

## An Add on Self Tuning Control System Using PR Controller for UPFC Application

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**Abstract:** *The growing energy demand has caused the interconnected power systems to operate close to their stability limit. As a consequence, poorly damped low-frequency oscillations are becoming a common phenomenon. Such oscillations weaken the system security and if not effectively damped can lead to widespread blackouts. A relatively recent solution based on the advancements in high-power semiconductors is the Flexible AC Transmission System (FACTS) technology meant for transmission locations. FACTS technology comprises of a multitude of FACTS devices among which the Unified Power Flow Controller (UPFC) possesses a unique capability of providing both power flow and voltage control particularly, with a suitable transient control system the UPFC can satisfactorily mitigate power system oscillations. This thesis proposes an adaptive control scheme that supplements an existing Proportional Resonant (PR) UPFC control system in damping power system oscillations. PI controller can also be used but it has more steady state error than PR controller. However, its application in a power system that experiences continuously changing system conditions demands its frequent re-tuning. On the other hand, the proposed scheme in this project is a Self Tuning (ST) controller that automatically adapts to the system changes and thereby provides an optimal control for a wide range of operating scenarios. By using ST Controller the problem of retuning is get solved. The simulation results based on MATLAB/ SIMULINK were performed to verify the effectiveness of PR controller of UPFC.*

**Keywords:** Flexible AC Transmission System, Unified Power Flow Controller, self-tuning, proportional integral, proportional resonant.

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### I. INTRODUCTION

In recent years energy, environment, right-of-way, and cost issues have delayed the development of each generation facilities and new transmission lines, while the demand for electrical power has continued to grow. This situation has necessitated a review of the standard facility ideas and practices to attain larger operative flexibility and higher utilization of existing power systems. During the last two decades, if not revolution semiconductor, advances have been made in high management technology. These technologies have been instrumental within the broad application of HVDC transmission and facility intertie schemes, and they have already made a big impact on AC transmission via the increasing use of thyristor controlled static volt-ampere compensators (SVCs).

A Unified Power Flow Controller (or UPFC) is an electrical device for providing fast-acting reactive power compensation on high-voltage electricity transmission networks. It uses a pair of three-phase governable bridges to manufacture current that's injected into a cable employing a series electrical device. The controller can control active and reactive power flows in a cable. The UPFC uses solid state devices, which give purposeful flexibility, generally not possible by typical thyristor controlled systems.

The UPFC is a combination of a static synchronous compensator (STATCOM) and a static synchronous series compensator (SSSC) coupled via a standard DC voltage link. The main advantage of the UPFC is to manage the active

and reactive power flows within the cable. If there are any disturbances or faults in the supply aspect, the UPFC will not work. The UPFC operates only below balanced sin wave supply. The controllable parameters of the UPFC area unit electrical phenomenon in the line are impedance, phase angle and voltage.

The UPFC allows a secondary however vital perform such as stability management to suppress power grid oscillations up the transient stability of power grid [1]. The UPFC can give synchronous management of all basic power system parameters (transmission voltage, impedance and part angle). The controller can fulfill functions of reactive shunt compensation, series compensation and phase shifting meeting multiple management objectives. From a functional perspective, the objectives are met by applying a boosting electrical device injected voltage and an exciting electrical device reactive current. The injected voltage is inserted by a series transformer.

Unified power flow controller (UPFC) has been the most versatile Flexible AC gear mechanism (FACTS) device because of its ability to regulate real and reactive power on transmission lines whereas dominant the voltage of the bus to that it's connected. UPFC being a multi-variable grid controller it's necessary to investigate its effect on power system operation. In recent years, greater demands have been placed on the transmission network, and these demands will continue to increase thanks to the increasing variety of nonutility generators and heightened competition among utilities themselves. Increasing demand on transmission, absence of long term planning and the ought to give open access to generating corporations and customers all at once have created tendencies toward less security and reduced quality of offer. This controller offers substantial advantages for the static and dynamic operation of power system. The UPFC is the most versatile and sophisticated power equipment that has emerged for the control and optimization of power flow in wattage transmission systems.

## **II. LITURATURE SURVEY**

In this paper “An Add-On Self-Tuning system for a UPFC Application” paper an add-on self-tuning (ST) management theme for a Unified Power Flow Controller (UPFC) to help its conventional PI management system in damping power oscillations is represented. For a wide range of operational conditions, the conventional PI-UPFC unless retuned suffers from scant non optimal damping performance. To overcome this drawback, the authors propose supplementing the PI controllers with an ST feedback loop comprised of a symbol and a postscript control rule [1].

The most purpose of the paper “Optimum Tuning of Unified Power Flow Controller via Ant Colony Optimization Technique” is to spot the optimum location of the Unified Power Flow Controller UPFC in wattage systems. In this paper, the CPF technique is used within the proposed algorithmic rule to spot the candidate buses for the UPFC placement [2].

In this paper “facility Security Improvement Using the Unified Power Flow Controller (UPFC)” a rule to notice the operative purpose of UPFCs for the improvement of system security level is presented. The sensitivity indicating the change of the index due to the changes within the UPFC real power output is calculated. In each iteration, according to this sensitivity, the proposed rule finds a new UPFC operative purpose to scale back the index or increase the safety margin. The projected rule enhances the security level of power system [3].

In this paper “Application of UPFC to Increase transient stability of Inter-Area Power System.” the improvement of transient stability of inter-area power system is presented. The mathematical model of UPFC is present in this paper. UPFC can be modeled as fictitious active and reactive load of power system. To incorporate UPFC into power system, the fictitious load models are transferred to susceptance models. These models can be controlled by parameters on a UPFC. This paper uses the line power flow between area 1 and area 2 to control a UPFC [10].

This paper “Load flow studies with upfc power injection model” focused on to improve the bus voltage and to reduce the active and reactive power losses in the transmission lines incorporating steady state model of UPFC in

Newton-Raphson (NR) power flow algorithm. The steady state model of the UPFC, derived from two voltage source representation, is presented and analyzed in detail [11].

In this paper “the unified power flow controller. a new approach to power transmission control” there is a description of the basic concepts of the proposed generalized P and Q controller and compares it to the more conventional, but related power flow controller such as the Controlled Series Capacitor and Thyristor Controlled Phase Angle Regulator. The paper also presents results of computer simulations showing the performance of the UPFC under different system conditions, providing the necessary functional flexibility required to solve many of the problems facing the utility industry [12].

In “Application of UPFC-based Adaptive Controller for Damping Inter-Area Oscillations “ paper a UPFC-based non-linear adaptive controller is proposed and designed to damp the tie line power oscillations. The adaptive controller design is based on determination of control signal using a new linear quadratic pole placement control law and identification of power system parameters using recursive least squares method with variable forgetting factor. This paper also describes the recently introduced proportional resonant (PR) and their quality for grid-connected converters current control [15].

### III. SYSTEM OVERVIEW

#### ➤ Unified power flow controller

The Unified Power Flow Controller is consists of two switching converters, that are considered as voltage sourced inverters using gate thyristor valves. These inverters "VSC1" and "VSC2" are operated with a common dc link provided by a dc storage capacitor. With this arrangement the ac power converter in which the active power can freely flow in either direction between the ac terminals of the two inverters and each inverter can severally produce as well as absorb the reactive power at its own ac output terminal. Since the series converter of the UPFC will inject a voltage with variable magnitude and phase angle it can exchange active power with the transmission line with the help of series transformer. However a UPFC as a whole (both converter) cannot supply or absorb active power in steady state (except for the power drawn to compensate for the losses). Until it has a power source at dc terminals. Therefore the shunt branch is needed for compensate (from the system for any real power drawn/supplied by the series branch and the losses. When the power balance is not maintained, at that time the capacitor cannot remain at a constant voltage. Shunt branch also can independently exchange reactive power with the system. Inverter 2 provides the main function of the UPFC by injecting a voltage  $V_{pq}$  with controllable magnitude  $V_{pq}$  ( $0 \leq V_{pq} \leq V_{pqmax}$ ) and phase angle  $\rho$  ( $0 \leq \rho \leq 360^\circ$ ), at the power frequency, insert with line by an insertion transformer. This injected voltage considered as synchronous ac voltage source.

The function of converter1 is to provide or absorb the active power required by converter 2 at the common dc link. The power of the dc link is converted back to ac and coupled to the transmission line by a shunt-connected transformer. If reactive power is needed then inverter 1 can also produce or absorb controllable reactive power, so it can provide independent shunt reactive compensation for the line. It is also important to note that whereas there is a closed "direct" path for the active power negotiated by the action of series voltage injection through Inverters 1 and 2 back to the line, corresponding the reactive power exchanged is supplied or absorbed locally by Inverter 2 and therefore the reactive power cannot flow through the line. So the Inverter 1 can be operated at a unity power factor or be controlled to have a reactive power exchange with the line independently of the reactive power exchanged by Inverter 2. That means there is no continuous reactive power flow. Inverter-1 is connected to the power system through a transformer T1 in shunt and the inverter-2 power system through another transformer T2 such that the secondary of the transformer T2 is in series

with the transmission line. The transformers T1 and T2 can be referred to as shunt and series transformers respectively for the purpose of clarity.

Where the shunt inverter and series inverter of a UPFC are modeled as a voltage source series with their transformer reactance is the simplest of all the models. The model provides for detailed interaction between the series and the shunt inverter. Figure shows the UPFC model. Xsh and Xse represent the reactance of transformers T1 and T2 respectively. Vsh and Vse, represent the voltage generated by the shunt and the series inverter respectively. Bus-E and bus-F represent the UPFC bus and the transmission line side bus of UPFC respectively.

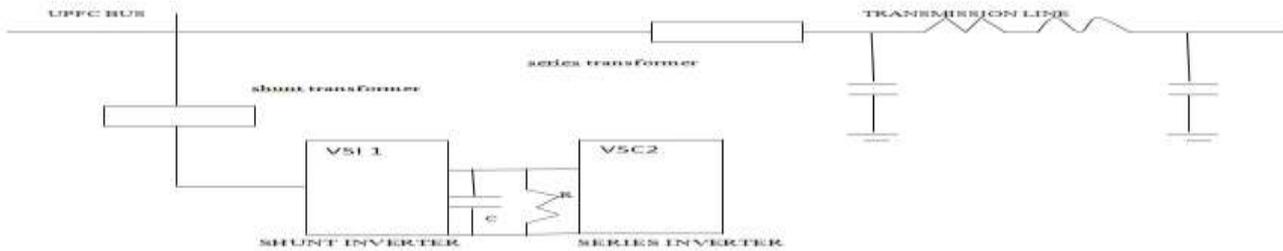


Figure 1: Unified power flow controller configuration

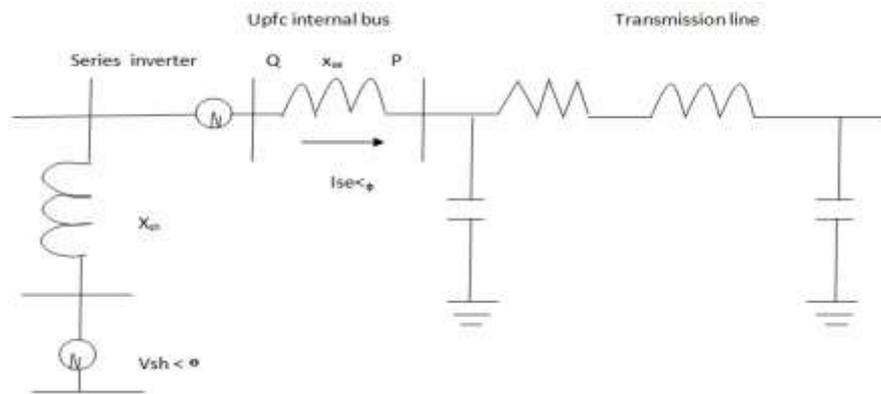


Figure 2:UPFC model

For performing load flow studies with UPFC, the series and the shunt inverters are assumed to produce balanced 50 Hz voltages of variable magnitude and phase angle. The shunt and the series voltage sources phasors can be mathematically represented as

$$\hat{V}_{sh} = V_{sh} (\cos \theta_{sh} + j \sin \theta_{sh})$$

$$\hat{V}_{se} = V_{se} (\cos \psi_{se} + j \sin \psi_{se})$$

Where  $V_{sh}$  and  $V_{se}$ , are the root mean squared magnitudes of the shunt and the series voltage sources.

### ➤ UPFC CONTROLL SYSTEM

The unified power flow controller (UPFC) is one of the most commonly used FACTS controllers and its main function is to control the voltage, phase angle and impedance of the power system thereby modulating the line reactance and controlling the power flow in the transmission line. The main components of the UPFC are two voltage source inverters (VSIs) connected by a common dc storage capacitor which is connected to the power system by a coupling transformers. One (VSIs) is connected in shunt to the transmission system through a shunt transformer, while the another (VSIs) is connected in series to the transmission line by a series transformer. Three phase system voltage of controllable magnitude and phase angle ( $V_c$ ) are inserted in series with the line to control real and reactive power flows in the

transmission line. So, this inverter will exchange active and reactive power within the line. The shunt inverter is operated in such a way as to demand this dc terminal power (positive or negative) from the line keeping the voltage across the storage capacitor ( $V_{dc}$ ) constant.

There are many possibilities of operating configurations by combing two or more converter blocks with flexibility. Among them, there is a novel operating configuration, namely the Generalized Unified Power Flow Controller (GUPFC) which is significantly extended to control power flows of multiline or a sub-network rather than control power flow of single line by a Unified Power Flow Controller (UPFC) or Static Synchronous Series Compensator (SSSC). The UPFC consists of two branches. The series branch consists of a voltage source converter which injects a voltage in series by a transformer. Since the series branch of the UPFC can inject a voltage with variable magnitude and phase angle it can exchange active power with the transmission line. The energy storing capacity of this dc capacitor is generally small. Therefore, real power drawn by the shunt converter should be equal to the real power produced by the series converter. The reactive power in the shunt or series converter can be chosen independently, giving greater flexibility to the power flow control. The coupling transformer is used to connect the device to the system.

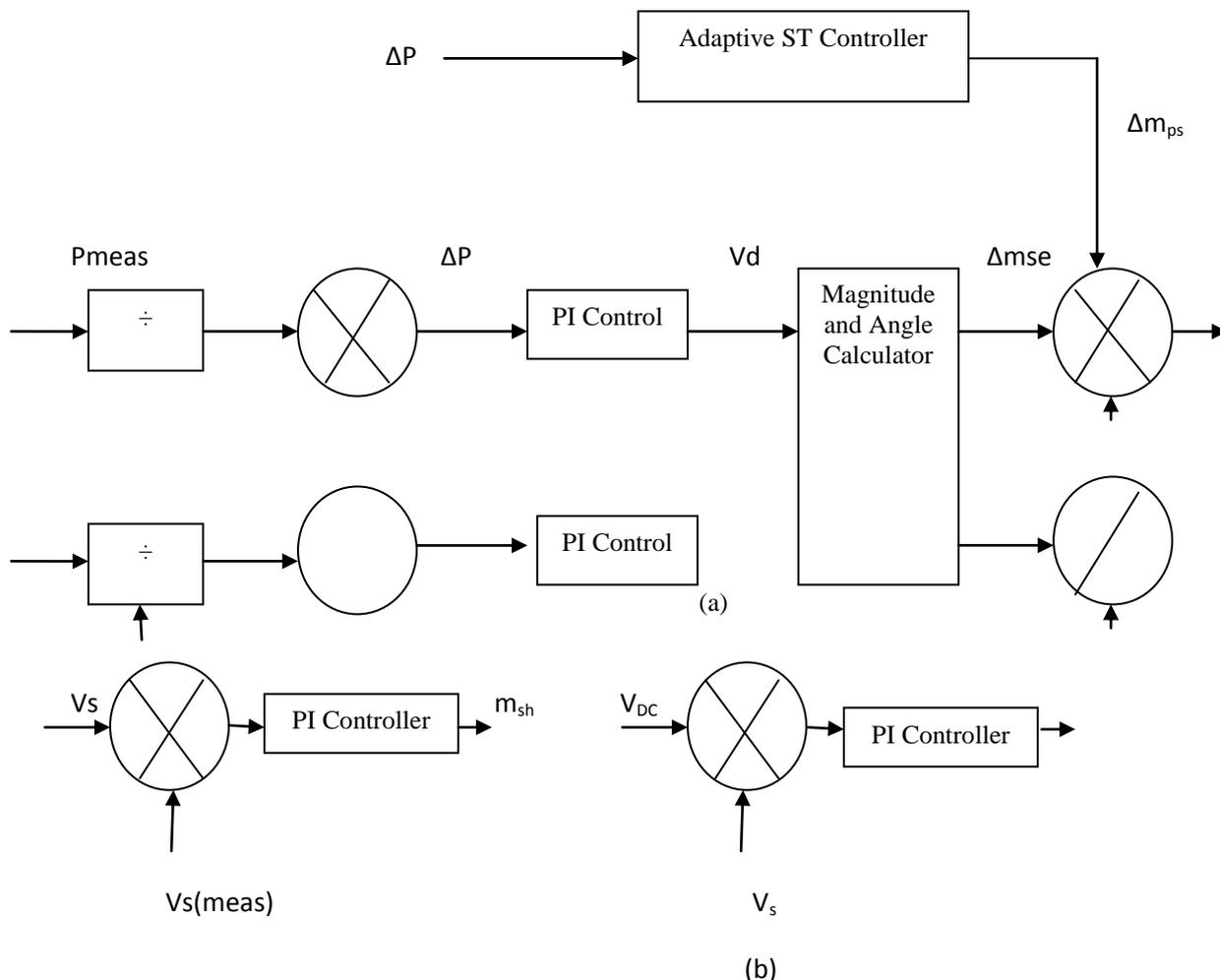


Figure 3: Overall UPFC control system for a damping application. (a) Series VSC control system; (b) Shunt VSC control system.

### ➤ PR controller:-

Gain at a certain frequency (resonant frequency) is provided by PR controller and normally no gain exists at another frequency. The transfer functions of single and three phase PR controllers and filters can be derived using internal model

control, modified state transformation or frequency-domain. PI controller has more steady state error than PR controller. PR controller is also able to identify and eliminate harmonic, which is not possible with PI controller .Using the PR controllers, the converter reference tracking performance can be enhanced and previously know drawbacks associated with conventional PI controllers can be alleviated.

### ➤ Proportional Integral (PI) Controller:-

Now days, the PI controller is most commonly used in industrial application due to its simple structure, easy to design and low cost. Despite these advantages, the PI controller fails when the controlled object is extremely nonlinear and uncertain. PI controller will remove forced oscillations and steady state error resulting in operation of on-off controller and P controller respectively. However, introducing integral mode has a negative effect on speed of the response and overall stability of the system. Thus, PI controller can not increase the speed of response. It can be expected since PI controller cannot have means to predict what will happen with the error in near future. This problem can be resolved by introducing derivative mode which has ability to predict what will happen with the error in near future and thus to decrease a reaction time of the controller. PI controllers are very often used in industry, especially when speed of the response is not an issue.

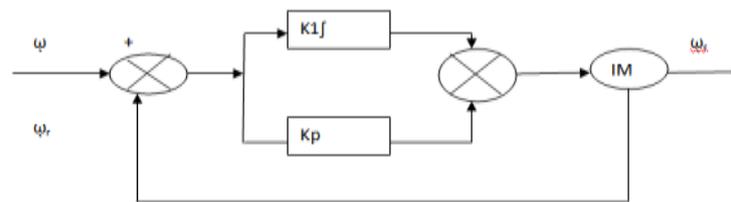


Figure 4. Block diagram PI controller

Block diagram PI controller an integral error compensation scheme, the output response depends in some manner upon the integral of the actuating signal.

### IV. SYSTEM'S SIMULATION AND RESULTS

In this phase system of 25 kv, 100MVA is used. One 3 phase Pi section feeder of 21km and another feeder of 2 km is used. Then one RC system is used for storing the active power in the system. We have also used 2 coupling transformer, one is shunt coupling transformer which will take or inject voltage from or to shunt converter or transmission line. Another transformer is series coupling transformer which connects series converter to transmission line and exchange of power between series converter and transmission line is done by series transformer.

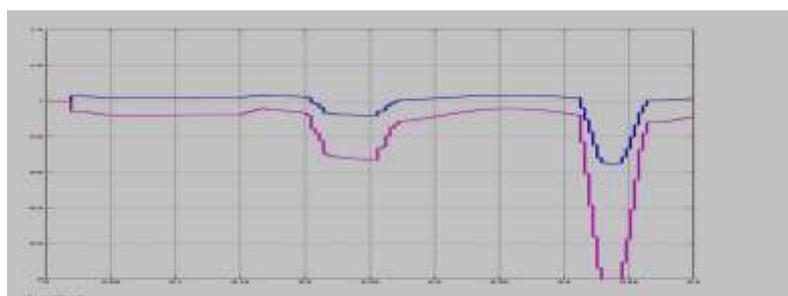


Figure 5: Voltage waveform of series transformer of UPFC

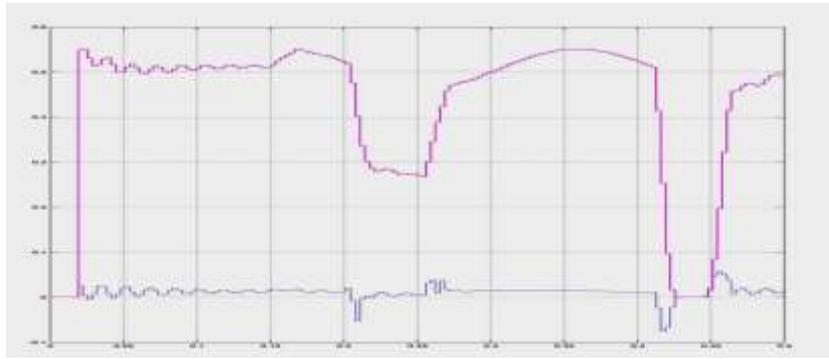


Figure 6: Active and reactive power of series transformer of UPFC

The above 2 figure (fig 5 and 6) graphs shows the voltage, active and reactive power waveform of series transformer of Unified power flow controller. As there is a 3 phase fault between 0.4 to 0.45s and single line to ground fault between 0.2 to 0.25sec, there is a distortion and drop in wave at that time.

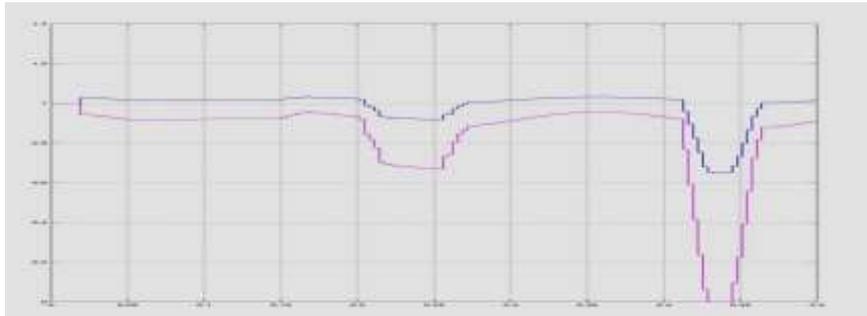


Figure 7: Voltage of shunt transformer of UPFC



Figure 8: Active and reactive power of shunt transformer of UPFC

The above 2 figure (fig 7 and 8) graphs shows the voltage, active and reactive power waveform of shunt transformer of Unified power flow controller. As there is a 3 phase fault between 0.4 to 0.45s and single line to ground fault between 0.2 to 0.25sec, so there is a distortion and drop in wave at that time.

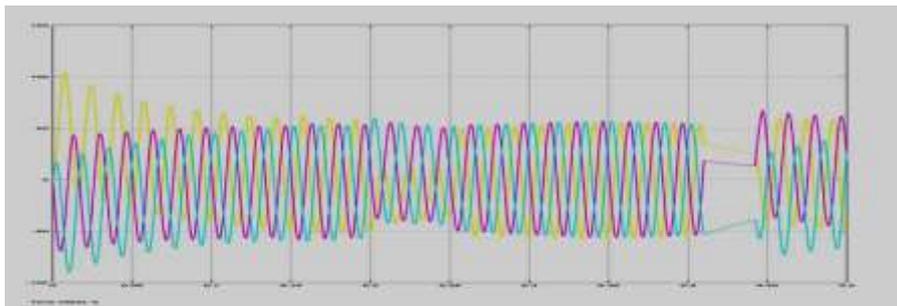


Figure 9: Three phase current near shunt transformer of UPFC

The above graph shows the 3 phase current waveform of shunt transformer of UPFC. As there is a fault between 0.4 to 0.45s and single line to ground fault between 0.2 to 0.25sec, so there is a distortion and drop in wave at that time. We can see that as soon as the fault is cleared the (current) wave are trying to take there stability position.

## CONCLUSION

The Unified Power Flow Controller (UPFC), with its unique combination of fast shunt and series compensation, is a powerful device which can provide power regulation, i.e. voltage magnitude and phase control. The add-on self tuning with PR controller provided significant damping improvement for the inter-area mode as compared to the conventional PI-UPFC controllers. The use of constrained-RLS over the standard RLS identifier for online parameter identification ensured favorable control performance even during large disturbances. UPFC can be used to improve transient stability margin or to damp low frequency oscillations. The UPFC is the versatile and sophisticated power equipment that has emerged for the control and optimization of power flow in transmission systems. It offers major potential advantages for the static and dynamic operation of transmission lines.

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