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Improvement of Power Quality in Multibus System by Interphase Power Controller

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Abstract: ***Interphase Power Controller (IPC) is new concept of controlling power flow Within AC network. Interphase Power Controller provide a solution for high short Situations .The application is based on the series connection of impedances between Different phases of the two (synchronous) sub networks to be interconnected. Interphase Power Controller provides passive solutions for normal and contingency conditions. Interphase power controller control the power flow and act as fault limiter. Interphase Power Controller is equipped with the Phase Shifting Transformer (PST) which Control the output power. The Interphase Power Controller can provide reactive power Support for the adjustment of voltages. The purpose of this technology is to facilitate the Supply of loads in flexible and rapid fashion, while providing optimal management of Electrical networks. Here, the basic theory and operating characteristics of the Interphase Power Controller. The Interphase power controller system will be modelled and simulation will be carried out in MATLAB.***

Keywords: Flexible alternating current transmission system (FACTS), Interphase Power Controller, Phase Angle Regulator, MATLAB, Phase Shifting Transformer (PST), TC-IPC, IPC, SSC,

1. Introduction

The Interphase Power Controller (IPC) is an emerging technology developed for the management of power flows within ac networks. Power flow control is becoming major issue in planning and operation of power system transmission network. In flexible AC transmission system phase shifting transformer, limiting reactor and series compensation may not be satisfactory. . It is a series-connected controller involving of two impedances per phase, one inductive and one capacitive, exposed to separately phase-shifted voltages one of the innovations of the IPC is its essential constant power characteristic gained in a passive manner. [1]

The IPC does not have a fixed conformation, being more a technology for creating different and pioneering power flow controllers with various characteristics and configurations. Because of the diverse characteristics these IPC applications can have, they have their own precise name. Conventional phase-shifting transformers (PST) are the first noticeable choice, but the IPC characteristics can also be obtained using predictable transformers. Due to the removal of the phase shift in one of the two branches of the IPC diminishes the amount of equipment and transfers the control characteristics a more satisfactory position in the power-angle plane results in optimization. [2]

The IPC guarantees reliable and expectable operation under normal as well as incident conditions. In addition, it is shown that in the case of contingencies, the IPC can provide reactive power support for the modification of voltages. IPC deals with the fast control of voltage and power at different points in the network in order to maintain stability .Also with the daily and seasonal load variation. [3]

2. IPC Modeling

The IPC is not new equipment but it is not well known among power engineers. The working mechanisms of some types of IPCs, i.e., flexibility and rapidity of reaction put this technology in the category of FACTS devices. A generic IPC model consists of two branches, one branch with an inductor in series with PST and the other branch with a capacitor in series with the PST. For while controlling power flow under normal and post contingency conditions and for SC reduction, the reactance of the inductor and capacitor are selected to be equal so as to impose an infinite impedance to the short circuit current (SCC) only. [4]

The basic IPC is a series connected device comprising two susceptances, one inductive and the other capacitive, subjected to properly phase-shifted voltages. The IPC controls the power flow in a link connecting two synchronous networks in a passive manner while providing short circuit isolation and voltage decoupling between them. [1]

The physical components B1(inductive)andB2(capacitive). IPC's can be assembled in types according to the mean used to provide the phase shifted voltages. In a first type, the phase shifts are achieved by a cross connection between phases, as in the IPC240 described in [6], where plus orminus120'phase shifts are used. In a second category, an inverting transformer as in the IPC 120 [6] or any connection of a transformer having Y or A secondary (ies) is used to provide the proper phase shifts. In this type, the transformer is rated for the full transferred power.[1]

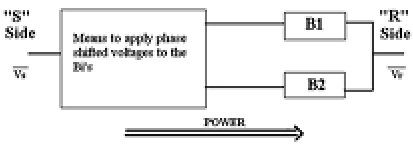

Figure 1: Single line diagram of principle IPC

3. Thyristor Controlled Interphe Powercontroller (TC-IPC)

The TC-IPC can be very effective to damp power systems oscillations. IPC system is shown in the figure. [1]

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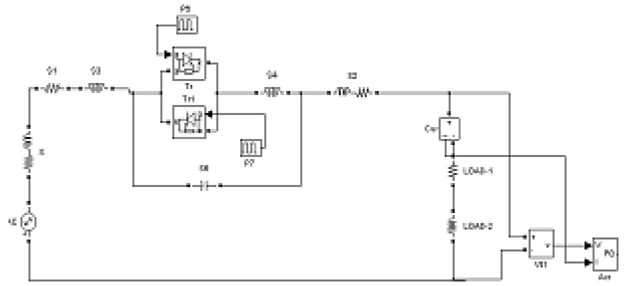

Figure 2: Interphase Power Controller with IPC.[1]

3.1 Operating Principle

The IPC technology is very flexible at the design stage and applications are possible. It has the intrinsic fault limitation ability of the tuned IPC that is the main feature. Figure 4 presents a topology adapted for operating the substation of Figure 2. Fig 4 .this TC-IPC can be conceptually represented by two parallel thyristors series with the capacitor. It is the collective installation of these two branches which provides the specific properties that make the TC-IPC technology typical. It consists of an autotransformer whose low voltage side is connected to a reactor, a capacitor series transformer [1].

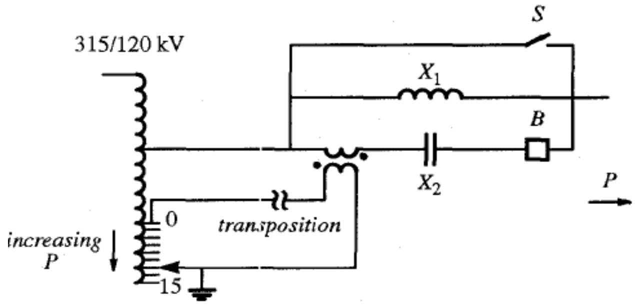

Figure 3: Equivalent Circuit

The phase shift Ψ in series with capacitor C is obtained by injecting a voltage phase-shifted Ψ by 120” with the series transformer. . Conferring to the IPC Theory [5,6], this phase-shift adjustment controls the power forced by the IPC into the load: the larger the angle yr, the higher the power flow. Reactances XI and X2 are almost conjugated impedances (tuned at 60 Hz) which means that for Ψ = 00 they form a high-impedance tuned circuit that delivers almost no current to the load .By controlling the amplitude of the injected voltage with the tap changer, the phase shift Ψ varies between 00 and a maximum value which in the present case is set to 200. However, when yf = 20", the reactances are such that the IPC carries its share of the nominal load current [1].

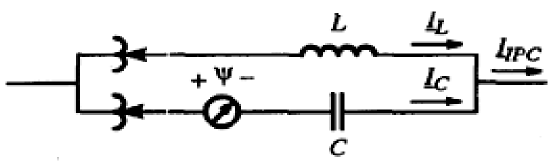

Figure 4: IPC for Substation Upgrading

To insure redundancy in the substation, the IPC has the same rated throughput as the other transformers. Depending upon the mode of operation, In transformer mode it performs voltage regulation, just like the other transformers whereas in the IPC mode, the tap changer is positioned to adjust the output current to the value of the other transformers. [1].

The simulations are executed for TC-IPC with fault occurred one out of three phases at Bus 6 and fault current limits by TC-IPC results are obtained by using Matlab Simulink. The simulation results which are obtained for TC-IPC placed in 25KV subsystem using variable load condition. Fig 5 shows IEEE 30 bus system without IPC (Bus 6) . Figure 8 shows that voltages in phase a, b, c with fault. Figure 9(b) shows that current over the phases after fault arisen. Figure 9(c) illustrates that inserted voltage by IPC, which compare stability marks with the PSTs only and with the TC-IPC involved. In case, the flow in the line is 25KV / 100 MVA. This slightly stable case is considered as tile stability limit. [1]

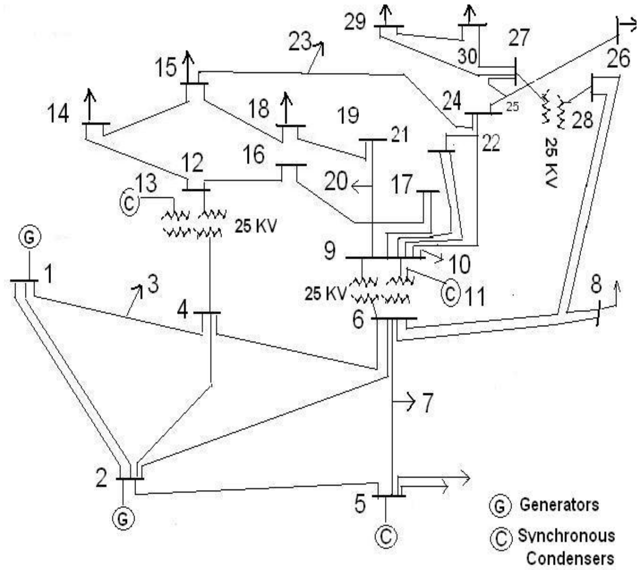

Figure 5: IEEE 30 Bus System Without IPC

Simulation results indicate the robustness of this Flexible AC transmission system (FACTS) controller to the variation of system operating too. The Real and Reactive Power is shown in Figure 6. (a) and (b).

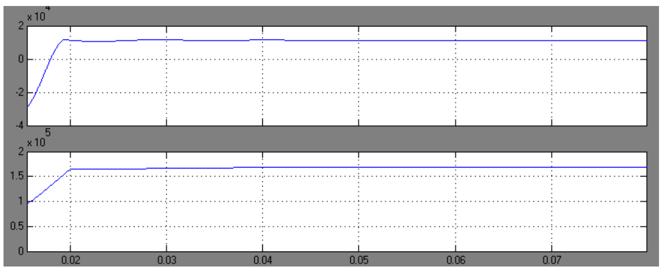

Figure 6(a): Real and Reactive Power at Alpha =144 Degree

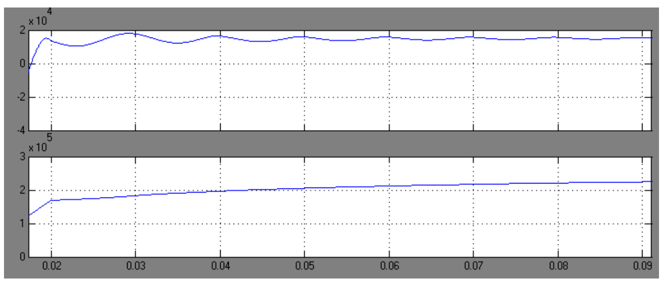

Figure 6(b): -Real and Reactive Power at Alpha =153 Degree

By varying "alpha" the real and Reactive power could be controlled in thyristor controlled IPC. [1]

Eight bus systems with TC-IPC is shown in figure7. The reactive power at bus 7, 1, 3 is shown in figure 8(a), (b), (c) [2].

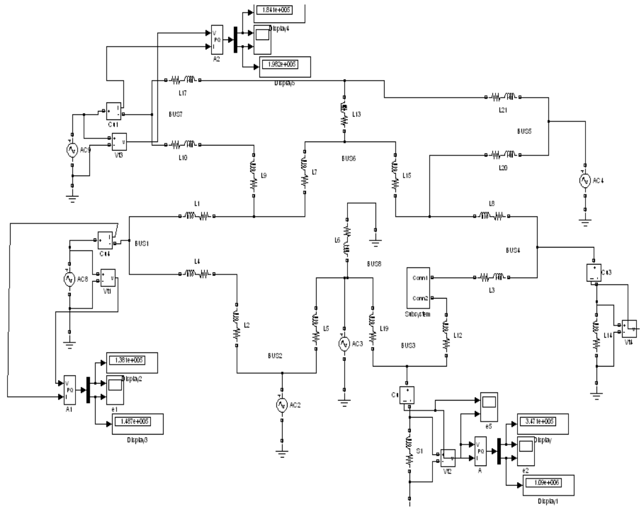

Figure 7: Bus System with TCIPC

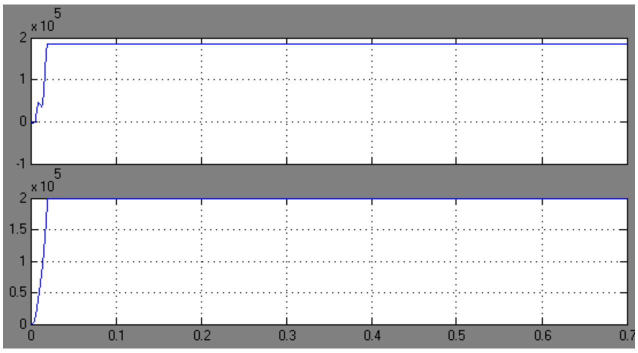

Figure 8(a): Real and reactive power across bus-7

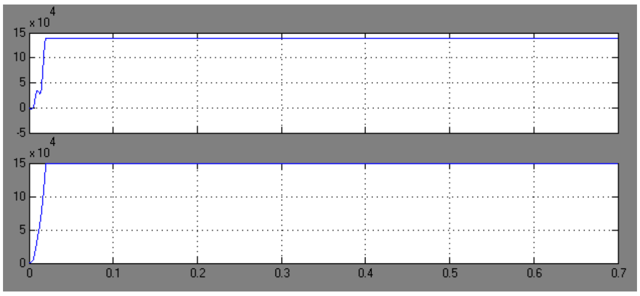

Figure 8(b): Real and reactive power across bus-1

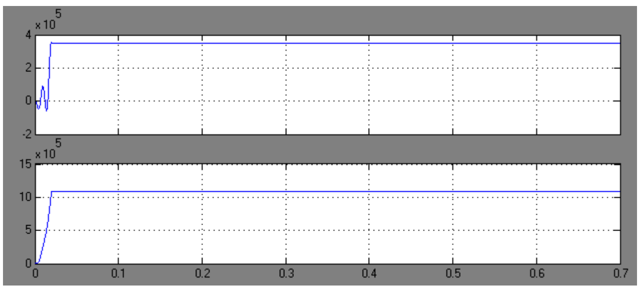

Figure 8(c): Real and reactive power across bus-3

Figure 5 illustrates that IEEE 30 bus system without IPC and simulations performed for IEEE 30 Bus system shown in Figure 7 with IPC. Thyristor controlled Interphase power control has coupled. Fig 9(a) and (b) displays that voltage through phases when fault occurs and current in all phases when fault arises current reduced to 70% of definite current. Figure 9(c) illustrations that current limit through the phases. In fig .9(d) shows that fault current limit by connecting TC-IPC through the series to the substation lines through the three transformers. After adding TC-IPC to the line current is stabilized in all phases Fig 9(e) explains the voltage stability in all phases by TC-IPC when fault arises.[1].

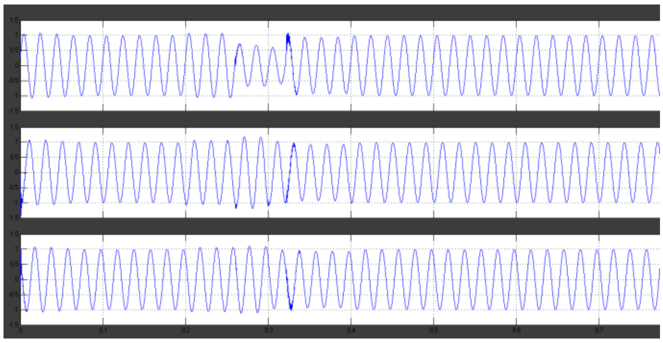

Figure 9(a): Voltage through phases when fault inserted at 0.26

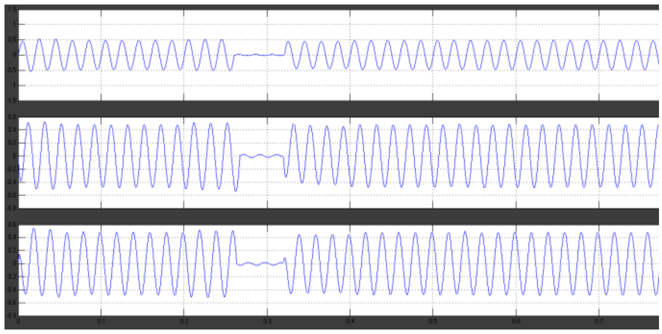

Figure 9(b): Current through the phase when fault occurs 0.26 secs

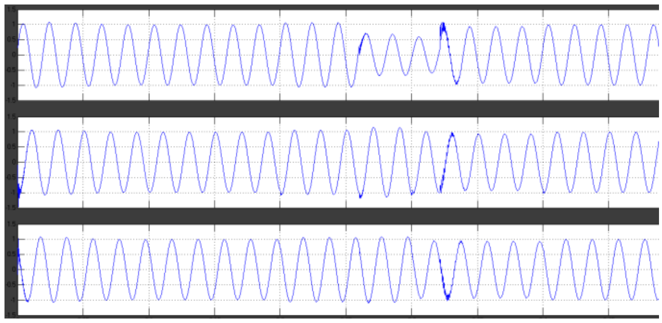

Figure 9(c): Voltage through phases IPC injected voltage

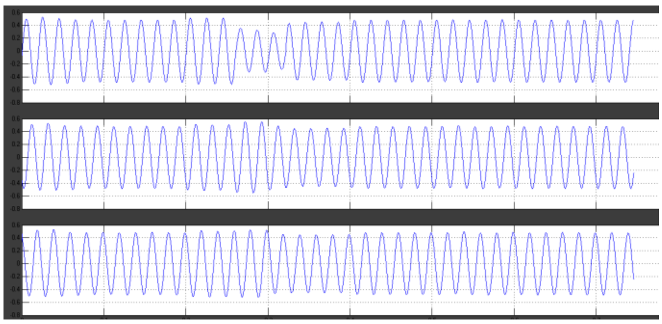

Figure 9(d): Current limit through the phases after fault occurs

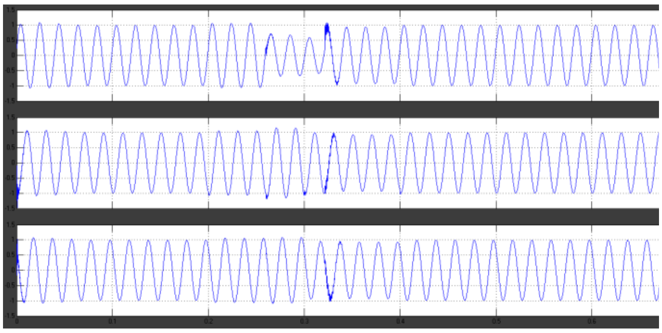

Figure 9(e): Load voltage after limits the fault

4. Equations

Figure 10 shows the tuned IPC in series with a transmission line connecting two power systems. Voltage and current equations modeling the behavior of the IPC are given as follows [5]:

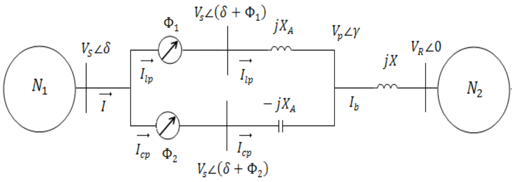

Figure 10: Tuned IPC in series with transmission line connecting Two power system

$$I_b = \frac{V_P\angle\gamma - V_R\angle 0}{jX} \tag{1}$$

$$I_b = I_l + I_c = \frac{V_S\angle(\delta+\psi_1) - V_P\angle\gamma}{jX_A} + \frac{V_S\angle(\delta+\psi_2) - V_P\angle\gamma}{-jX_A} \tag{2}$$

$$V_P = \frac{X}{X_A}\left[V_S\angle(\delta+\psi_1) - V_S\angle(\delta+\psi_2)\right] + V_R\angle 0 \tag{3}$$

$$I_b = \frac{V_S\angle(\delta+\psi_1-90^\circ) - V_S\angle(\delta+\psi_2-90^\circ)}{X_A} \tag{4}$$

$$I_b = -\frac{V_S\angle\delta}{X_{IPC}\angle\psi_{IPC}} \tag{5}$$

where:

$$\psi_{IPC} = \frac{\psi_1+\psi_2}{2} \tag{6}$$

$$X_{IPC} = \frac{X_A}{2\sin(\frac{\psi_1-\psi_2}{2})} \tag{7}$$

we have:

$$S_R = V_R I_R^* = P_R + jQ_R = \frac{V_S V_R\angle(90^\circ-\delta-\psi_1)}{X_A} - \frac{V_S V_R\angle(90^\circ-\delta-\psi_2)}{X_A} \tag{8}$$

then:

$$P_R = \frac{2V_S V_R}{X_A}\cos(\delta+\frac{\psi_1+\psi_2}{2})\sin(\frac{\psi_1-\psi_2}{2}) \tag{9}$$

$$P_R = \frac{V_S V_R}{X_{IPC}}\cos(\delta+\psi_{IPC}) \tag{10}$$

and

$$Q_R = -\frac{2V_S V_R}{X_A}\sin(\delta+\frac{\psi_1+\psi_2}{2})\sin(\frac{\psi_1-\psi_2}{2}) \tag{11}$$

$$Q_R = -\frac{V_S V_R}{X_{IPC}}\sin(\delta+\psi_{IPC}) \tag{12}$$

In a special case, if $\Psi_1 = -\Psi_2 = \Psi$ then the above equations e simplified as follows:

$$I_b = -\frac{2V_S\sin(\psi)\angle\delta}{X_A} \tag{13}$$

$$P_R = \frac{2V_S V_R}{X_A}\cos(\delta)\sin(\psi) \tag{14}$$

$$Q_R = -\frac{2V_S V_R}{X_A}\sin(\delta)\sin(\psi) \tag{15}$$

According to these equations for current, active and reactive Transmitted power, they can be controlled by adjusting Ψ in Phase shifting Transformer [5].

5. Other Recommendation

Thyristor Controlled interphase Controller can be very efficient than other type of IPC. Matlab can be used for the simulation purpose in multi-bus system to improve the dynamic performance of the system.

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