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Evaluation of Impact of TC-IPC in Power System

V. V. Satyanarayana Rao R* and S. Rama Reddy**

Abstract: Ever growing electricity demand forced the existing congested power system to enhance loadability of existing transmission system and transformation of transmission line topologies to augment the levels of electric power transmission and improve stability. To solve the above paradigm, numerous solutions have been advocated. Among them incorporation of Flexible AC Transmission System devices have technically and economically proven to provide optimum solution to the increasing stress on the conventional power system. They are numerous advantages including transmission line stability improvement. Inter Phase Power Flow (IPC) Controller is one such device considered in this paper applied to fifty bus test system.

Index Terms: Stability, flexible transmission, static, thyristor, controller.

1. INTRODUCTION

For successful operation of the power system, the deviation in the voltages levels should be minimum or well within the tolerance levels and loss of synchronism should not occur at any instant. In case of disturbance in the system, the original operating conditions should be restored within shortest possible time. The disturbance may be momentary or transient in nature or dynamic. The capability of the power system to restore back normal conditions when subjected to major loss of synchronism (disturbance) is called stability in transient domain. After post fault clearance, the condition to be satisfied to maintain transient stability is the curve corresponding to accelerating region should be equal to the decelerating region based on equal-area criteria. For first swing stability, quick and reliable control strategy for power flow is essential. Modern excitation systems, breaking resistors, superconducting magnetic energy storage systems are some of the readily available solutions.

Advancements in thyristor technology facilitated the possibility of advanced power control and conversion and lead to development of a new class of device called FACTS (Flexible AC Transmission Systems) devices.

They articulate power flow control dynamics. CSC (Controlled Series Compensator), SPS (Static Phase Shifting Transformers), UPFC (Unified Power Flow Controller) are few such devices which improve transient stability. FACTS devices are basically static controllers which aim at providing flexible flow of electric power transmission with proper variation in line impedance, current, voltage or phase angle. They in turn provide system security and reliability. IPC (Interphase Power Controller) is one among the FACTS devices considered in this paper due to its technical and other added advantages. Also Static Phase Shifting Transformer (SPS) is used in place of Phase Shifting Transformer (PST) is another modification in the system. This lead to the birth of new device called Thyristor Controlled IPC or TC-IPC.

Thermal stability concerning with transmission lines is one of the major issue in interconnected electric power systems. The effect of instability causes increase in the short circuit level of the system due to overrating of substation equipment. The bus sectionalisation, series reactors, high impedance transformers, non-usage of old substation equipment like CBs (circuit breakers) some of useful methods to reduce the

* Research Scholar, SCSVMV University. *Email: rvvs_ssiet@yahoo.com*
** Professor, Jersulam College of Engineering

system short circuit levels. All of these methods fail incorporate dynamic redirect or control of power flow in the system limiting the exploitation of the existing capacity of present transmission system. Bus sectionalisation mitigates the effect due to fault at the substation level but the degree of power transfer or control is reduced significantly. In practical point of view, the reconfiguration of the existing bulk power system is complex and cumbersome effort which seems to impossible at this point of time. Series reactors stand in middle of the above two constraints satisfying none of the above conditions. In case of overloading, series reactors tend to cause voltage regulation problems. Derating of circuit breakers one of the common problem in power system which should addressed at express level. Replacement of the existing CBs is solely dependent on line voltage which might involve structural and functional breakthrough at planning and implementation level.

Effective methodologies for fault clearance and minimising the effect of damage due to occurrence of fault are penetration of FACTS technology into the existing power system. IPC is one of the lucrative option among the FACTS devices.

Various FACTS controllers are presented by Hingorani [1]. Stability analysis of TC-IPC in deregulated power systems is given by Chitra [2]. TC-IPC for power system dynamic studies is given by Mohammadi [3]. Overview of FACTS is given by Morin [4]. Design aspects of various FACTS controllers to damp over swings is given by Larsen [5]. Thyristor based FACTS controllers are given by Varma [6]. An overview of fault current limiters is given by A.J. Power [7]. The behaviour of typical standard eight bus system with TC-IPC is given by Rao [8]. Modelling and Simulation of fourteen bus system with TC-IPC is given by Rao [9].

2. IPC DESCRIPTION

IPC is the ideal passive solution for issues related to frequency, in particular nominal frequency problems. IPC uses active elements like reactor, capacitor or PST and sometimes in combination with static switches to facilitate quick control in order to damp oscillations or voltage swells.

It requires less maintenance without commutation losses. The structure of IPC is flexible and is generally dependent on the required characteristics suitable for the system operating conditions. It consists of two branches connected in parallel fashion and each with impedance in series with a phase-shifting mechanism which provide flexibility in design aspects making it suitable for wide range of applications. The configurations derive their respective nomenclature from the inherent characteristics they tend to possess.

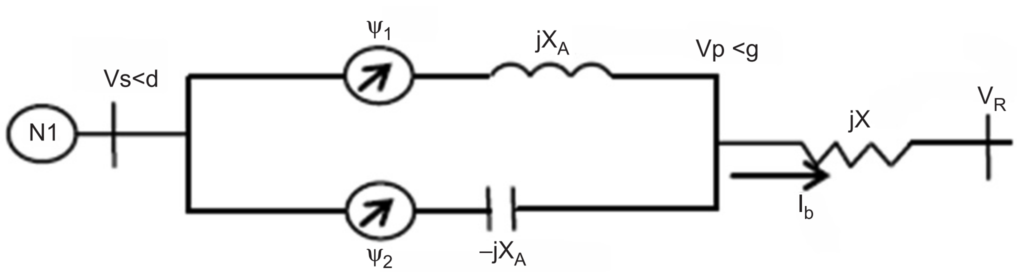

Figure 1: Block diagram of IPC

IPC should be made compatible and adaptive to system which creates the need for robust optimisation strategy.

IPC provide the facility flexible phase shifting in the power-angle plane including internal phase shifts or eliminating the shift among the branches of IPC which modification of the control characteristics to achieve optimum system operating conditions. Although this can be achieved to some extent by PST with auxiliary windings, but the dynamics and degree of flexibility can be achieved only through IPC.

3. RESULTS AND DISCUSSIONS

The simulation study involves extensive modelling of standard 50 bus system and investigating the effect of TC-IPC . The equivalent circuit of transmission line is combination of resistance and inductive reactance and load is represented by shunt impedance. The watt and wattles powers along with bus voltage corresponding to bus 3 are shown in Figures 2.2 and 2.3 respectively. The voltage, real and reactive powers at bus 16 are shown in Figures 2.4 and 2.5 respectively. The reactive and real powers along with bus voltage corresponding to bus 21 are outlined in Figures 2.6 and 2.7 respectively. The reactive and real powers along with bus voltage corresponding to bus 45 are shown in Figures 2.8 and 2.9 respectively.

Standard fifty bus power system single line diagram with TC-IPC is shown in Figure 3.1. Four numbers of TC-IPC are introduced to control the power through lines. The model for TC-IPC is shown in Figure 3.2. Voltage, Real and reactive power of bus 3 are shown in Figures 3.3 and 3.4 respectively. The voltage, real and reactive powers at the bus 21 are shown in Figures 3.5 and 3.6 respectively. Voltage, real and reactive powers at bus 29 are shown in Figures 3.7 and 3.8 respectively.

The reactive and real powers along with bus voltage corresponding to bus 35 are shown in Figures 3.9 and 3.10 respectively. The reactive and real powers along with bus voltage corresponding to bus 38 are shown in Figure 3.11. The voltage, real and reactive power at bus 45 is shown in Figures 3.12 and 3.13 respectively. The real and reactive power indices are presented in Table 1. The real and reactive powers increased by about 10% by adding TC-IPC.

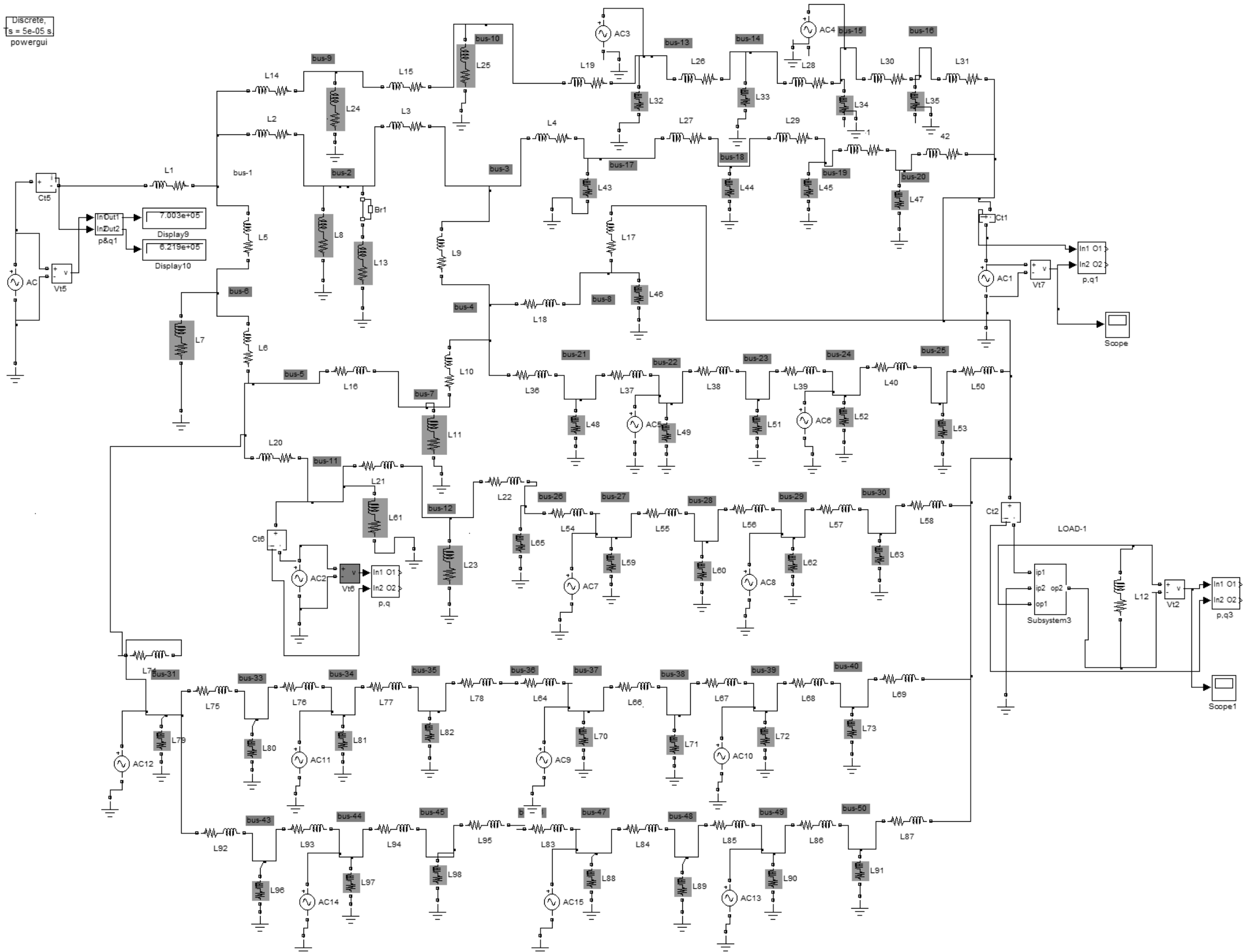

Figure 2.1: Standard 50 Bus system without TC-IPC

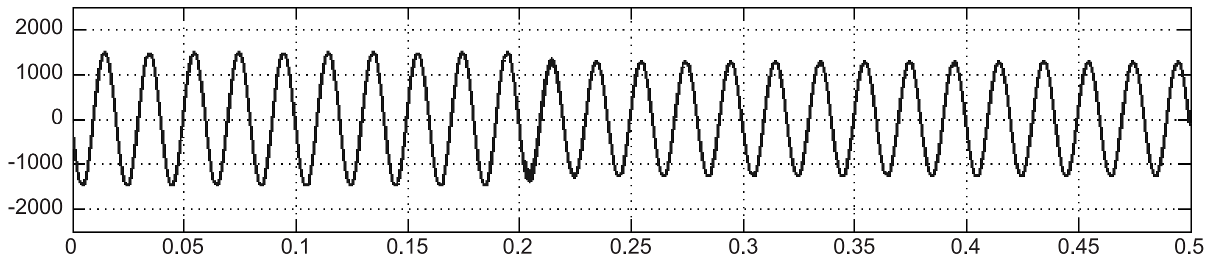

Figure 2.2: Voltage at bus 3

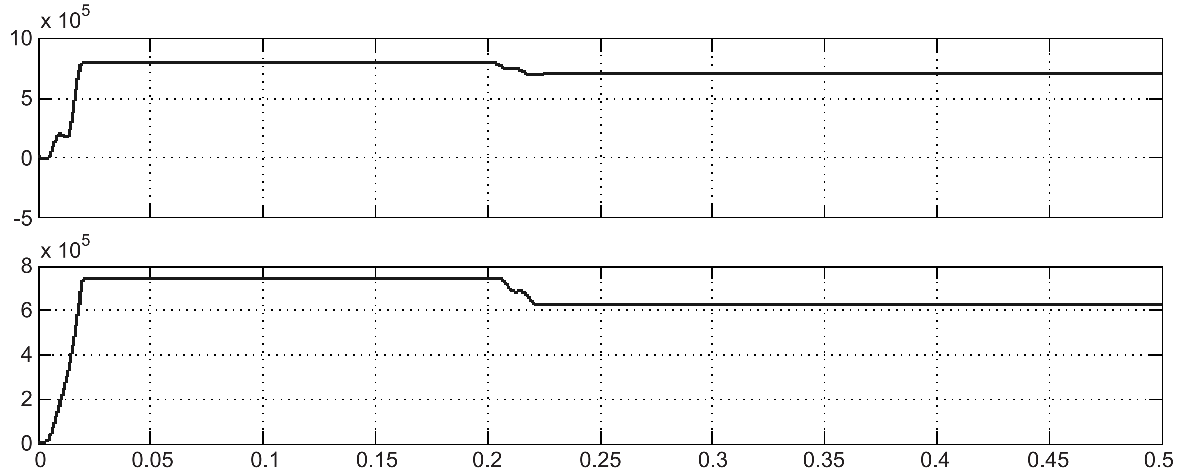

Figure 2.3: Real and Reactive power at bus 3

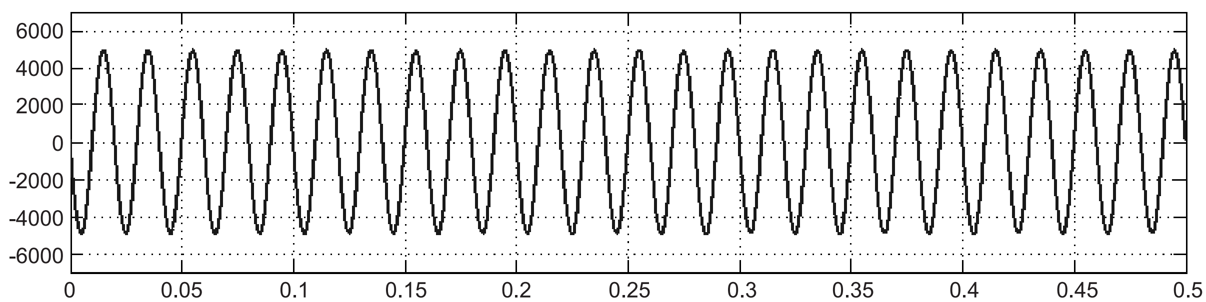

Figure 2.4: Voltage at bus 16

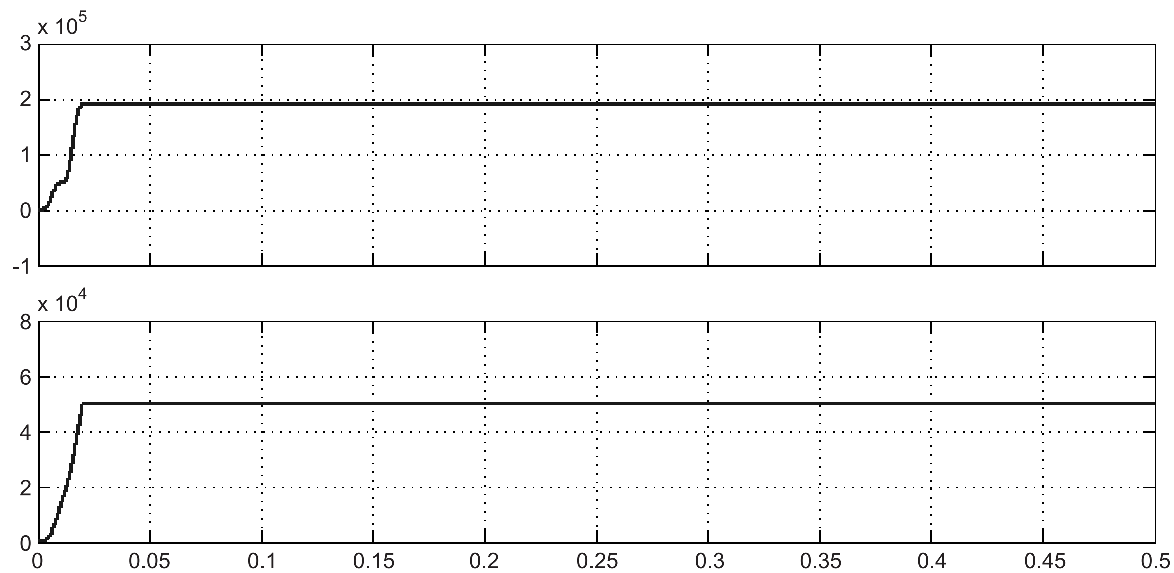

Figure 2.5: Real and Reactive power at bus 16

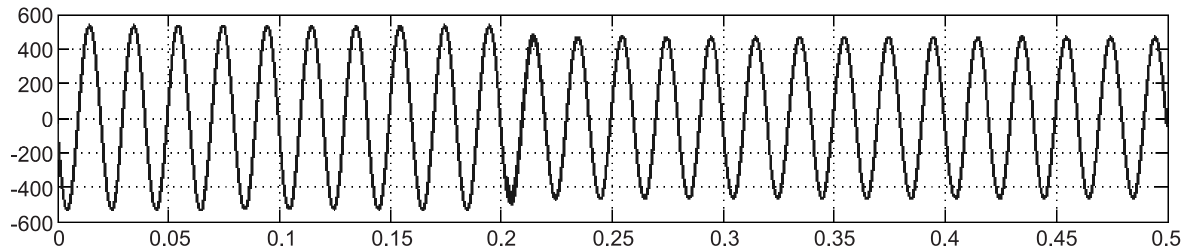

Figure 2.6: Voltage at bus 21

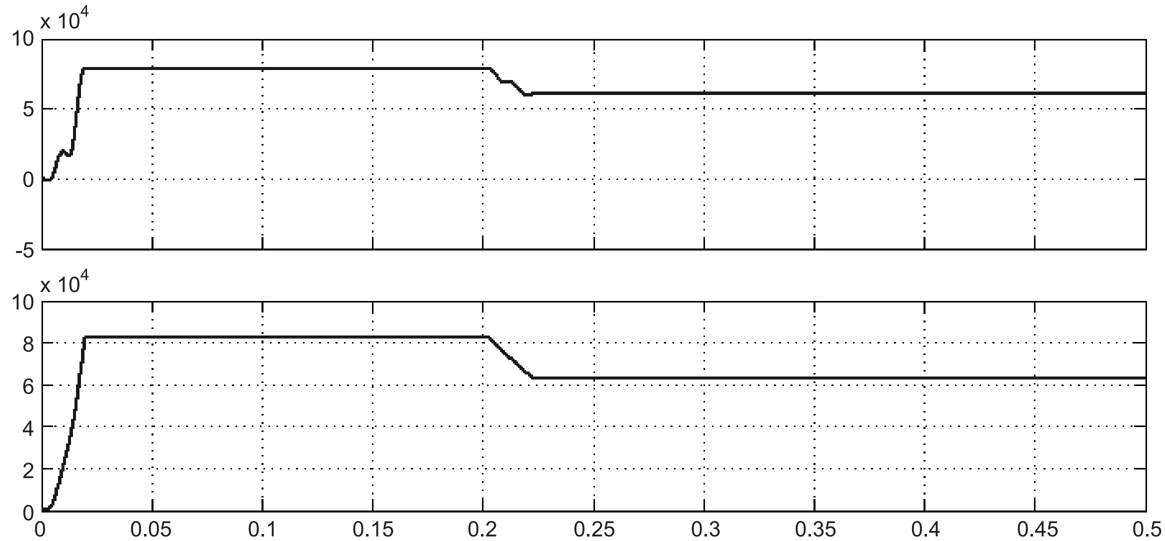

Figure 2.7: Real and Reactive power at bus 21

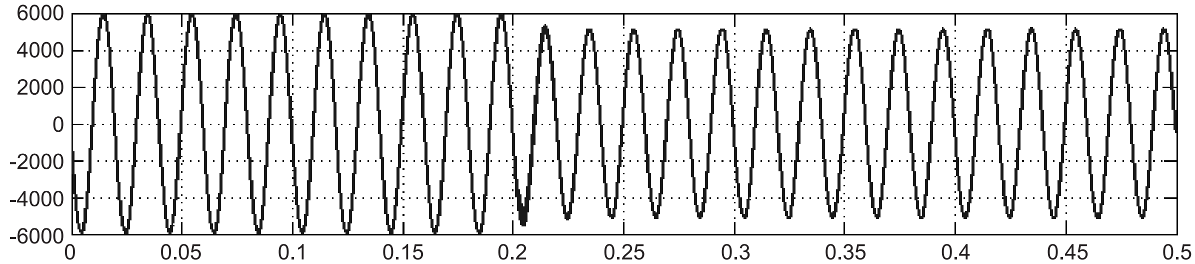

Figure 2.8: Voltage at bus 45

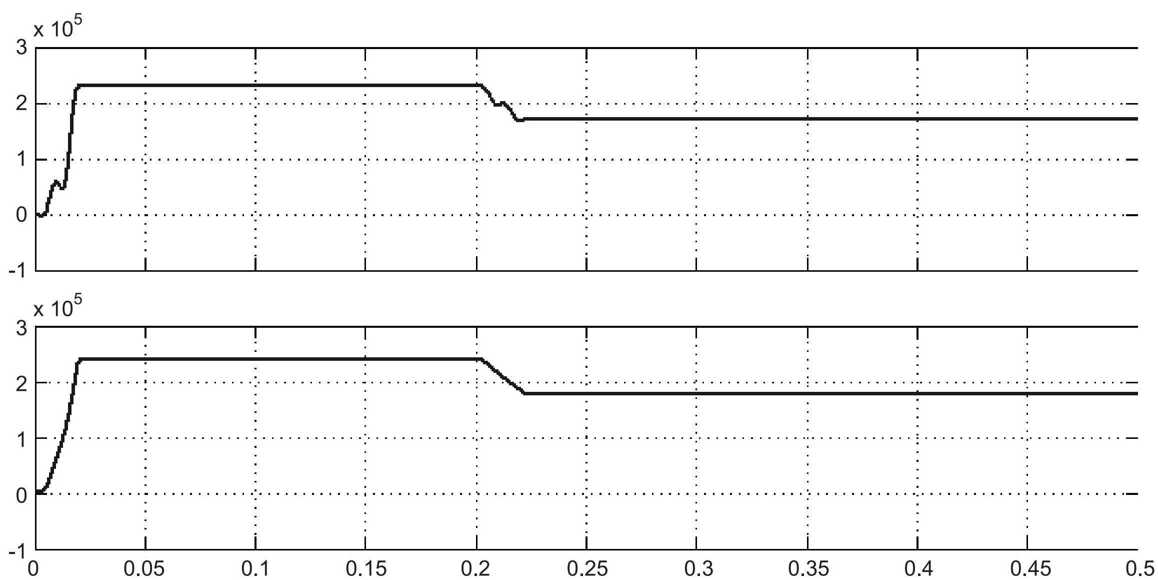

Figure 2.9: Real and Reactive power at bus 45

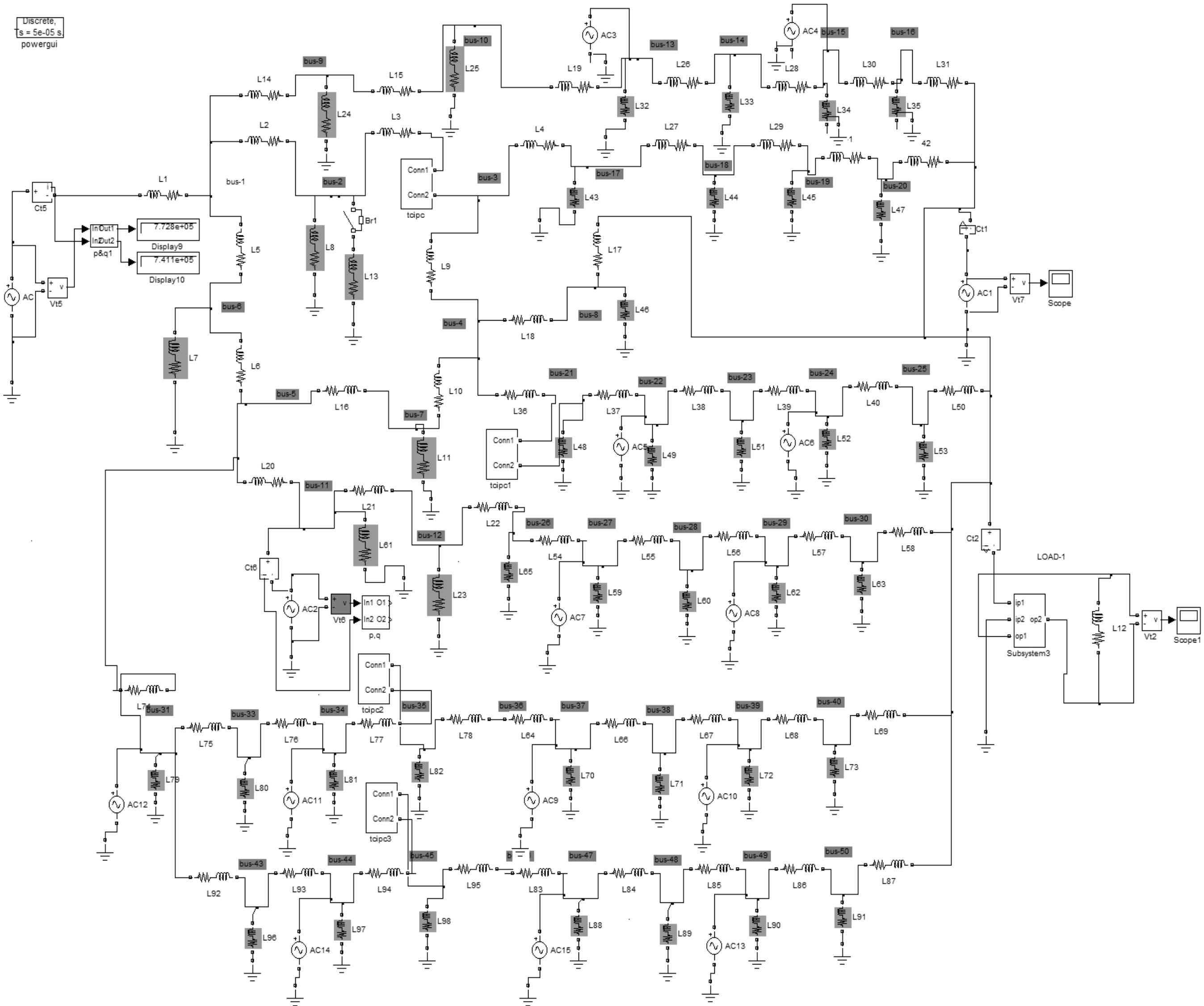

Figure 3.1: Standard 50 Bus System with TC-IPC

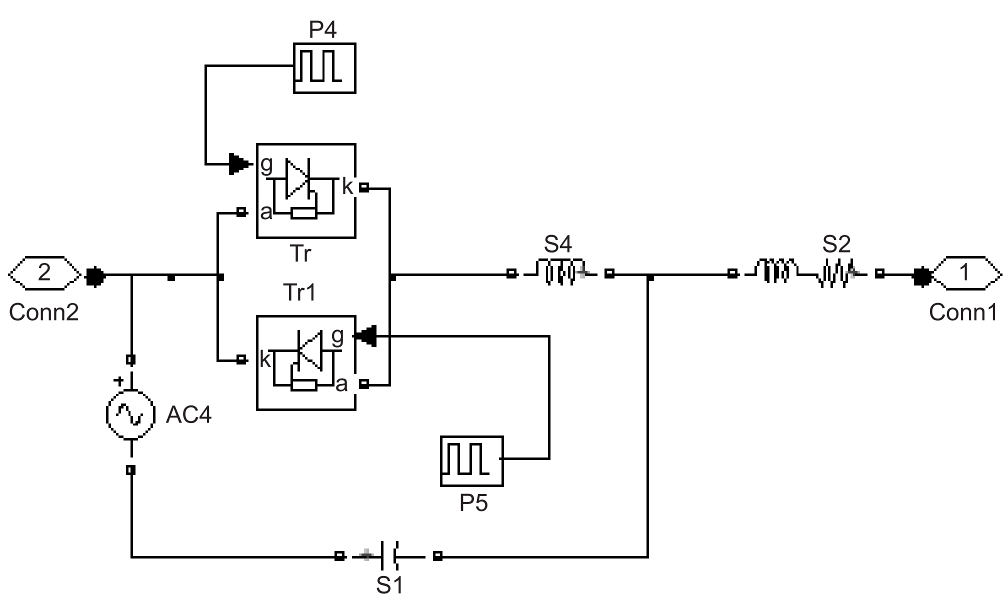

Figure 3.2: TC-IPC Model

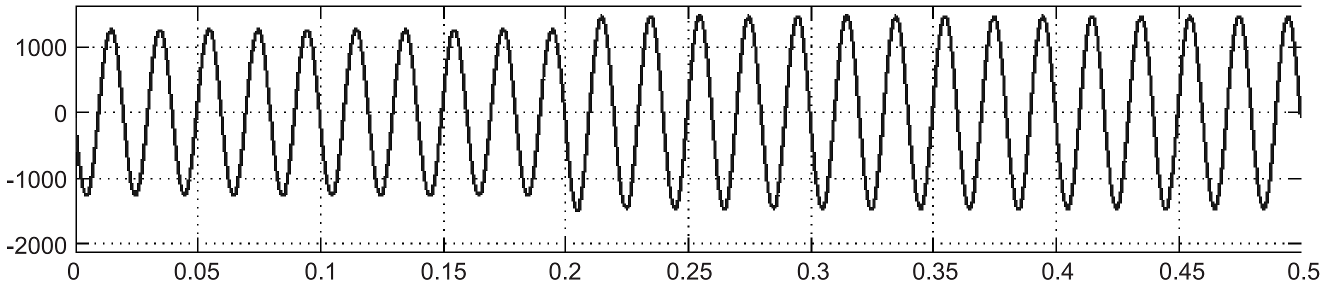

Figure 3.3: Voltage at bus 3

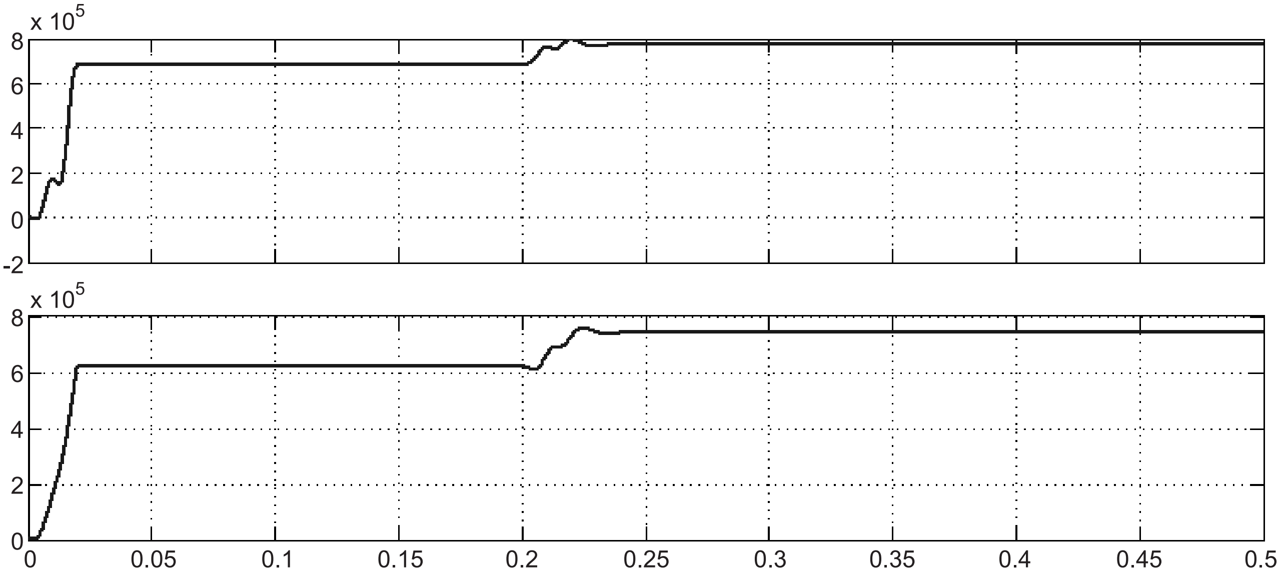

Figure 3.4: Real and Reactive power at bus 3

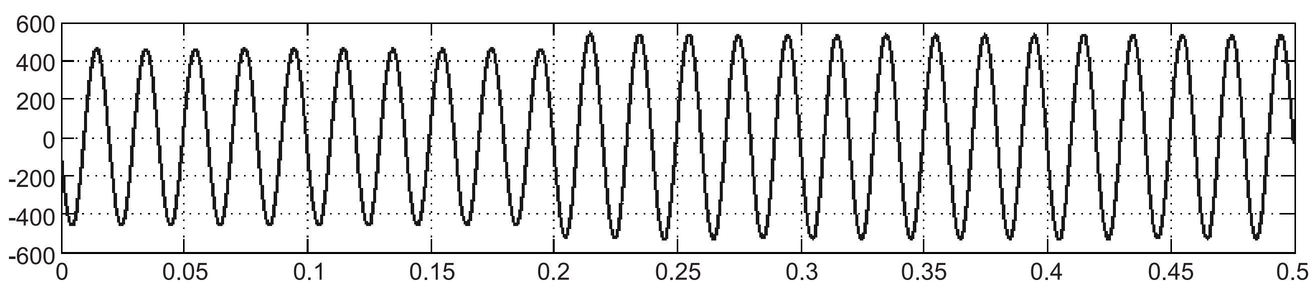

Figure 3.5: Voltage at bus 21

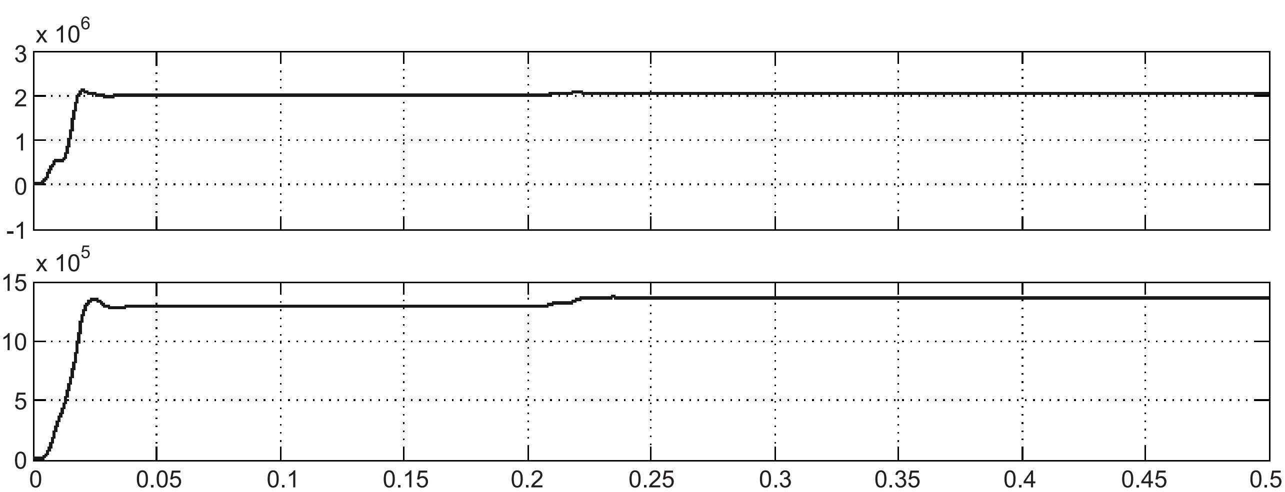

Figure 3.6: Real and Reactive power at bus 21

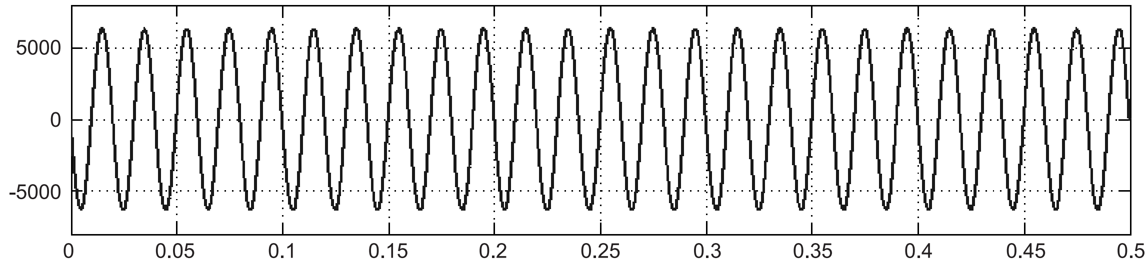

Figure 3.7: Voltage at bus 29

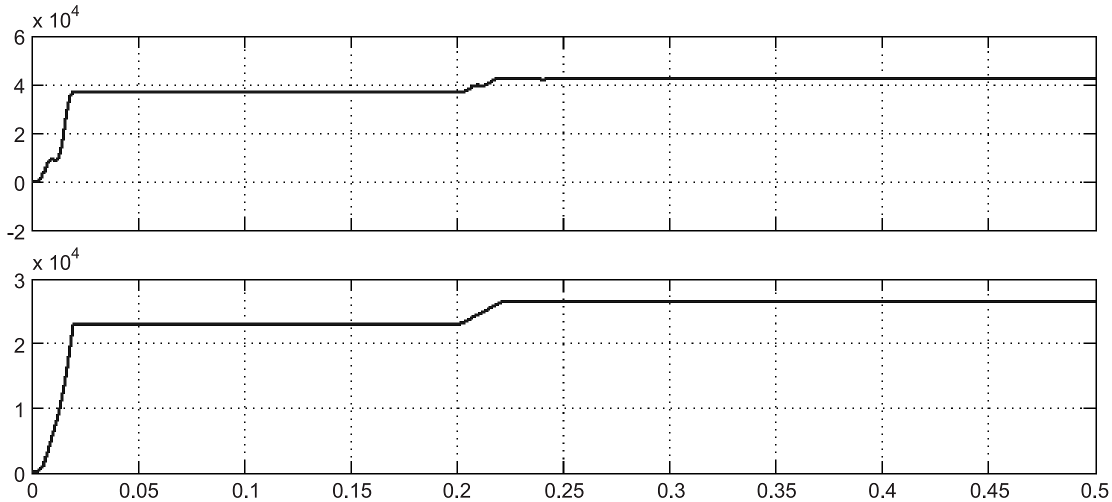

Figure 3.8: Real and Reactive power at bus 29

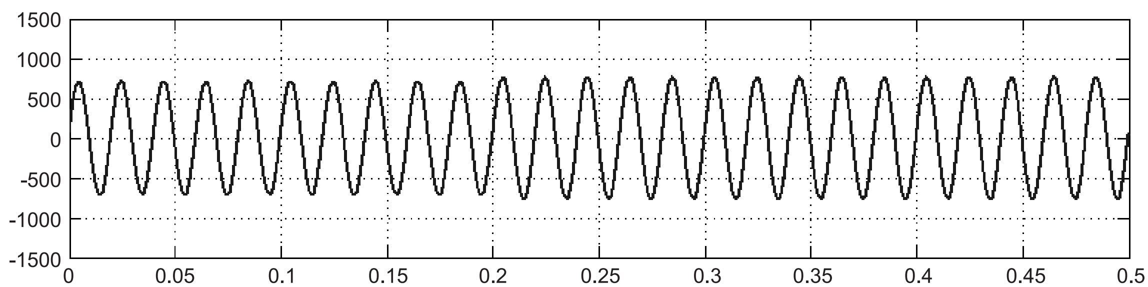

Figure 3.9: Voltage at bus 35

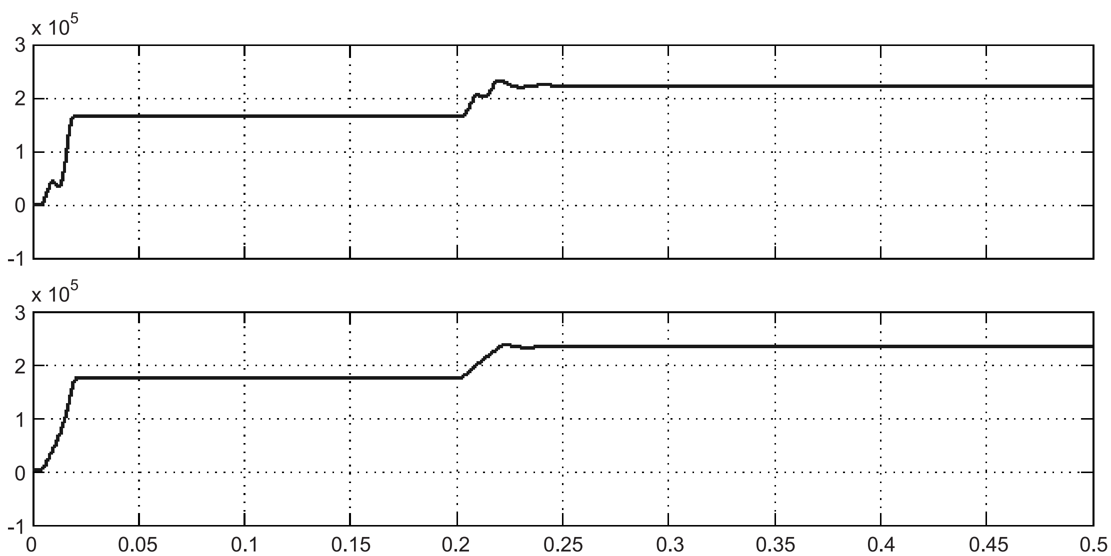

Figure 3.10: Real and Reactive power at bus 35

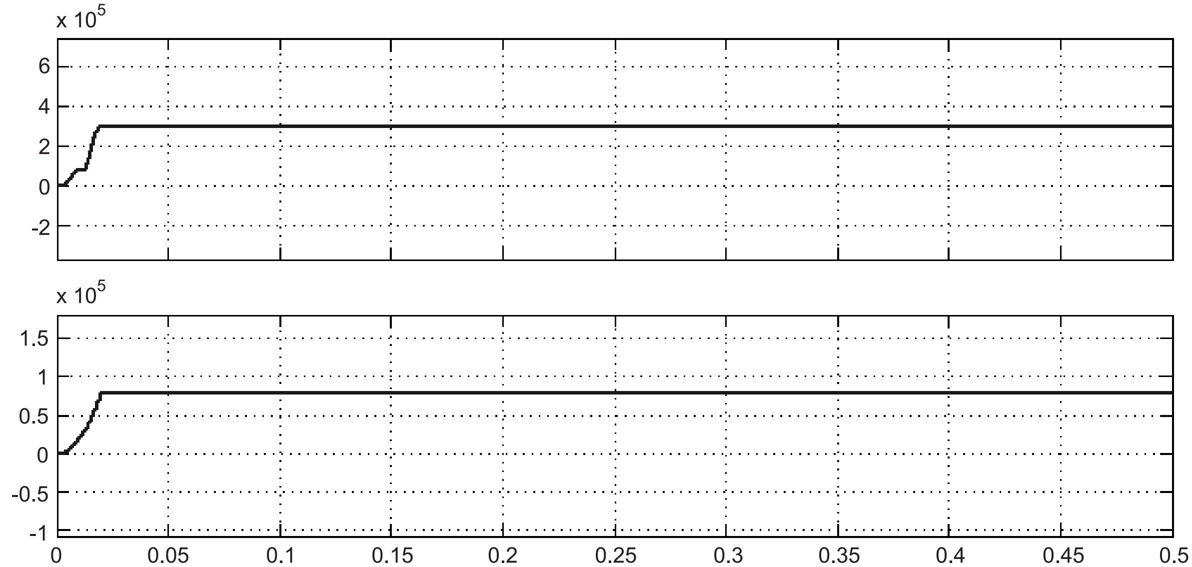

Figure 3.11: Real and Reactive power at bus 38

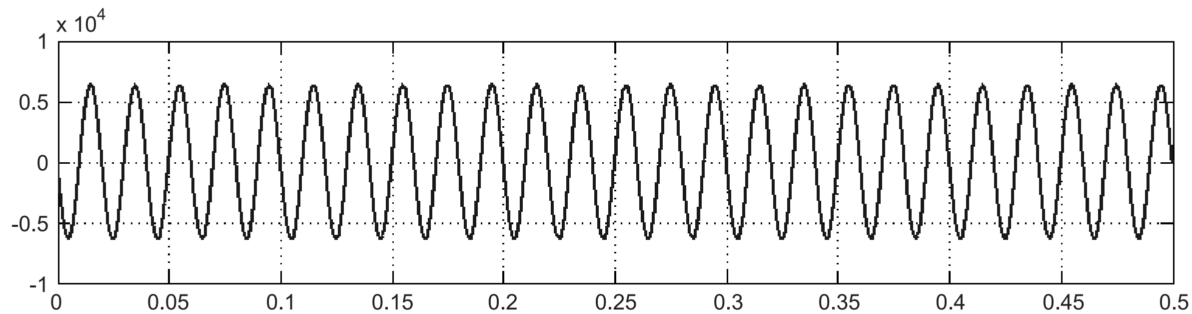

Figure 3.12: Voltage at bus 45

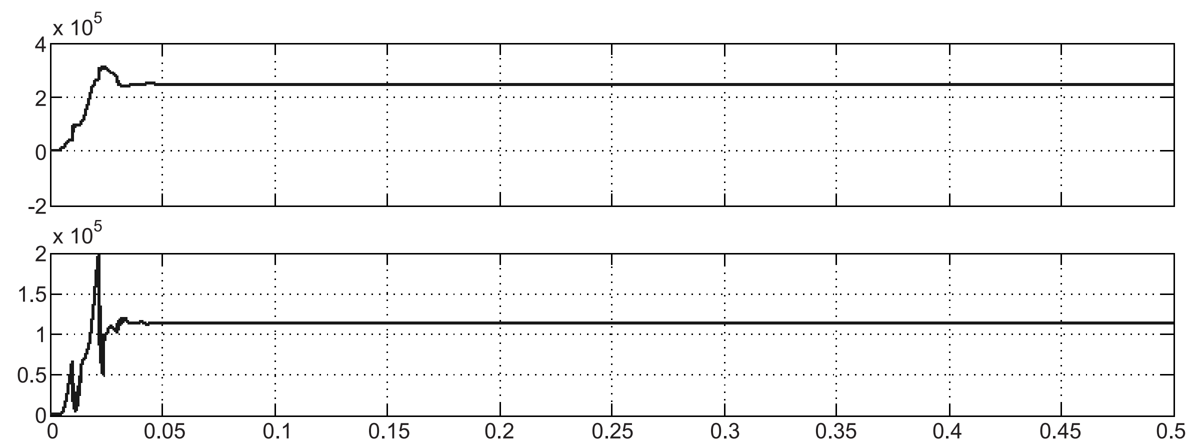

Figure 3.13: Real and Reactive power at bus 45

Table 1
Real and Reactive Power indices for 50-bus system with and without TC-IPC

BUS NO	*Real power (MW) without controller*	*Real Power (MW) with TCIPC Controller*	*Reactive ower (Mvar) without controller*	*Reactive Power (Mvar) with TCIPC controller*
2	0.658	0.697	0.618	0.389
3	0.551	0.781	0.601	0.721
4	0.521	0.658	0.621	0.683
5	0.488	0.586	0.523	0.587

BUS NO	*Real power (MW) without controller*	*Real Power (MW) with TCIPC Controller*	*Reactive ower (Mvar) without controller*	*Reactive Power (Mvar) with TCIPC controller*
6	0.456	0.478	0.468	0.513
7	0.468	0.489	0.456	0.501
8	0.423	0.463	0.448	0.498
9	0.438	0.456	0.415	0.479
10	0.381	0.408	0.304	0.398
12	0.331	0.415	0.357	0.406
14	0.316	0.386	0.348	0.398
16	0.303	0.378	0.338	0.386
17	0.284	0.358	0.224	0.367
18	0.235	0.376	0.281	0.361
19	0.286	0.351	0.313	0.348
21	0.046	0.259	0.064	0.282
23	0.231	0.232	0.044	0.045
25	0.199	0.249	0.208	0.321
26	0.612	0.623	0.487	0.487
28	0.432	0.486	0.469	0.571
29	0.342	0.442	0.347	0.487
30	0.365	0.497	0.473	0.489
33	0.314	0.414	0.422	0.452
35	0.412	0.483	0.587	0.607
38	0.451	0.523	0.497	0.567
40	0.389	0.468	0.356	0.488
42	0.318	0.561	0.289	0.587
45	0.336	0.537	0.326	0.478
48	0.347	0.548	0.350	0.469
50	0.451	0.523	0.497	0.567

4. CONCLUSION

This paper demonstrates the simulation study of incorporation of FACTS devices in the existing power system. The typical system considered here is fifty bus and the FACTS device is TC-IPC. The TC-IPC has relative merits and advantages compared to that of conventional IPC which is evident from the simulation results. TC-IPC will improve dynamic stability and overall performance of the system in addition to control of reactive as well as real power in the transmission system.

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