Digital Simulation of Thyristor Controlled Interphase Power Control Technology (TC-IPC) to limit the fault currents

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Abstract—**This paper presents simulator demonstration of fault current limitation based on the Thyristor controlled Interphase Power Controller (IPC) technology. From a power system point of view, this TC-IPC has the same function as a transformer: it handles its share of the load current but, during a fault, it does not contribute to the fault current. It thus allows a substation to be uprated without increasing the fault level. A 25 kV substation is used to illustrate the concept. In this paper simulation results are obtained using Matlab Simulink in order to show the performance of TC-IPC when fault occurs in an one bus in IEEE 30 bus systems**.

Keyword-IPC,TC-IPC, Fault Currents, IEEE-30 Bus systems, PST

I. INTRODUCTION

Power flow control is becoming more and more a major concern in planning and operation of modern power transmission networks. Strong needs, environmental, legislative or contractual, have triggered investigation of new concepts to manage power flows and insure proper voltage control. These concepts are making the headlines as Flexible AC Transmission Systems (FACTS) [1, 2]. The acronym FACTS is normally used for power electronics based systems and evokes fast dynamics. However, situations exist where flexibility is the key factor and rapidity is not required. In such situations, solutions like phase-shifting transformers (PST), limiting reactors and series compensation might not be completely satisfactory. In addition to these conventional solutions, [6] proposes an original approach: the Interphase Power Controller (IPC).

The Interphase Power Controller (IPC) is an emerging technology developed for the management of power flows within ac networks. It is a series-connected controller consisting of two impedances per phase, one inductive and one capacitive, subjected to separately phase-shifted voltages. In the particular case where the impedances have conjugated values, each side of the IPC can be represented as a voltage-dependent current source. One of the novelties of the IPC is its inherent constant power characteristic obtained in a passive manner. This makes the IPC a very robust and predictable controller.

The main objectives of this simulator study were to:

- Demonstrate that the IPC behaves as predicted and to verify that control (start/stop) and protection strategies do not lead to unacceptable situations
- Establish the maximum stresses on the equipment for the open circuit condition, which is the worst situation for a current-source device, and demonstrate the effectiveness of the overvoltage protection system
- Establish the sensitivity to variations in system variables such as voltage, unbalances, frequency, etc.

One of the most promising application areas for the IPC is the Control of power flow in interconnections between strong networks that high short-circuits levels would otherwise not allow. The diagram also shows the overvoltage protection system protecting against open-circuit conditions. This paper describes the models implemented on the simulator and reports on the simulation results for the 25Kv IEEE 30 bus system. The results confirm the basic attributes of the IPC. Indeed, they show that the IPC:

- Is a robust power flow controller with inherent power-angle characteristics obtained in a passive manner and insensitive to changes in the network
- Does not contribute to increasing short-circuit levels
- Tadpoles the voltages on both sides thus reducing the impact of perturbations interconnected networks.

II. DESCRIPTION ABOUT TC-IPC

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. The basic IPC is a series-connected device comprising two susceptances, one inductive and the other capacitive, subjected to properly phase-shifted voltages, as shown in Fig. 1. In this paper the term susceptance refers to the physical components BI (inductive) and B2 (capacitive). IPC's can be grouped in categories according to the mean used to provide the phase shifted voltages. In a first category, the phase shifts are achieved by a cross connection between phases, as in the IPC 240 described in [6], where plus or minus 120' 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 appropriate phase shifts. In this category, the transformer is rated for the full transferred power.

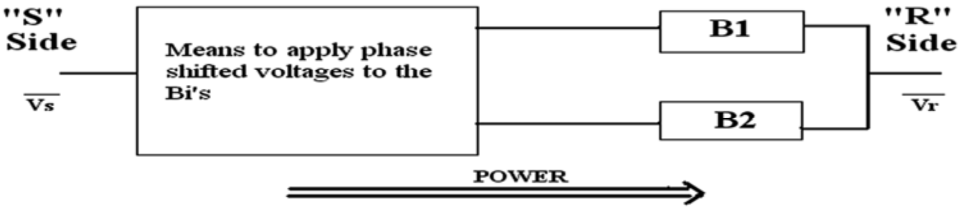

Fig.1. Single line diagram of principle IPC

A. Operating principle

The IPC technology is very flexible at the design stage and implementations are possible. So far. It has been applied for power flow controls of synchronous interconnections the present context; it is the inherent fault limitation capability of the tuned IPC that is the main feature. Figure 3 a) presents a topology adapted for uprating the substation of Fig. 2. It consists of an autotransformer whose low voltage side is connected to a reactor, a capacitor series transformer. As shown in Fig. 3 b), this TC-IPC can be conceptually represented by two parallel thyristors series with the capacitor. It is the combined installation of these two branches which provides the specific properties that make the TC-IPC technology distinctive.

The phase shift Ψ in series with capacitor C is obtained by injecting a voltage phase-shifted Ψ by 120" with the series transformer. By controlling the amplitude of the injected voltage with the tap changer, the phase shift Ψ varies between 0^0 and a maximum value which in the present case is set to 20^0. According to the IPC Theory [5,6], this phase-shift adjustment controls the power forced by the IPC into the load: the larger the angle y_r, the higher the power flow. Reactances XI and X2 are almost conjugated impedances (tuned at 60 Hz) which means that for $\Psi = 0^0$ they form a high-impedance tuned circuit that delivers almost no current to the load. However, when yf = 20", the reactances are such that the IPC carries its share of the nominal load current. To insure redundancy in the substation, the IPC has the same rated throughput as the other transformers.

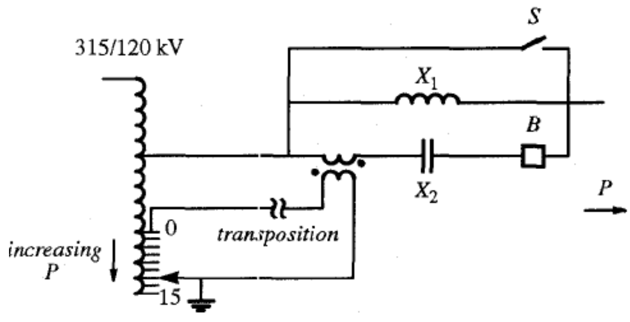

Fig. 2. Equivalent circuit

The IPC offers two modes of operation, namely, the IPC and the stand-alone transformer modes. Due to short-circuit constraints, it operates in the IPC mode when all the four transformers are in service. When there are three transformers in service, the IPC can be used either as an IPC or as a conventional transformer just like the others. The modes of operation are selected with the by-pass switch S and the circuit breaker B. The IPC mode is obtained with S open and B closed, while the reverse produces the transformer mode.

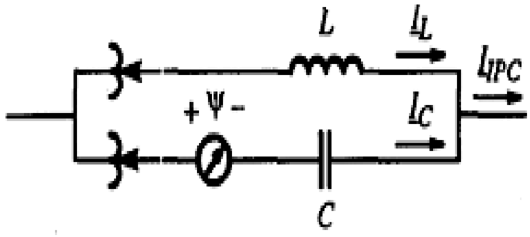

Fig. 3. IPC for substation uprating

Hence, the IPC controller has two different tasks, depending on the mode of operation. In the IPC mode, the tap changer is positioned to adjust the output current to the value of the other transformers, whereas in the transformer mode, it performs voltage regulation, just like the other transformers.

Figure 4 shows the simplified network used to characterize the substation operation. The IPC is connected in parallel with one branch representing the Substation transformers of which there can be three or four, depending on the presence of a contingency. The transformer of the IPC is assumed ideal, with no leakage impedance, since the major pan. of this impedance can be compensated at the design stage by appropriate selection of the IPC reactive elements.

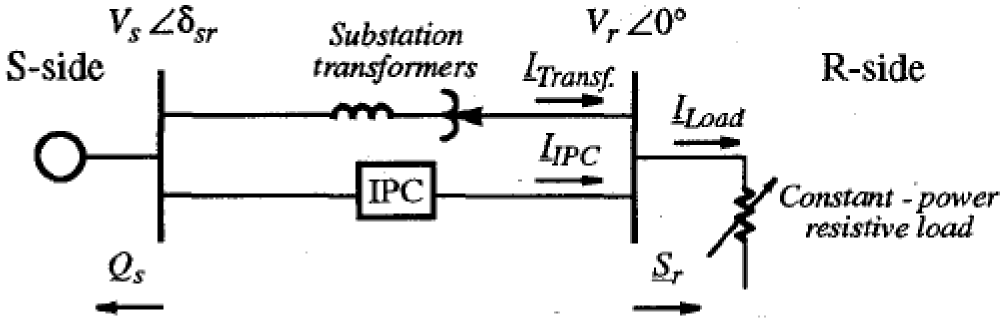

Fig. 4. Simplified network for combined operation of TC-IPC and transformers

Steady-state load representation assumes a unity power factor and constant power independent of the voltage *Vr* , a load representation which is quite adequate considering the very low impact of an inductive load on the results. During normal operation, that is with all transformers and the IPC in service, the currents I_{transf} and I_{IPC} flowing out of the substation work together to carry the resistive load current. As shown in Fig. 5 a), the IPC current exhibits a reactive part that returns in the transformers, indicating that the IPC has the capability of producing reactive power which can help compensate the reactive consumption of the parallel transformers or of the load when inductive.

B. Short-circuit limitation

When a fault occurs on the R side, the collapse of the voltage on this side causes a rotation of the TC-IPC currents those results in a small net current, Fig 6. This current is in quadrature with the current delivered by the transformers into the fault. Hence the tuned parallel circuit passively limits the IPC contribution to the fault. A similar behaviour of the IPC would be obtained if the fault were applied on the S side and there were a source on the R side.

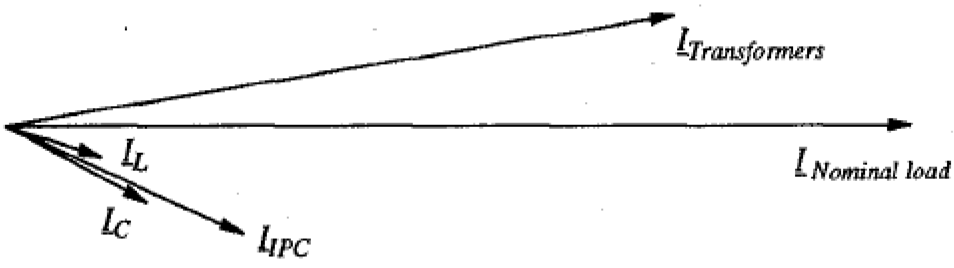

Fig. 5. Currents at nominal operation

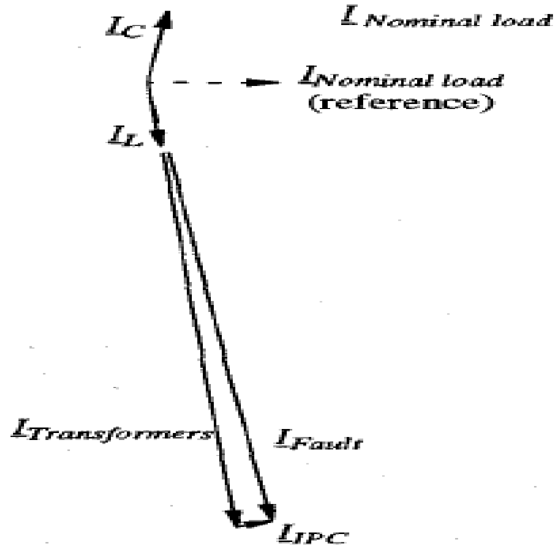

Fig. 6. Currents at Fault condition(R side)

III. Results analysis

The simulation results are obtained for TC-IPC placed in 25KV subsystem using variable load condition. The simulations are performed 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. Fig 7 illustrates IEEE 30 bus system without IPC(Bus 6) . Fig.8 shows that voltages in phase a,b,c with fault. Fig.9 shows that current through the phases after fault occurred. Fig.10 illustrates that injected voltage by IPC, which compare stability results with the PSTs alone and with the TC-IPC included. In case, the flow in the line is 25KV / 100 MVA. This marginally stable case is considered as tile stability limit.

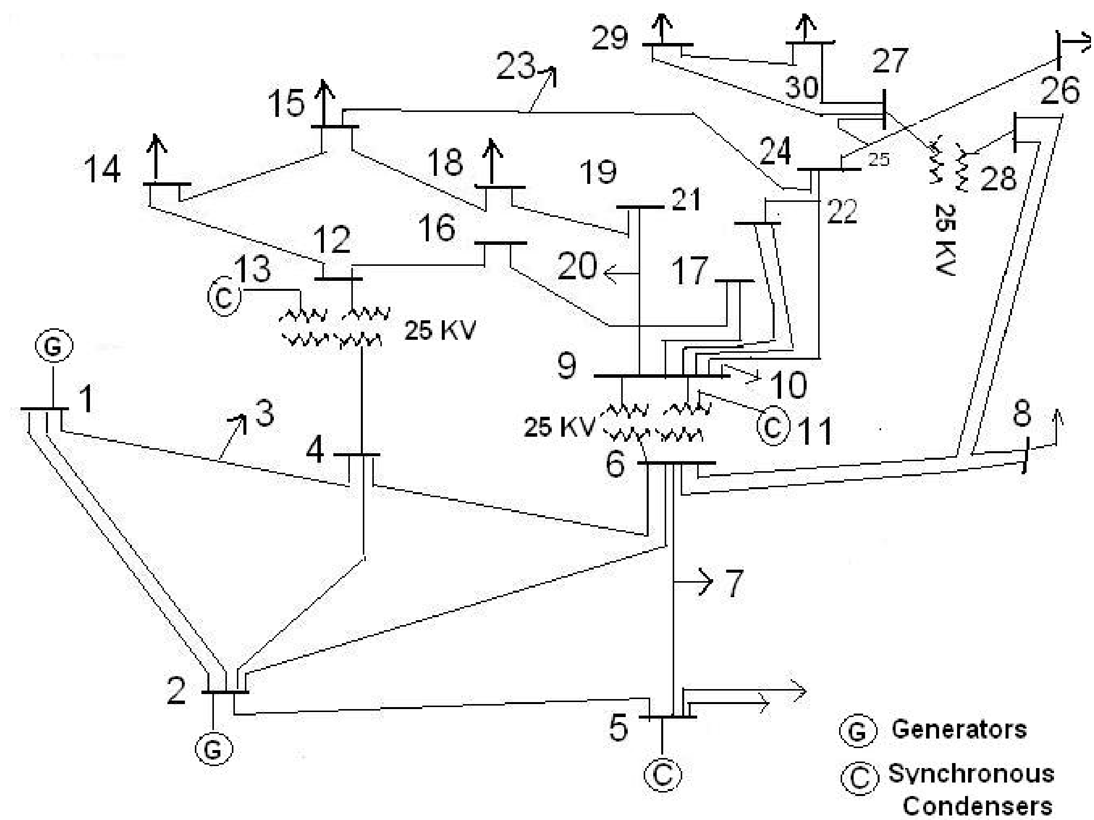

Fig. 7. IEEE 30 Bus system without IPC

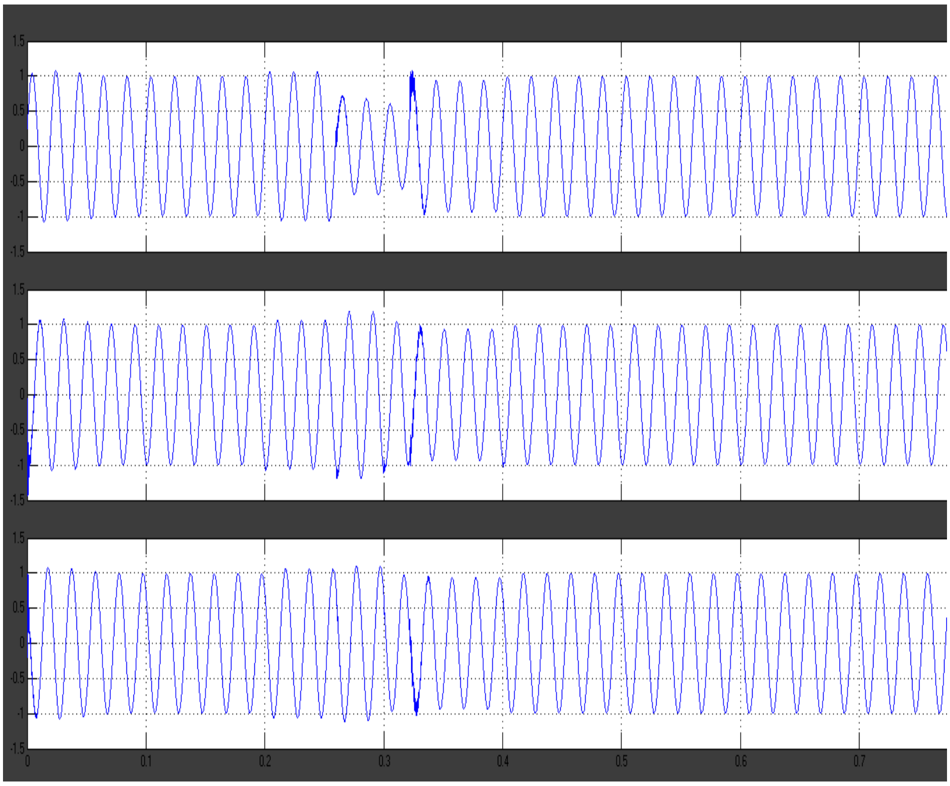

Fig. 8. Voltage through phases when fault inserted at 0.26 sec

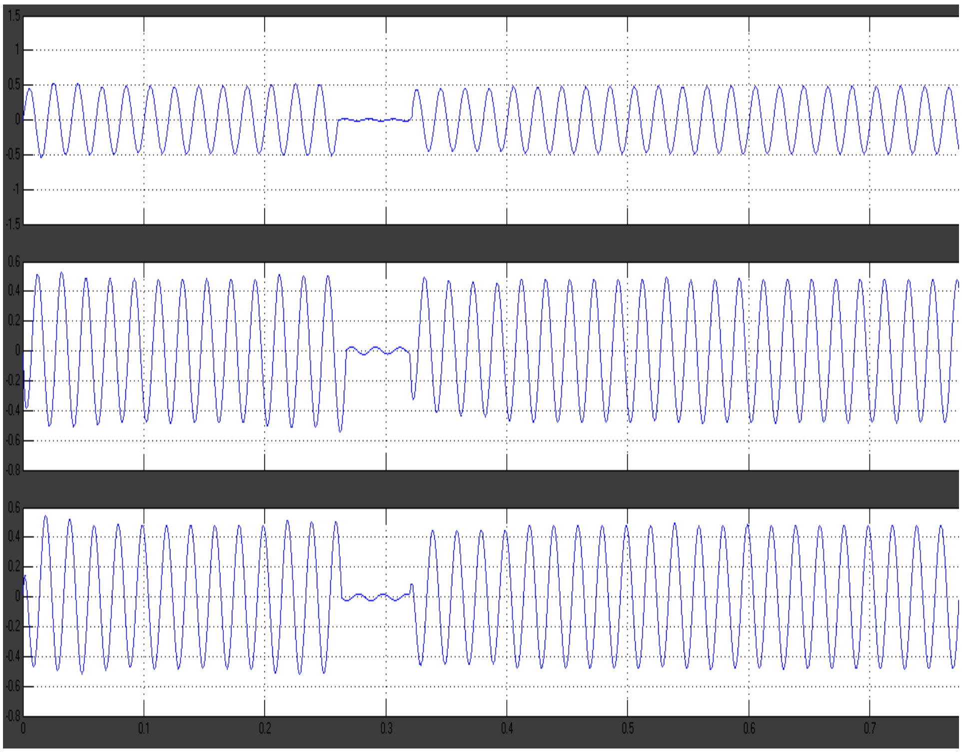

Fig. 9. Current through the phase when fault occurs 0.26 secs

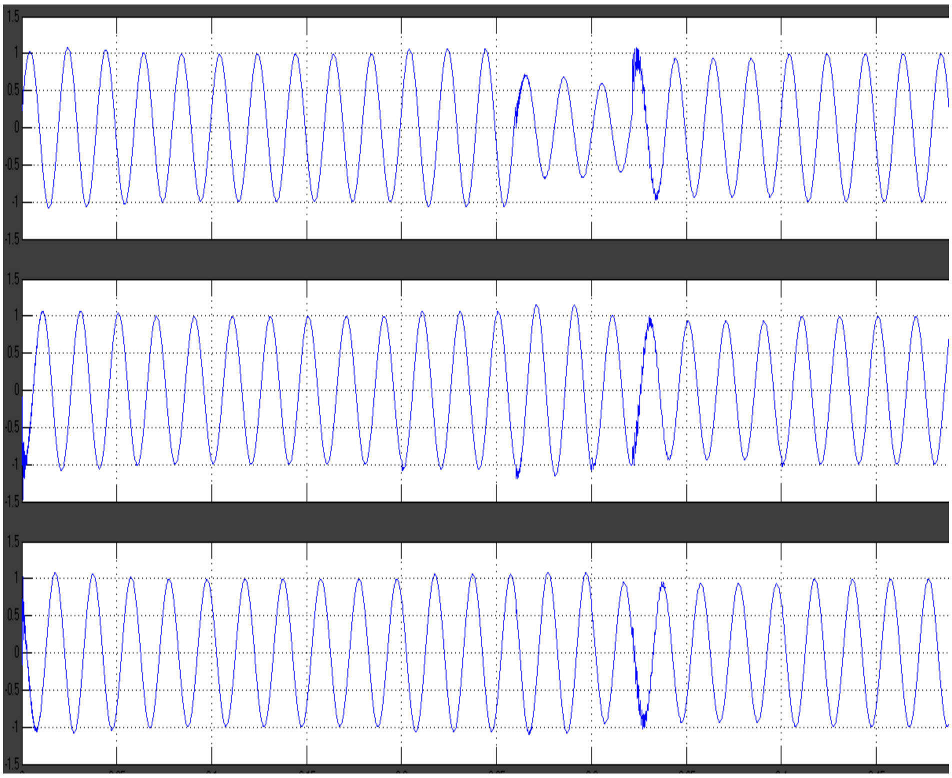

Fig. 10. Voltage through phases IPC injected voltage

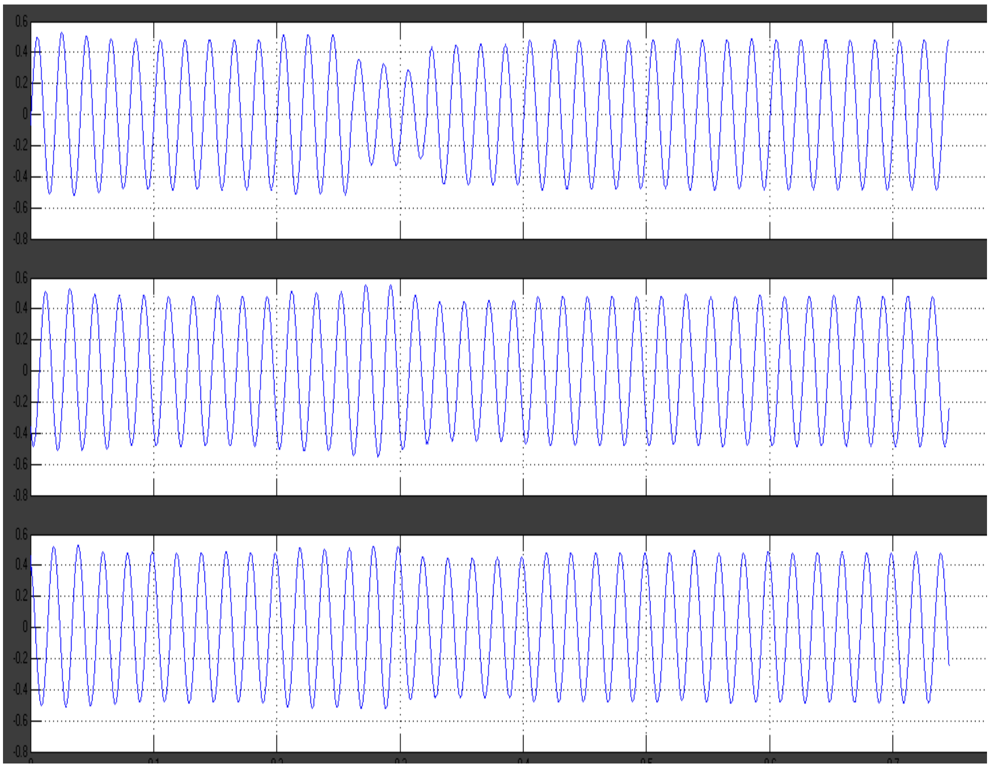

Fig. 11. Current limit through the phases after fault occurs

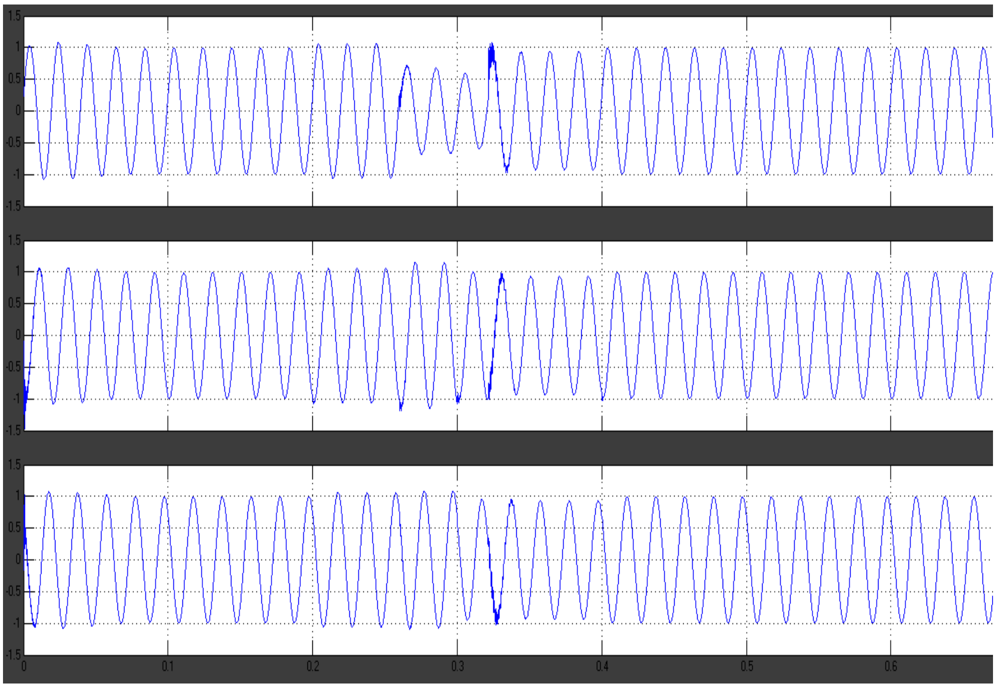

Fig. 12. Load voltage after limits the fault

Fig.7 illustrates that IEEE 30 bus system without IPC and simulations performed for IEEE 30 Bus system shown in fig.7 without IPC and with IPC. Thyristor controlled Interphase power control has connected at Bus 6 with the 25KV transformer. Fig.8&9 shows that voltage through phases when fault occurs and current in all phases when fault occurs current reduced to 70% of actual current. Fig.10 shows that current limit through the phases. In fig.11 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.12 illustrates the voltage stability in all phases by TC-IPC when fault occurs.

IV. Conclusion

In this paper simulator demonstration of TC-IPC technology to limit fault currents in a substation line. The stability in phase voltages and currents are tested by inserting a fault in one phase of three phases. Thyristor controlled Interphase power controller is controls the phase currents whenever fault occurs in a line. In this paper TC-IPC was tested in between two 25KV substation lines and TC-IPC is also tested in IEEE 30 bus system. The simulation results have been obtained by using Matlab simulink. The observations are made the TC-IPC is improving the stabilization and power quality in distribution lines.

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