STUDY OF POWER SYSTEM STABILITY USING THYRISTOR CONTROLLED – INTERPHASE POWER CONTROLLER

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ABSTRACT: -Environmental, regulatory and economic constraints have restricted the growth of electric power transmission facilities, and the technologies to enlarge the levels of power transmission and enhance stability through existing transmission lines have become greatly needed. Many approaches have been proposed for solving the stability problems found in power system operations. Considering the diversity of both, the solutions and the problems, it is often difficult to identify the most suitable solution. The main purpose of this paper is to demonstrate the capability of IPC (Interphase Power Controller) as a mean for stability improvement in power systems. In this paper this device has been modeled. Based on this model it is demonstrated that the Thyristor Controlled Interphase Power Controller (TC-IPC) can be very effective to damp power system oscillations. Simulation results indicate the robustness of this Flexible AC Transmission System (FACTS) controller to the variation of system operating conditions too.

Key-Words: - Interphase Power Controller, FACTS, Power System Stability, Phillips-Heffron model

1.INTRODUCTION

The basic operating requirements of an AC power system are that the synchronous generators must remain in synchronism and the voltages must be kept close to their rated values. The capability of a power system to meet these requirements in the face of possible disturbance is characterized by its transient (or first swing), dynamic (or power oscillation), and voltage stability. Transient stability may be defined as the ability of an electric power system to remain in synchronism after being subjected to a major system disturbance (such as a short circuit). According to equal-area criteria transient stability of a power system is maintained if the accelerating area equals the decelerating area during the first rotor swing following the fault clearance.

To avoid stability problems a fast power flow control within the first swing of the generator is required. This can be achieved by different means, such as high performance excitation systems and high ceiling voltage [1], breaking resistors usage [2], superconducting magnetic energy storage systems [3] and etc.

The recent availability of solid-state power switching devices with controlled turn off capability has made possible further advances in power conversion and control, leading to the development of a new generation of FACTS devices. FACTS (Flexible AC Transmission Systems) devices, as reported in numerous references [4], are first of all, effective tools for dynamic power flow control. On the other hand power flow is clearly related to a system's transient stability problems. As a result FACTS devices, such as UPFC (Unified Power Flow Controller)[5], SPS (Static Phase Shifting Transformers) [6], CSC (Controlled Series Compensator) [7], are presented as an effective tool to mitigate transient stability problems in electric power systems. These devices are power electronic based controllers, which can influence transmission system voltages, currents, impedances and/or phase angle rapidly. Thus FACTS devices (or controllers) can improve both the security and flexibility of a power system.

This paper presents the capability of IPC (Interphase Power Controller) [8] as a mean for power stability improvement. Concerning this matter, it is necessary to replace the conventional PST (Phase Shifting Transformer) with the static PST (SPS). The result of these changes is a new FACTS device, which is referenced to it as Thyristor Controlled IPC or TC-IPC.

2.IPC and TC-IPC Steady State Model

The generic construction of an Interphase Power Controller (IPC), shown in Fig.1, is a series–connected power flow controller consisting of an inductive and a capacitive impedance in each phase, which are subjected to individually phase–shifted voltages [8].

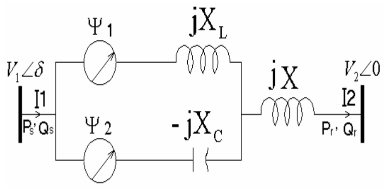

Fig. 1: The Single Line Diagram of the Generic IPC

IPCs should solve both pre- and post-contingency operating problems, only assisted by means of mechanical switching devices. But according to desired application the IPC can take many forms, e.g. inductive and capacitive impedances can be replaced by TCR (Thyristor Controlled Reactor) or TCSC (Thyristor Controlled Series Capacitor), respectively. This paper suggests the replacement of the phase shifting transformers with the static phase shifters. The resulted device is named TC-IPC (Thyristor Controlled IPC).

The following assumptions have been considered for the modeling of the TC-IPC:

- The TC-IPC is lossless,
- The static phase shifters are phase angle regulators and the phase shifts (i.e. ψ_1 and ψ_2) are the only control variables,
- The phase shifts can be changed rapidly during the fault conditions
- The TC-IPC is a tuned type, i.e. $X_L = X_C$ in Fig.1

It is shown in [8] that for the IPC the following equations can be derived. The same equations are valid for TC-IPC too.

$$P_S = P_r = P = \frac{X_L V_1 V_2 \mathrm{Sin}(\delta+\psi_2) - X_C V_1 V_2 \mathrm{Sin}(\delta+\psi_1)}{X(X_L - X_C) - X_L X_C} \quad (1)$$

$$Q_S = \frac{V_1^2 (X_L - X_C + 4X\mathrm{Sin}^2(\frac{\varphi_1-\varphi_2}{2})) - V_1 V_2 (X_L \mathrm{Cos}(\delta+\varphi_2) - X_C \mathrm{Cos}(\delta+\varphi_1))}{X(X_L - X_C) - X_L X_C} \quad (2)$$

$$Q_r = \frac{V_1 V_2 (X_L \mathrm{Cos}(\delta+\psi_2) - X_C \mathrm{Cos}(\delta+\psi_1)) - V_2^2 (X_L - X_C)}{X(X_L - X_C) - X_L X_C} \quad (3)$$

$$I_1 = \frac{V_1\angle(\delta-90)\times(X_L - X_C + 4X\mathrm{Sin}^2(\frac{\psi_1-\psi_2}{2})) + jV_2(X_L\angle-\varphi_2 - X_C\angle-\psi_1)}{X(X_L - X_C) - X_L X_C} \quad (4\text{-a})$$

$$I_2 = \frac{V_1\angle(\delta-90)\times(X_L\angle\psi_2 - X_C\angle\psi_1) + jV_2(X_L - X_C)}{X(X_L - X_C) - X_L X_C} \quad (4\text{-b})$$

According to the Eq.1 and considering Fig.1, it is obvious that a short circuit fault at node 2 can decouple subsystems for all values of δ, ψ_1 and ψ_2, because in this case P_s and P_r are equal to zero.

Applying the assumption $X_L = X_C$ in the above mentioned equations, we will have:

$$P_S = P_r = P = \frac{V_1 V_2}{X_A}(\mathrm{Sin}(\delta+\psi_1) - \mathrm{Sin}(\delta+\psi_2)) \quad (5)$$

$$Q_S = \frac{-V_1 V_2}{X_A}(\mathrm{Cos}(\delta+\psi_1) - \mathrm{Cos}(\delta+\psi_2)) - \frac{4XV_1^2}{X_A^2}\mathrm{Sin}^2(\frac{\psi_1-\psi_2}{2}) \quad (6)$$

$$Q_r = \frac{V_1 V_2}{X_A}(\mathrm{Cos}(\delta+\psi_1) - \mathrm{Cos}(\delta+\psi_2)) \quad (7)$$

$$I_1 = \frac{2V_m \mathrm{Sin}(\frac{\psi_1-\psi_2}{2})}{X_A} e^{j(\delta_m - \frac{\psi_1+\psi_2}{2})} \quad (8\text{-a})$$

$$I_2 = \frac{2V_1 \mathrm{Sin}(\frac{\psi_1-\psi_2}{2})}{X_A} e^{j(\delta + \frac{\psi_1+\psi_2}{2})} \quad (8\text{-b})$$

Where $X_L = X_C = X_A$, V_m and δ_m are magnitude and phase angle of the voltage at node m.

According to Eq.8-a and Eq.8-b it can be seen that the TC-IPC can be presented by two voltage–dependent current sources (Fig. 2).

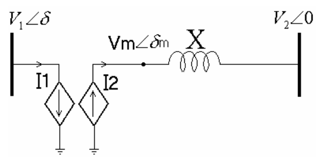

Fig. 2: Voltage–Dependent Current Source Model of IPC

Eq.5 and Eq.6 can present the $Q_S - \delta$, $Q_r - \delta$ and $P_e - \delta$ curves in Fig.3-a, Fig.3-b and Fig.4, respectively. In these figures, it is assumed that;

$X = 0.1$ p.u., $X_A = 0.4$ p.u., $\psi_1 = 10^\circ$, $\psi_2 = -15^\circ$, and $V_1 = V_2 = 1$ p.u.

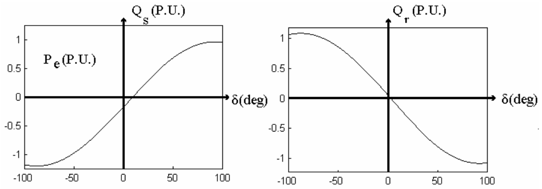

Fig. 3: Reactive Power Characteristic a: in Sending End b: in Receiving End

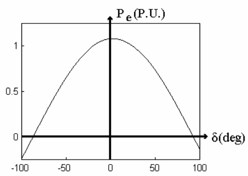

Fig. 4: Transferred Active Power Characteristic

Considering these equations it can be said that [6]:

- The active and generated/absorbed reactive transmitted powers can be controlled independently by controlling the TC-IPC parameters.
- Since the TC-IPC behaves as a voltage-dependent current source, it provides an AC link between two subnetworks and increases the transmission capacity with no corresponding increase in short-circuits levels and without transferring perturbations between two areas.
- The TC-IPC maintains the transmitted real power almost constant without any control actions or delays, because the control characteristic is inherent to the IPC.

3.EQUAL – AREA CRITERIA FOR TC – IPC

The equal area criterion has been used in this paper because:

- It is easy to understand,
- Two groups of coherent machines can be transformed to the one-machine infinite-bus system and
- It is possible to transform the transient stability of a multi-machine system to the one-machine infinite-bus system with time varying parameters, too.

Assume that the complete system of the one-machine infinite–bus is characterized by the P versus δ curve shown in Fig. 5 and it is operating at angle δ_0 to transmit power $P_e = P_m$ when a three phase fault occurs. During the fault, P_e decreases to zero while mechanical input power (P_m) remains substantially constant. As a result the transmission angle increase from δ_0 to δ_f at which the fault is cleared and the sending–end generator absorbs accelerating energy, represented by area A_1. The maximum critical angle reached at δ_m, where decelerating energy, represented by area A_2 must become equal to the area A_1.

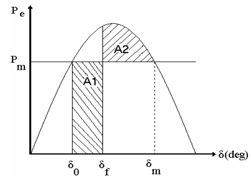

Fig. 5: Fault Effect on $P-\delta$ Curve

Now assume that the sending–end generator connected to the infinite–bus Via a TC-IPC. According to Eq.5, Fig. 6 shows that the mechanical power (P_m) intersects the $P-\delta$ curves at points S_1 and S_2. Considering a perturbation for these points, it is obvious that the point S_2, is unstable but the S_1 is an asymptotic stable point. In general it can be said that the steady state stability limit of this system is angle $-\frac{1}{2}(\psi_1+\psi_2)$ and the system has a stable operating point for the transmission angle lower than $-\frac{1}{2}(\psi_1+\psi_2)$.

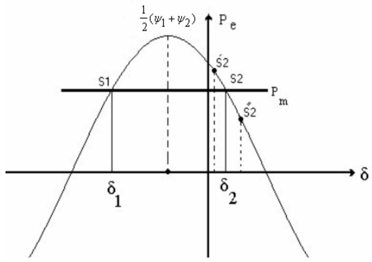

Fig. 6: The Effect of TC-IPC on the $P-\delta$ Curve

In the Fig. 7 the equal area criterion has been shown for this case, assuming a three-phase fault at the sending-end generator bus (TC-IPC receiving bus). It can be seen that the stability criterion is $A_2 \geq A_1$.

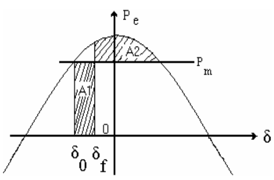

Fig. 7: Stability Criteria for a System (TC-IPC included)

As a result, the increment of the area A_2 means the improvement of the transient stability.
Fig. 8-a and Fig. 8-b show the possible increment methods; shift to the right and upward shifting of the $P-\delta$ curve, after fault clearing.

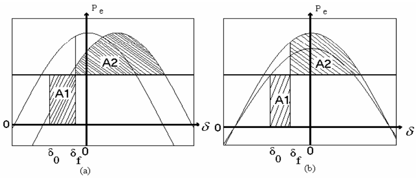

Fig. 8: A_2 Increment Methods a: Right Shift b: Upward Shift

4.Dynamic Model of TC-IPC

Fig.8 is a single machine infinite bus (SMIB) power system which has a TC-IPC as a FACTS controller.

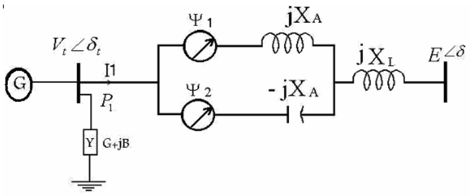

Fig.5: TC-IPC in SMIB power system

Using Eq.5 and Eq.8 and assumptions presented in the section 2, the following equations can be derived:

$$P_1 = \frac{2EV}{X_A} Sin(\frac{\psi_2 - \psi_1}{2}) Cos(\delta_t - \delta - \frac{\psi_1 + \psi_2}{2}) \quad (9)$$

$$I_1 = \frac{V_t\angle(\delta_t - \psi_1)}{j(X_A + X_L)} - \frac{V_t\angle(\delta_t - \psi_2)}{j(X_A - X_L)} - \frac{2E\angle\delta\, X_L}{j(X_A^2 - X_L^2)} \quad (10)$$

Where:

$$V_t \angle \delta_t = V_d + jV_q \quad (11)$$

$$I_1 = I_{1d} + jI_{1q} \quad (12)$$

The nonlinear dynamic model of a synchronous generator can be expressed by the following equations [13]:

$$V_d = X_q i_q \quad (13)$$

$$V_q = e'_q - X'_d i_d \quad (14)$$

$$T_e = i_q e'_q + (X_q - X'_d) i_d i_q \quad (15)$$

$$\dot{e}'_q = \frac{1}{T'_{d0}}[E_{fD} - e'_q - (X_d - X'_d) i_d] \quad (16)$$

Substituting Eq.12 in Eq.10 results in the following nonlinear functions:

$$i_{1d} = f'(\psi_1, \psi_2, \delta, V_d, V_q) \quad (17)$$

$$i_{2q} = g'(\psi_1, \psi_2, \delta, V_d, V_q) \quad (18)$$

If we consider the local load current as follows:

$$i_d = f(\psi_1, \psi_2, \delta, V_d, V_q) \quad (19)$$

$$i_q = g(\psi_1, \psi_2, \delta, V_d, V_q) \quad (20)$$

and linearizing Eq.1, it is possible to obtain the following equations:

$$\Delta i_d = a_1 \Delta\psi_1 + a_2 \Delta\psi_2 + a_3 \Delta\delta + a_4 \Delta e'_q$$
$$\Delta i_q = b_1 \Delta\psi_1 + b_2 \Delta\psi_2 + b_3 \Delta\delta + b_4 \Delta e'_q \quad (21)$$

Where:

$$a_1 = \left.\frac{\partial f(\psi_1, \psi_2, \delta, e'_q)}{\Delta\psi_1}\right|_{i_{d0}, i_{q0}} \qquad b_1 = \left.\frac{\partial g(\psi_1, \psi_2, \delta, e'_q)}{\Delta\psi_1}\right|_{i_{d0}, i_{q0}}$$

$$a_2 = \left.\frac{\partial f(\psi_1, \psi_2, \delta, e'_q)}{\Delta\psi_2}\right|_{i_{d0}, i_{q0}} \qquad b_2 = \left.\frac{\partial g(\psi_1, \psi_2, \delta, e'_q)}{\Delta\psi_2}\right|_{i_{d0}, i_{q0}}$$

$$a_3 = \left.\frac{\partial f(\psi_1, \psi_2, \delta, e'_q)}{\Delta\delta}\right|_{i_{d0}, i_{q0}} \qquad b_3 = \left.\frac{\partial g(\psi_1, \psi_2, \delta, e'_q)}{\Delta\delta}\right|_{i_{d0}, i_{q0}}$$

$$a_4 = \left.\frac{\partial f(\psi_1, \psi_2, \delta, e'_q)}{\Delta e'_q}\right|_{i_{d0}, i_{q0}} \qquad b_4 = \left.\frac{\partial g(\psi_1, \psi_2, \delta, e'_q)}{\Delta e'_q}\right|_{i_{d0}, i_{q0}} \quad (22)$$

In the above mentioned equations i_{d0} and i_{q0} are the system steady state operating points.
linearizing Eq.15 and using Eq.21, it is possible to obtain:

$$\Delta T_e = (e'_{q0} + (X_q - X'_d) i_{d0})(b_1 \Delta\psi_1 + b_2 \Delta\psi_2 + b_3 \Delta\delta + b_4 \Delta e'_q)$$
$$(X_q - X'_d) i_{q0})(a_1 \Delta\psi_1 + a_2 \Delta\psi_2 + a_3 \Delta\delta + a_4 \Delta e'_q) + i_{q0}\Delta e'_q$$
$$\Delta T_e = K_1 \Delta\psi_1 + K_2 \Delta\psi_2 + K_3 \Delta\delta + K_4 \Delta e'_q \quad (23)$$

Where:

$$K_1 = (e'_{q0} + (X_q - X'_d) i_{d0}) b_1 + (X_q - X'_d) i_{q0}) a_1 \quad (24)$$

$$K_2 = (e'_{q0} + (X_q - X'_d) i_{d0}) b_2 + (X_q - X'_d) i_{q0}) a_2 \quad (25)$$

$$K_3 = (e'_{q0} + (X_q - X'_d) i_{d0}) b_3 + (X_q - X'_d) i_{q0}) a_3 \quad (26)$$

$$K_4 = (e'_{q0} + (X_q - X'_d) i_{d0}) b_4 + (X_q - X'_d) i_{q0}) a_4 \quad (27)$$

Linearizing Eq.16 and substituting Eq.21 results in the following equations:

$$(1 + ST'_{d0})\Delta e'_q = \Delta E_{fD} - (X_d - X'_d)(a_1 \Delta\psi_1 + a_2 \Delta\psi_2 + a_3 \Delta\delta + a_4 \Delta e'_q)$$

$$(1 + ST'_{d0} + (X_d - X'_d) a_4)\Delta e'_q = \Delta E_{fD} - (X_d - X'_d)(a_1 \Delta\psi_1 + a_2 \Delta\psi_2 + a_3 \Delta\delta_q)$$

$$(1 + ST'_{d0} K_5)\Delta e'_q = K_5(\Delta E_{fD} + K_6 \Delta\psi_1 + K_7 \Delta\psi_2 + K_8 \Delta\delta_q) \quad (28)$$

Where:

$$K_5 = \frac{1}{(1 + (X_d - X'_d) a_4)} \quad (29)$$

$$K_6 = -(X_d - X'_d) a_1 \quad (30)$$

$$K_7 = -(X_d - X'_d) a_2 \quad (31)$$

$$K_8 = -(X_d - X'_d) a_3 \quad (32)$$

Using Eq.11, Eq.13 and Eq.14 the following equation can be obtained.

$$\Delta V = (\frac{V_{d0}}{V_0}) X'_q \Delta i_q + (\frac{V_{q0}}{V_0})(\Delta e'_q - X'_d \Delta i_d) \quad (33)$$

In this equation the subscription o indicates the initial operating condition of the system.

For V_d it can be shown that we have:

$$\Delta V_d = K_9 \Delta\psi_1 + K_{10}\Delta\psi_2 + K_{11}\Delta\delta + K_{12}\Delta e'_q \quad (34)$$

Where:

$$K_9 = (\frac{V_{d0}}{V_0})X'_q b_1 - (\frac{V_{q0}}{V_0})X'_d a_1 \quad (35)$$

$$K_{10} = (\frac{V_{d0}}{V_0})X'_q b_2 - (\frac{V_{q0}}{V_0})X'_d a_2 \quad (36)$$

$$K_{11} = (\frac{V_{d0}}{V_0})X'_q b_3 - (\frac{V_{q0}}{V_0})X'_d a_3 \quad (37)$$

$$K_{12} = (\frac{V_{d0}}{V_0})X'_q b_4 - (\frac{V_{q0}}{V_0})X'_d a_4 \quad (38)$$

According to the above mentioned equations, the dynamic model of TC-IPC can be combined with the Phillips-Heffron model, as shown in Fig.9.

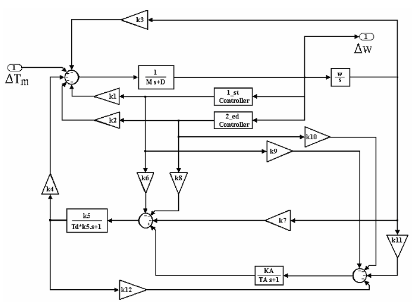

Fig.9: The extended Phillips-Heffron model

5.TC-IPC CONTROL STRATEGIES

In this section, the proposed control strategies of the TC-IPC for the enhancement of the system stability are discussed. The transmission characteristic for various values of ψ_2 is presented in Fig. 10-a. As it can be seen the decrease of ψ_2 results in the simultaneously right and upward shifts of the $P-\delta$ curves or the increment of area A_2. Fig. 10-b shows the $P-\delta$ characteristic for different values of the control variable, ψ_1. It is obvious that the increment of ψ_1 can shift up the $P-\delta$ curve and meanwhile to the left. As a result it can be said that the control variable, ψ_2 is more useful than ψ_1 for the transient stability improvement. But the control variable ψ_1 can be used for the dynamic power flow control.

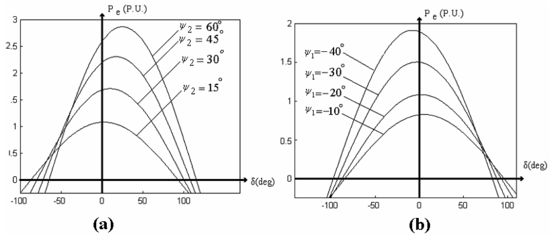

Fig. 10: $P-\delta$ Curve a: Variation of ψ_2 with $\psi_1 = 10^\circ$ b: Variation ψ_1 of with $\psi_2 = -15^\circ$ Other Assumptions: $X_A = 0.4$ P.U. $V_1 = V_2 = 1$ P.U.

To study the low frequency oscillations, Fig. 11 must be considered. In this figure the area A_1 represents the accelerating area during the speed increment period and a procedure for its reduction may improve the low frequency oscillation problem. As it is shown in the Fig. 11 a simultaneous upward shift and left shift of $P-\delta$ curve is useful. This can be done by the increment of the control variable, ψ_1 (see Fig. 10-b).

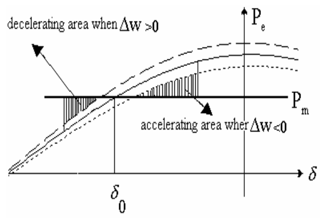

Fig. 11: Low Frequency Oscillation Damping by TC-IPC

It should be noted that the feedback signals can be, the transmitted output power of the generator (P_e), the generator speed deviation from the synchronous speed (Δw) or the power angle variation ($\Delta\delta$). At the stage of selecting the feedback signals of the stabilizers, not only the effectiveness of the stabilizer at a typical operating condition, where the stabilizer are designed, but also their robustness over all the range of power system operating conditions should be examined. Among the most popular techniques, the modal control analysis and the damping torque analysis methods have been applied both, for FACTS-based stabilizers [4]. However a great effort needs to be directed to investigate the design of an effective and robust TC-IPC, which must not impose negative interactions on other stabilizers in the system.

6.Simulations

6.1. Damping of Low Frequency Oscillation

To study the damping effect of TC-IPC against low frequency oscillations a case study has been considered. The parameters of SMIB system, shown in figures 8 and 9, are given in the appendix.
The transfer functions of controller in inductive and capacitive branches of TC-IPC are given in the following equations.

$$G_1(s) = (12 + \frac{22}{s} + 0.6s) \quad (39)$$

$$G_2(s) = -(12 + \frac{22}{s} + 0.6s) \quad (40)$$

Fig.12 shows the simulation result for the parameter ΔW (the deviation of speed from synchronous speed) in the case of a step change in mechanical torque. The same system; but without TC-IPC; has been simulated too. The result of the simulation is illustrated in Fig.13.

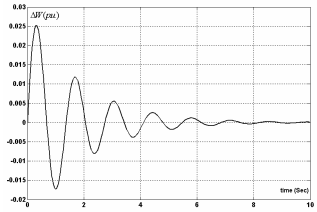

Fig.12: ΔW changes (with TC-IPC)

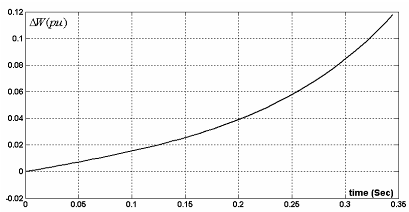

Fig.13: ΔW changes (without TC-IPC)

Compression of theses figures show the effectiveness of TC-IPC for low frequency oscillations stability and mitigation.

6.2. Compression of Control Variables

It is shown that in case of positive and negative ΔW, increase in ψ_2 (capacitive branch phase shift) and decrease in ψ_2, respectively can improve transient stability. Furthermore for a positive and negative ΔW decrease in ψ_1 (inductive branch phase shift) and increase in ψ_1, respectively will improve small signal stability behavior of system. As a result it can be said that the control variable ψ_1 is useful for small signal stability improvement and the control variable ψ_2 is useful for transient stability improvement. This point has been used to select proper controller parameters. For example, if the proportional controllers have been used and if the feedback signal is ΔW then the controller gain for ψ_1 must be negative and for ψ_2 it must be positive. Fig.14shows the ΔW changes when the gain of ψ_1 controller has been set to zero. Fig.15 shows the same parameter but in this case the gain of ψ_2 controller is equal to zero. As it can be seen, the system oscillation damping is better in the second case. As a result the simulations verify the capability of control variable ψ_1 for dynamic stability improvement.

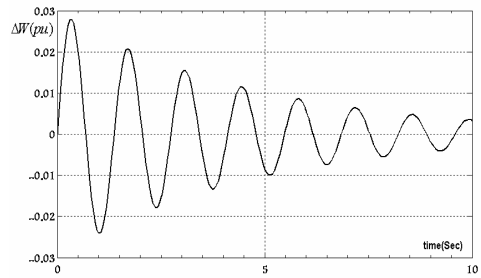

Fig.14: ΔW, when the gain of ψ_1 controller is set to zero

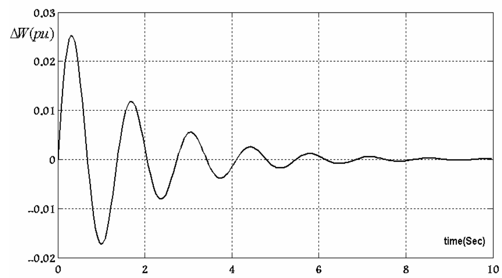

Fig.15: ΔW, when the gain of ψ_2 controller is set to zero

4.3. Sensitivity to System Operating Conditions

The damping of system is dependent to the system operating conditions. It is shown in [13] that increasing of load, i.e. (P_e) in the case of SMIB power system, can result in the decrease of the system damping. In this section of the paper, the effect of generator output power (P_e) variations has been studied. It is assumed that the same step change of mechanical torque has been applied to the system with different operating conditions, i.e. $P_e = 0.25\ p.u.$; $P_e = 0.5\ p.u.$ and $P_e = 0.75\ p.u.$. Simulation results have been presented in Fig.16. As it can be seen the TC-IPC damping control and robustness to variation of system operating conditions are obtained and the increase of P_e has no effect on the decrease of the system damping. This is important point for power system dynamics.

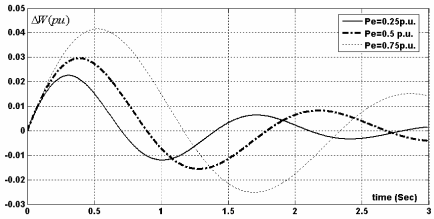

Fig.16: ΔW curve for variation of generator output power

7.Conclusion

This paper presents the dynamic model of Thyristor Controlled Interphase Power Controller (TC-IPC). Based on this model, simulation results have been shown that TC-IPC can improve the system security and meanwhile preserved the merits of a conventional IPC. Compression of results indicate that TC-IPC, as a FACTS controller, can improve the dynamic performance of system and the increase of power generation (variation of operating conditions) does not result in the system damping reduction.

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APPENDIX: CASE STUDY PARAMETERS

$X_d = 1.305 p.u.$	$X'_d = 0.296 p.u.$	$X_q = 0.774 p.u.$	$X'_q = 0.6 p.u.$
$D = 1$	$K_A = 50$	$T_A = 0.05$	$B = G = 0$
$P_{e0} = 0.75 p.u$	$Q_{e0} = -0.2 p.u.$	$V_{t0} = 1 p.u.$	$E = 1.05 p.u.$
$X_L = 1.5\ p.u$	$X_A = 3.75 p.u.$	$\psi_1 = -30^0$	$\psi_2 = 30^0$
$K_1 = 0.9581$	$K_2 = -0.6886$	$K_3 = 0.6483$	$K_4 = 0.2693$
$K_5 = 1.125$	$K_6 = -0.0992$	$K_7 = -0.6822$	$K_8 = -0.7814$
$K_9 = 0.1758$	$K_{10} = -0.3616$	$K_{11} = -0.9454$	$K_{12} = -0.18$