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# Performance Analysis of ZSI Based UPFC in Transmission System under Faulty Condition

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***Abstract:*** *UPFC (Unified power flow controller) is one of the most powerful and complex FACTS (Flexible AC transmission system) devices in a power system today. It is primarily used for simultaneous or independent control of real and reactive power in transmission lines for flexible, reliable and economic operation and loading of power systems. In this paper, the effectiveness of UPFC has been explored in transmission system network when subjected to three phase to ground fault condition. The comparison has been made between VSI (Voltage Source Inverter) based UPFC and ZSI (Z-Source Inverter) based UPFC. From the results so obtained, it has been established that the performance of ZSI based UPFC is superior as compared to that of VSI based UPFC.*
***Keywords:*** *UPFC, FACTS, VSI, ZSI.*

## I. Introduction

In interconnected power systems, it is important to have control over power transfer. FACTS devices have been shown to be effective in controlling power flow and damping power system oscillations. Unified power flow controller **(**UPFC) is one of the most complex FACTS devices in a power system today. UPFC allows simultaneous or independent control of all these three parameters, with possible switching from one control scheme to another in real time [1][2]. New concept of power transmission is to improve the power system stability and efficiency. The shunt and series part of Unified Power Flow Controller (UPFC) should be located at different places [3][4].The unified power flow controller consists of two switching converters. These converters are operated from a common dc link provided by a dc storage capacitor as shown in Fig. 1[5-7].

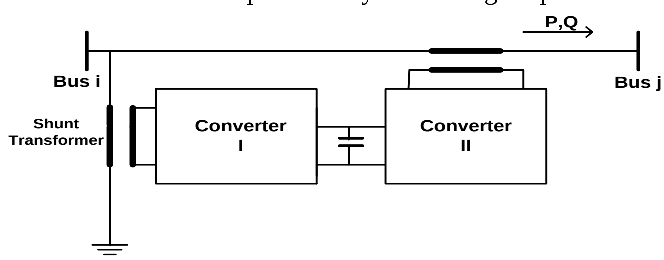


**Fig 1. UPFC**

## II. VSI Vs ZSI

The V-source converter is widely used. VSI is shown in Fig 2. VSI has the following limitations.

- The V-source inverter is a buck (step-down) inverter for dc-to-ac power conversion and the V-source converter is a boost (step-up) rectifier (or boost converter) for ac-to-dc power conversion.
- Wave distortion due to EMI (Electromagnetic Interference).
- An output LC filter is needed for providing a sinusoidal voltage, which causes additional power loss and control complexity [8] [9].

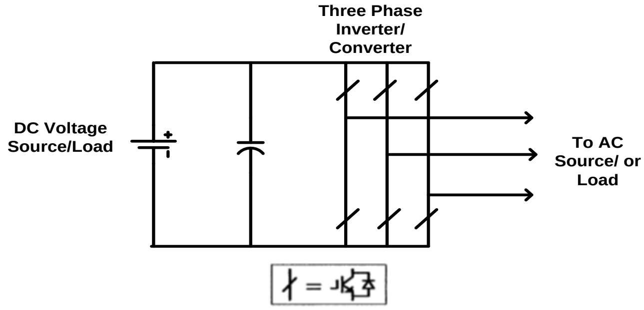


**Fig 2. VSI**

A two-port network that consists of a split-inductor and capacitors that are connected in X shape is employed to provide an impedance source (Z-source) coupling the inverter to the dc source, or another converter. Switches used in the converter can be a combination of switching devices and anti-parallel diode as shown in Fig 3.1.3 [9].

Z-source inverter can boost dc input voltage with no requirement of dc-dc boost converter or step up transformer, hence overcoming output voltage limitation of traditional voltage source inverter as well as lower its cost. Moreover, for Z-source inverter we have not to worry about EMI influence since shoot through are welcome and even exploited. This in turn enhances the inverter reliability [10].

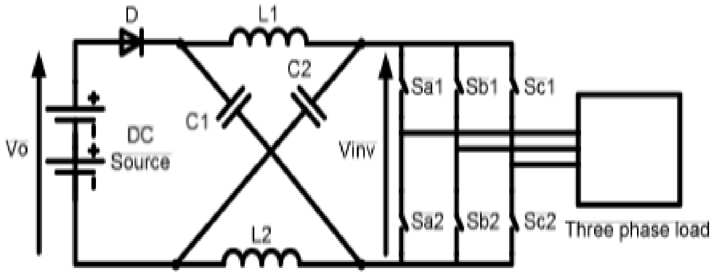


**Fig 3. ZSI**

The UPFC consists of series and shunt part. UPFC can be designed for VSI based series part or ZSI based series part.

## III. Simulation Models Under Three Phase Fault Condition

To study the response of VSI based UPFC and ZSI based UPFC under Three phase fault condition, Simulation models for two cases have been studies. The fault has been created for 0.01 sec in each case and the fault resistance is set to 0.01 ohms. In the simulation models, A Unified Power Flow Controller (UPFC) is used to control the power flow in a 500 kV transmission system. It consists of two 100-MVA, three-level, 48-pulse GTO-based converters. The shunt (STATCOM) and series(SSSC) converters can exchange power through a DC bus. The series converter can inject a maximum of 10% of line-to-ground voltage (28.87 kV) in series with line. PI control strategy is used. Different cases are studied under different conditions and results are shown at the end.

Case I is Power System with Programmable Voltage Source under Three phase to ground fault condition. Fault current level curve and $I^2R$ vs Time curve without using UPFC have been shown in Fig. 4 and Fig. 5 respectively. Fault current level curve and $I^2R$ vs Time curve with VSI based UPFC is shown in Fig. 6 and Fig. 7 respectively. Fault current level vs Time curve and $I^2R$ vs Time curve with ZSI based UPFC have been shown in Fig. 8 and Fig. 9, respectively.

Case II is Power System with Programmable Voltage Source and Hydropower plants under three phase to ground fault condition. Fault current level curve and $I^2R$ vs Time curve without using UPFC have been shown in Fig. 10 and Fig. 11 respectively. Fault current level vs Time curve and $I^2R$ vs Time curve with VSI based UPFC have been shown in Fig. 12 and Fig. 13, respectively. Fault current level vs Time curve and $I^2R$ vs Time curve with ZSI based UPFC have been shown in Fig. 14 and Fig. 15, respectively.

**Case I: Power System with Programmable Voltage Source**

**(i) Without UPFC**

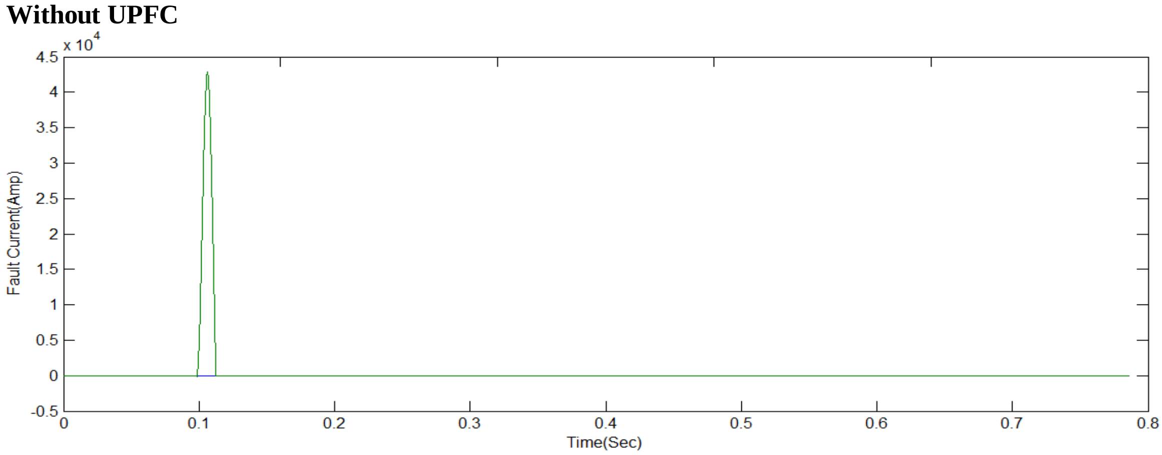


**Fig. 4. Fault Current Level**

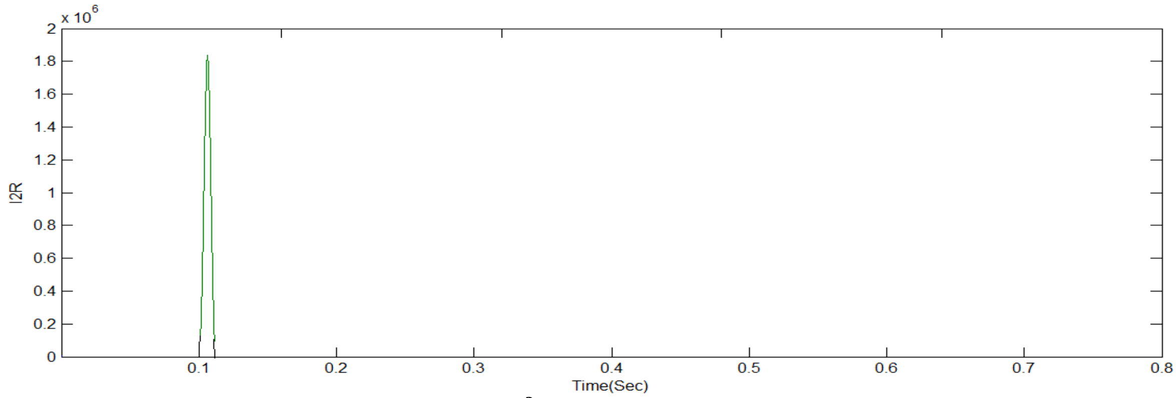


**Fig 5.I$^2$R vs time Curve**

**(ii) With VSI based UPFC**

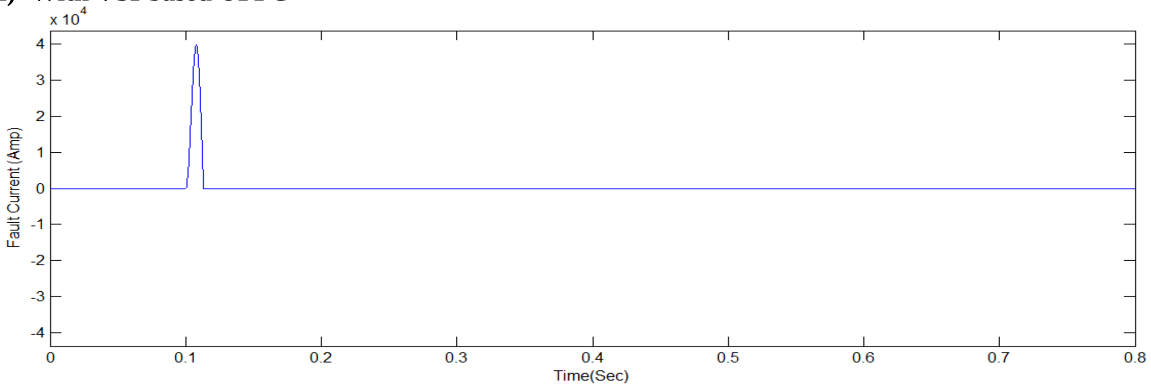


**Fig. 6. Fault Current Level**

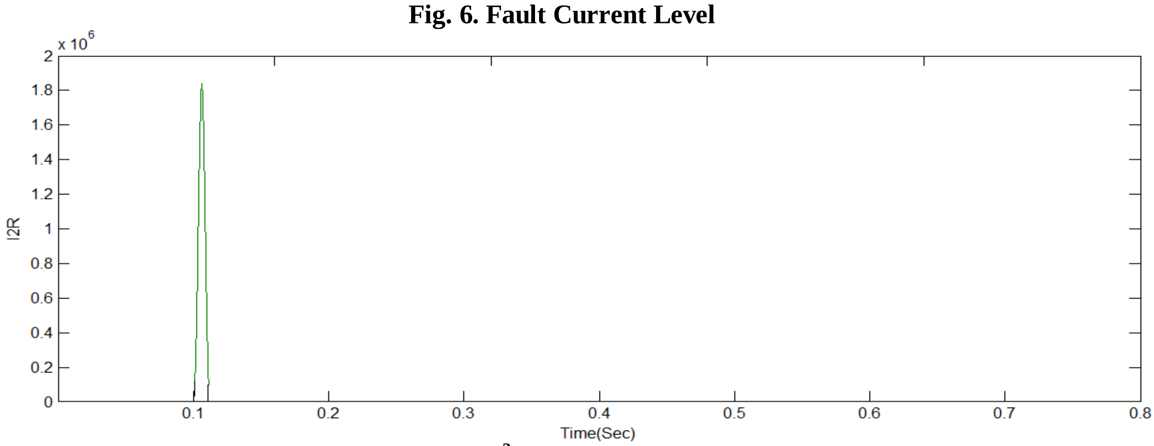


**Fig 7.I$^2$R vs time Curve**

**(iii) With ZSI based UPFC**

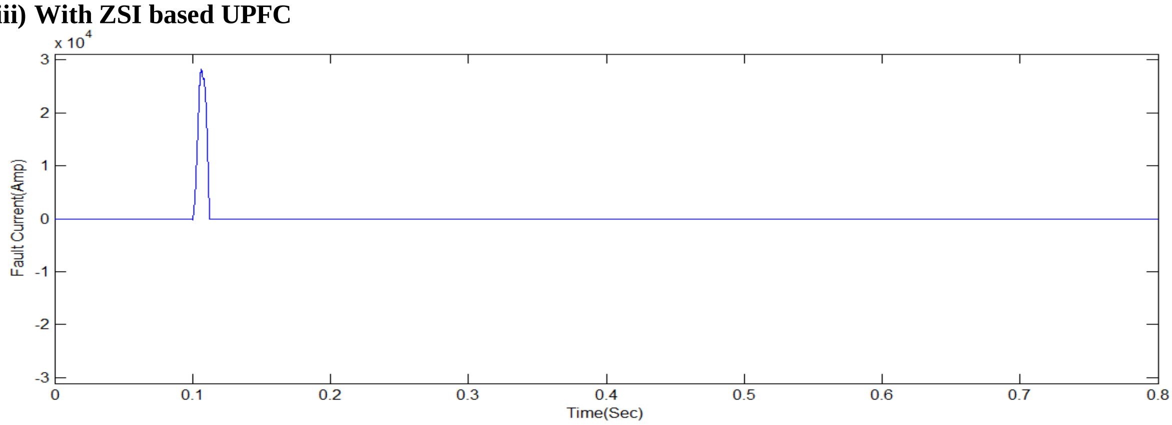


**Fig. 8. Fault Current Level**

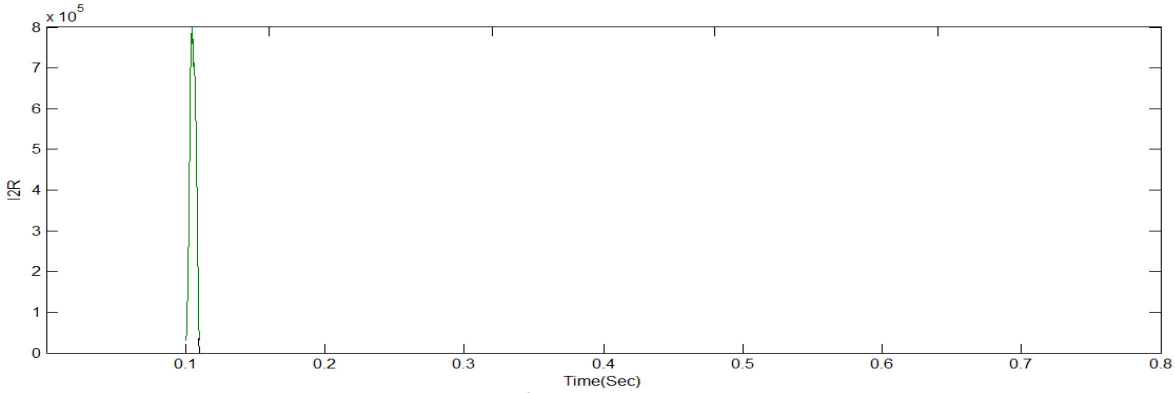


**Fig 9.I$^2$R vs time Curve**

**Case II: Power System with Programmable Voltage Source and Hydro power plant**
**(i) Without UPFC**

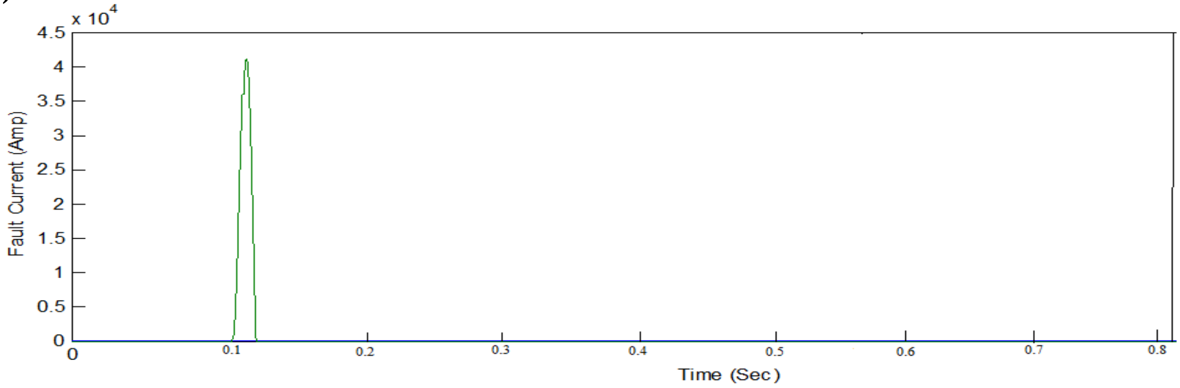


**Fig. 10. Fault Current Level**

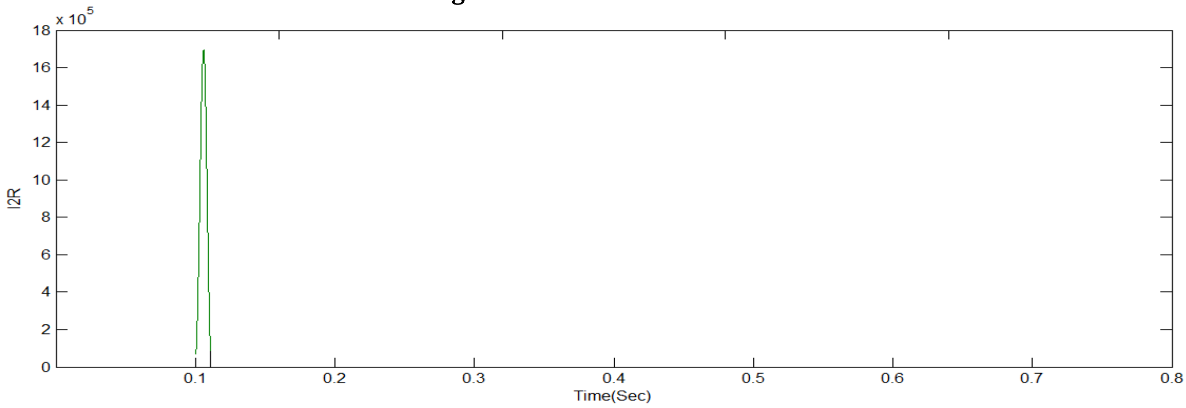


**Fig 11.I$^2$R vs time Curve**

**(ii) With VSI based UPFC**

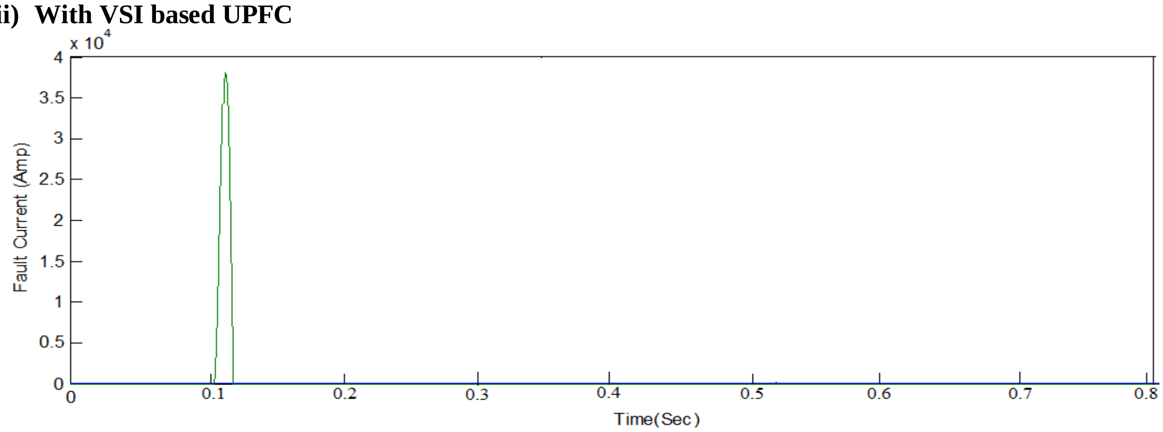


**Fig. 12. Fault Current Level**

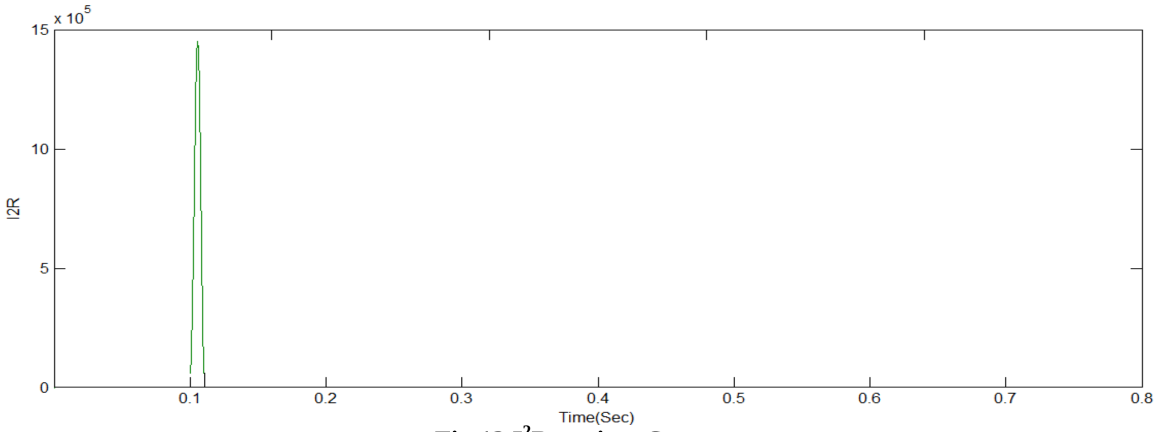


**Fig 13.$I^2R$ vs time Curve**

**(iii) With ZSI based UPFC**

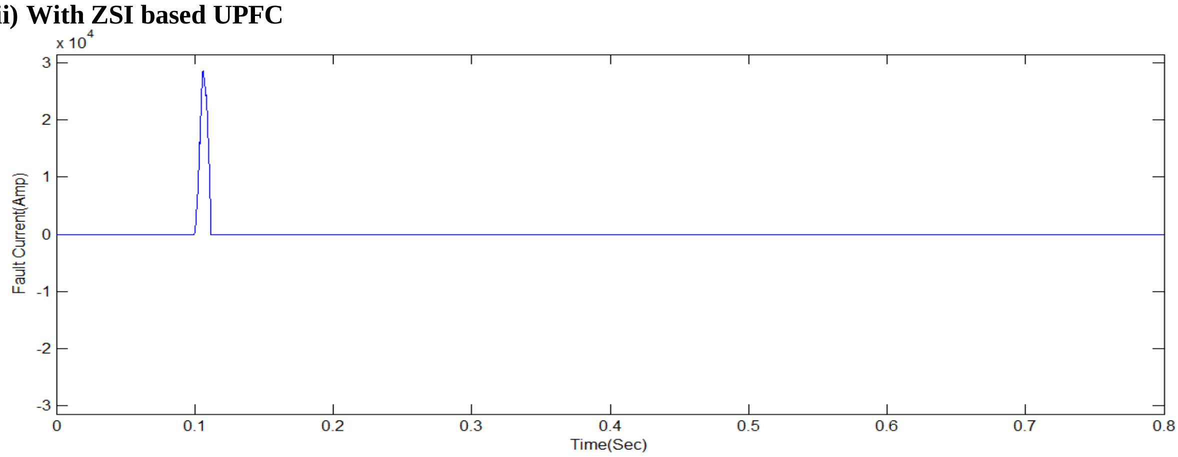


**Fig. 14. Fault Current Level**

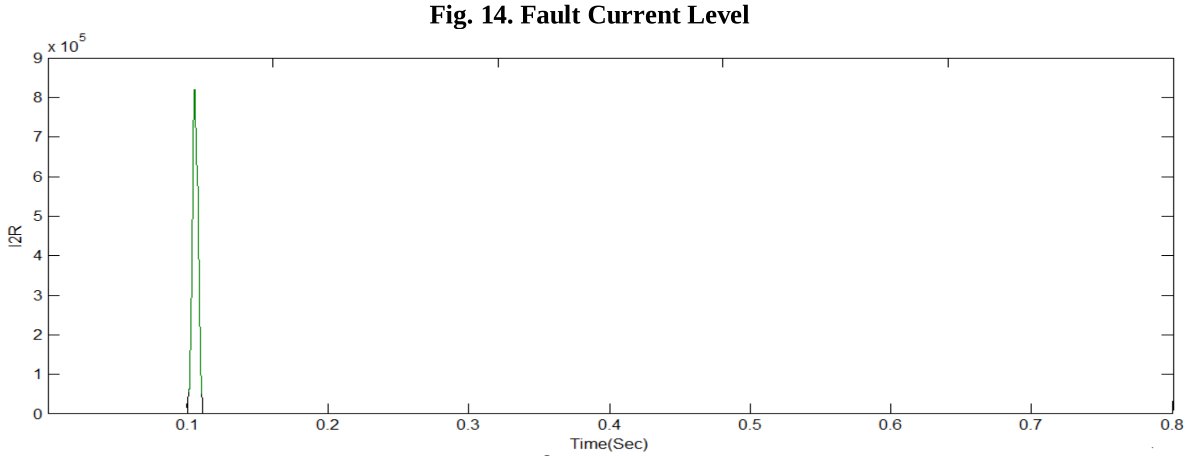


**Fig 15. $I^2R$ vs time Curve**

## IV. Results

| $I^2R$ Loss (Watt) | **Without UPFC** | **With VSI based UPFC** | **With ZSI based UPFC** |
|---|---|---|---|
| CaseI: Power System with Programmable Voltage Source | 9183 | 7866 | 4000 |
| CaseII: Power System with Programmable Voltage Source and Hydro Power Plant | 8470 | 7273.5 | 4100 |

## V. Discussions

In Case I, It has been observed that fault current has been reduced greatly with the use of VSI based UPFC and the magnitude is further reduced with the use of ZSI based UPFC. The $I^2R$ loss without using UPFC is 9183 Watt. By using VSI based UPFC it has been reduced by 1317 Watt and it is further reduced by 5183 Watt by using ZSI based UPFC.

In Case II, It has been observed that the fault current has been reduced greatly with the use of VSI based UPFC and the magnitude is further reduced with the use of ZSI based UPFC. The $I^2R$ loss without using UPFC is 8470 Watt. By using VSI based UPFC it has been reduced by 1196.5 Watt and it is further reduced by 4370 Watt by using ZSI based UPFC.

## VI. Conclusions

In this research work, simulation models for performance analysis in a transmission system without UPFC, with VSI based UPFC and with ZSI based UPFC have been made. The system models are observed with Programmable Voltage Source and with the combination of Hydro power plant and programmable Voltage source. The analysis is done on the basis of Fault level during Three phase to Ground Fault condition and $I^2R$ Loss in the system during Three phase to Ground Fault condition. From the results, following conclusions are obtained:

- It is also observed that the magnitude of oscillations is less when the system is provided with VSI based UPFC and the magnitude of oscillations has been further reduced by using ZSI based UPFC.
- The $I^2R$ Loss in the system is greatly reduced in case of VSI based UPFC and ZSI based UPFC as compared to the system without UPFC.

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