC Located at the right end of line L2 is used to control the active and reactive powers at the 500-kV bus B3, as well as the voltage at bus B UPFC. It consists of a phasor model of two 100-MVA, MOSFET based, converters (one connected in shunt and one connected in series and both interconnected through a DC bus on the DC side and to the AC power system, through coupling reactors). Parameters of the UPFC Power components are given series converter can inject a maximum of 10% of nominal line-to-ground voltage (28.87 kV) in series with line L2. The blue numbers on the diagram show the power flow with the UPFC in service and controlling the B3 active and reactive powers respectively at 300 MW and -93 Mvar.

UPFC used for transmission line to measure Active and reactive power. There are two components UPFC Measurement and VPQ lines measurement in which Active power measurement and reactive power measurement as well as active power compensation and reactive power compensation in transmission line. We set in UPFC parameter block Reference values of $P_{Q_{reference}}$ and V_{dq} initially in three phase voltage UPFC voltage as reference values. To control magnitude and phase angle compensate power to the grid line.

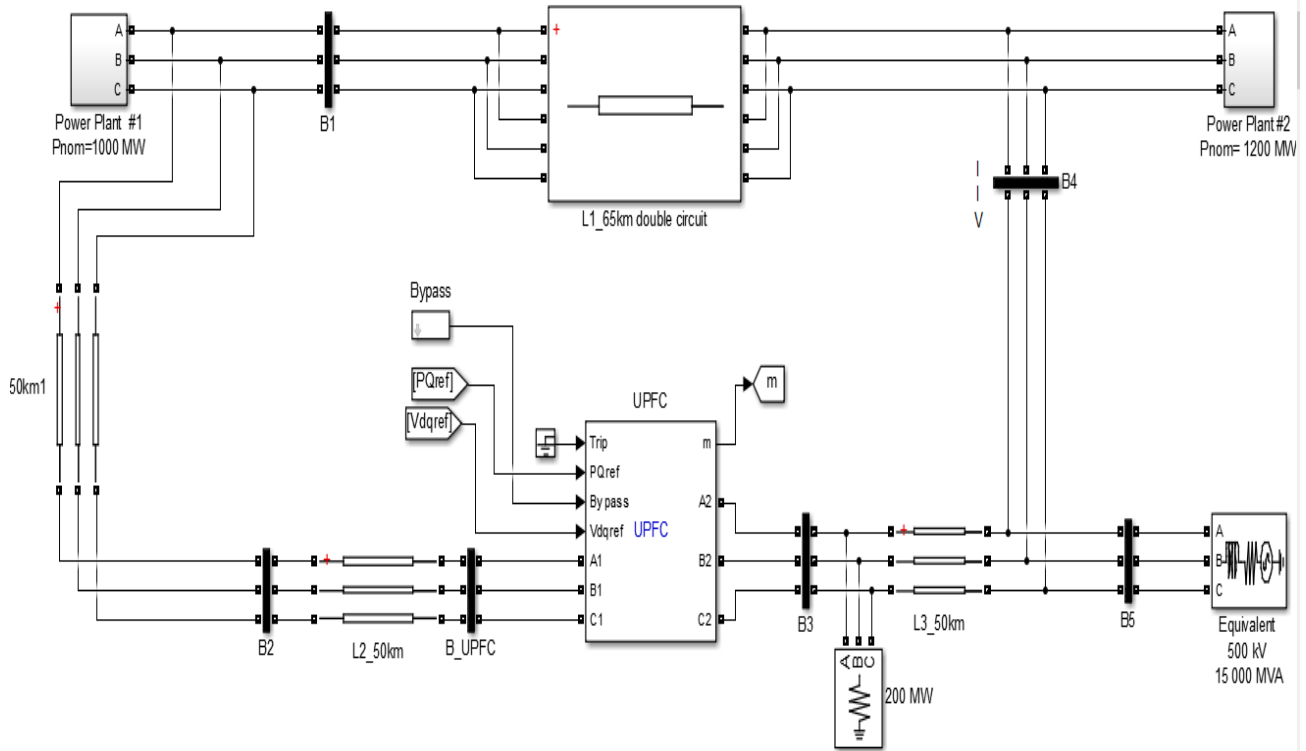


Fig.3. Three phase transformer less UPFC MATLAB Simulation

A. Power control with the Transformer less UPFC

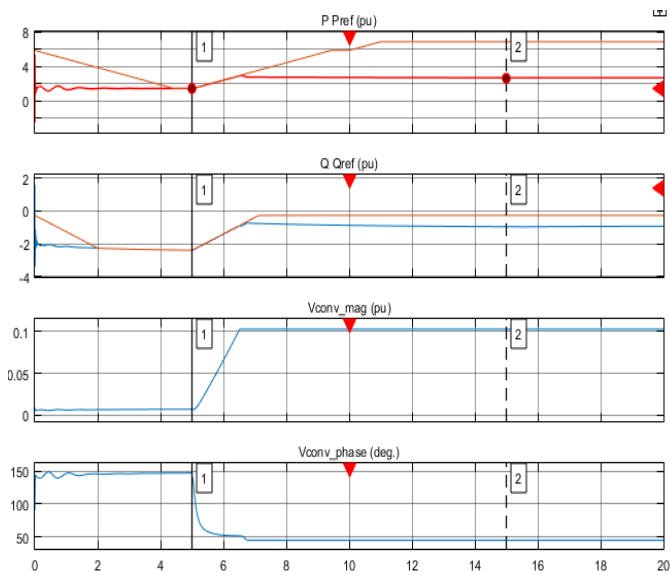


Fig.4. UPFC controllable parameters

$P_{Pref}(pu)$, $Q_{Qref}(pu)$, $V_{conv_mag}(pu)$ and $V_{conv_phase}(deg)$.

The UPFC reference active and reactive powers are set in the magenta blocks labeled “Pref(pu)” and “Qref(pu)”. Initially the Bypass breaker is closed and the resulting natural power flow at bus B3 is 268 MW and -93 Mvar. The Pref block is programmed with an initial active power of 5.87 pu corresponding to the natural flow. Then, at t=10s, Pref is increased by 1 pu (100 MW), from 5.87 pu to 6.87 pu, while Qref is kept constant at -93 pu. Run the simulation and look on the UPFC scope how P and Q measured at bus B3 follow the reference values shown in fig.4.

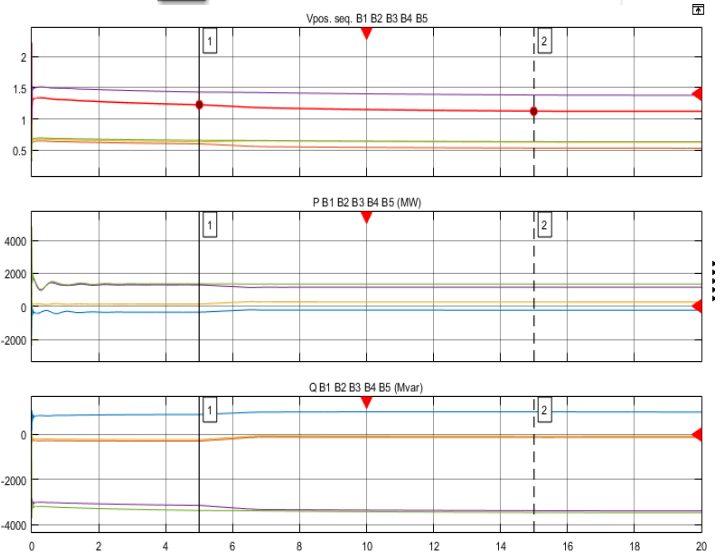


Fig.5. VPQ lines measurements

At t=5 s, when the Bypass breaker is opened the natural power is diverted from the Bypass breaker to the UPFC series branch without noticeable transient. At t=10 s, the power increases at a rate of 1 pu/s. It takes one second for the power to increase to 900 MW. This 100 MW increase of active power at bus B3 is achieved by injecting a series voltage of 0.089 pu. This results in an approximate 100 MW decrease in the active power flowing from 268 MW to 1400 MW, which now carries an acceptable load. See the variations of active powers at buses B1 to B5 on the “VPQ Lines” scope shown in fig.5.

B. UPFC P-Q controllable region

Now Show Control parameters (series converter). Select “Mode of operation= Manual Voltage injection”. In this control mode the voltage generated by the series inverter is controlled by two external signals V_{dq} multiplexed at the

“ V_{dqref} ” input and generated in the V_{dqref} , magenta block. For the first five seconds the Bypass breaker stays closed, so that the PQ trajectory stays at the (-93Mvar, 268 MW) point. Then when the breaker opens, the magnitude of the injected series voltage is ramped, from 0.0094 to 0.1 pu. At 10 s, the angle of the injected voltage starts varying at a rate of 45 deg./s.

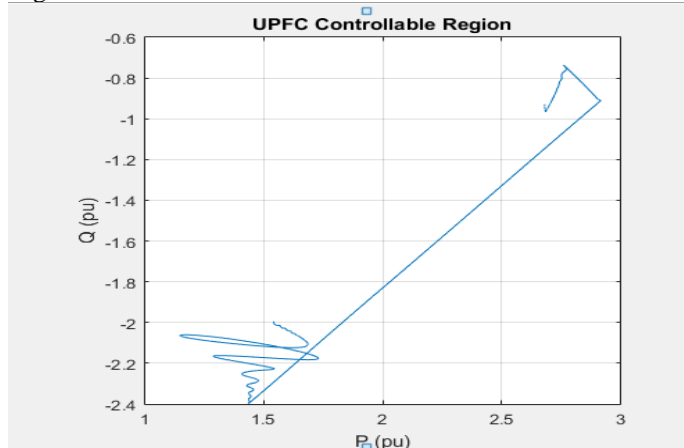


Fig.6. UPFC Controllable region

Initially $P_{Pref}(pu)$ set a particular pu values as 4-8pu values when UPFC connect in circuit the value of power flow will changes and to control active and reactive power demand without change in frequency. Compensation of active and reactive power in Transmission line about 10% of system voltage. To control voltage magnitude $V_{conv_mag}(pu)$ ($0 \leq 0.05 \leq 0.1$) and $V_{conv_phase}(deg)$ ($0 \leq \delta \leq 45$).

Table.1. VPQ Measurements

Bus	Active Power (MW)	Reactive Power (MW)
B1	-217.8	978.1
B2	270.6	-137.7
B3	268.1	-93.01
B4	1168	-3389
B5	1358	-3466

Run the simulation and look on the UPFC scope the P and Q signals that vary according to the changing phase of the injected voltage. At the end of the simulation, double-click on the blue block located at the bottom right of the model. The trajectory of the UPFC reactive power as function of its active power, measured at bus B3 will be displayed. Active and reactive power controllable region shown in fig.6.

IV. CONCLUSION

The transformer less UPFC can realize the same function as convention UPFC without using transformer. It is expected that the transformer less UPFC Will have enormous technological and economic impacts on controlling the routing of energy over the existing power grid. Furthermore, the enabling technology of modularity and scalability makes it easy installation anywhere in the existing grid. UPFC

damps the oscillations, improves reliability and proven to be cost effective. In future, Generalized Unified Power Flow Controller (GUPFC) will significantly extend the voltage and power flow capability, and offers a great potential in solving many of the problems facing the electric utilities these applications of innovative transformer less unified power controller (UPFC) interconnecting two synchronous AC grids.

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