Development and Analysis of MATLAB for Improvement in transmission system parameters using UPFC

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Abstract— **The Unified Power Flow Controller (UPFC) is a robust power regulation device that functions as both a series and shunt compensator, effectively managing active and reactive power in power transmission lines. UPFC is primarily used to reduce voltage sag and swell, enhancing power system stability. Its circuit design integrates a rectifier and inverter, enabling dynamic control over power flow. By implementing UPFC in a MATLAB/Simulink environment, power quality is improved through real-time voltage regulation. The simulation results validate UPFC's ability to suppress fluctuations by analyzing frequency response, voltage deviations, and reactive power support. In case of system faults or disturbances, UPFC ensures rapid stabilization, significantly outperforming systems without it. This study highlights the effectiveness of UPFC in maintaining power system stability, optimizing voltage control, and improving energy transmission efficiency by mitigating fluctuations in voltage levels and reactive power variations.**

Keywords: UPFC,FACTS,MATLAB etc.

I. INTRODUCTION

The ongoing deregulation of power systems around the world may not only bring cheaper electricity and better service to the customers but also present new technological challenges to the power industries and researchers. In a deregulated environment, the open access to the transmission networks requires adequate Available Transfer Capability (ATC) to guarantee economic transactions However, in a privatized electricity market, the major traditional ways to enhance ATC, such as rescheduling active power generations, adjusting terminal voltage of generators, and changing taps of on-load tap changer, etc, may not be centrally controlled by the transmission network owner or system operator. Construction of new transmission lines has always been an option, but it is subject to tougher and tougher environmental restrictions and sometimes social problems too. With the availability of the fully controlled semiconductor devices such as the Gate Turn-off Thyristor (GTO) and the Insulated Gate Bipolar Transistor (IGBT), and the invention of new topologies, i.e. the combination of multiple compensators, the hitherto most powerful and versatile group of FACTS devices, namely combined compensators, has been developed. Its representatives include the Famous Unified Power Flow Controller (UPFC) and the Interline Power Flow Controller (IPFC). The latter is the latest generation of FACTS devices. It is well known that heavily loaded lines and buses with relatively low voltages are factors that significantly limit

1. The power system is an interconnection of generating units to load centers through high voltage electric transmission lines and in general is mechanically controlled.

2. It can be divided into three subsystems: generation, transmission and distribution subsystems. Until recently all three subsystems were under supervision of one body within a certain geographical area providing power at regulated rates

3. A special arrangement of two SVSs, one connected in series with the ac system and the other one connected in shunt, with common dc terminals is called Unified Power Flow Controller (UPFC). It represents series - shunt type of controller.

With the advancement of interconnection of enormous electric force frameworks there have been unconstrained framework motions at low frequencies in the request for a few cycles for every moment. These low recurrence motions are overwhelmingly because of the absence of damping of mechanical method of the framework. Since power swaying is a supported unique function, it is important to differ the applied remuneration to check the quickening and decelerating swings of the upset machine. The idea of Flexible AC transmission framework (FACTS) conceives the utilization of strong state regulators to accomplish adaptability of intensity framework by quick and dependable control of intensity framework boundaries influencing power stream in transmission line, specifically voltage, impedance as well as stage point.

Bound together Power Flow Controller (UPFC), a multifunctional Flexible AC Transmission framework (FACTS) Controller opens up new open doors for controlling force and improving the usable limit of present, just as new and updated lines. An UPFC advantageous damping regulator has been introduced in the UPFC control framework for damping the electromechanical mode motions. In efficient plan of four option UPFC damping regulators are introduced. Notwithstanding, these UPFC damping regulator gains are planned based on ostensible working conditions and stay autonomous of framework working conditions and line loadings. Likewise the regulator gains and subsequently the control structure is distinctive for the different decisions of UPFC control signals. Since damping of low recurrence motions might be one of the optional elements of the multifunctional UPFC dependent on its other significant control tasks, the broadly differing control structure as for the decision of control signals makes the continuous execution unyielding. This work proposes a versatile fluffy deduction framework (ANFIS) based UPFC advantageous damping regulator to superimpose the damping capacity on the control sign of UPFC for damping of intensity framework electromechanical motions. The versatile fluffy regulator is gotten by installing the fluffy derivation framework into the structure of versatile networks.

The proposed ANFIS based damping regulator execution is inspected for the four decisions of UPFC control signals dependent on balancing record and voltage stage point of UPFC arrangement and shunt converters by reproductions on a linearized Philips-Hefron model of a force framework with UPFC. The viability of this regulator is upheld by the outcomes seen in reenactments, which show the capacity of the regulator in damping motions over a wide reach of loading conditions and system parameters with the four choices of alternative UPFC control signals when compared to constant gain damping controllers designed using phase compensation technique at selected operating point.ntegrating this approach to a multi-machine power system and through non- linear simulation the robustness of theproposed controller is validated.

II. PROBLEM IDENTIFICATION

Electric power system regularly faces disturbances due to its dynamic nature and also high-power quality is the big difficulty due to greater number of nonlinear loads. So, there is need to restrict these disturbances and mitigates the issues of power quality to improve its performance. The Flexible Alternating Current Transmission (FACTS) devices such as UPFC are becoming important in suppressing power system oscillations and improving system damping.

Causes Of Poor Power Quality:

- Variation of voltage magnitude and frequency.
- Variation in magnitude can be due to sudden rise or fall of load, outages, power electronics converter, inverter, lightning, etc.
- Variation in frequency can rise of out of system dynamics or harmonics injection.

III. METHODOLOGY

A. Overview

The basic components of UPFC are two voltage source inverters (VSIs) sharing a common dc storage capacitor which is connected to the power system through coupling transformers. One of the VSI is connected to power system via a shunt transformer, while the other one is connected in series through a series transformer. A basic UPFC functional diagram is shown in Fig. 1. The series inverter is operated to inject a symmetrical three phase voltage system (Vse), of controllable magnitude and phase angle in series with the line to control active and reactive power flows on the power system. So, this inverter will exchange active and reactive power with the line. The shunt inverter is operated in such a way that it demands the dc terminal power (positive or negative) from the line keeping the voltage across the storage capacitor Vdc constant. So, the net real power absorbed from the line by the UPFC is equal only to the losses of the inverters and their transformers.

In this case the shunt inverter is operates as a STATCOM that generates or absorbs reactive power to regulate the voltage magnitude at the connection point. On the other hand the series inverter is operates as SSSC that generates or absorbs reactive power to regulate the current flow, and hence the power flow on the Power system. The UPFC has many possible operating modes. In particular, the shunt inverter operates in such a way that it injects a controllable current, Ish into the transmission line. The shunt inverter can be controlled in two different modes. A.VAR Control Mode: The reference input is an inductive or capacitive VAR request. The shunt inverter control translates the var reference into a corresponding shunt current request and adjusts gating of the inverter to establish the desired current. For this mode of control a feedback signal representing the dc bus voltage, Vdc, is also required. B. Automatic Voltage Control Mode: The shunt inverter reactive current is automatically regulated to maintain the transmission line voltage at the point of connection to a reference value. For this mode of control, voltage feedback signals are obtained from the sending end bus feeding the shunt coupling transformer.

B. Basic Structure of UPFC

UPFC performs three compensation functions simultaneously which are voltage, phase angle and impedance by varying reactance of line and controlling flow of power in the transmission and distribution lines. UPFC contains dual voltage source converters one is shunt while other is series converter. These converters are merged by a common dc link. Converters are connected with the transmission line through shunt and series transformers [3].

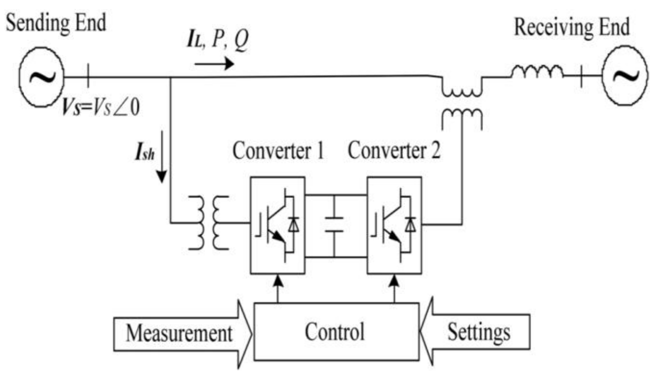

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Fig. 1: basic structure of UPFC

Basic structure of UPFC is shown in Fig. 1. Shunt controller performs the function of controlling reactive power and it also provide dc power necessary for combined converters whereas controlling the phase angle and magnitude of voltage in series with the transmission line is done by series converter. The UPFC fundamentally introduce voltage in series with the line. Phase angle and magnitude of voltage can varies between 0 to 2π with respect to the terminal voltage and from 0 to defined maximum value respectively [4]. VAR control and automatic voltage control modes are two possible modes of UPFC. In first control mode, the reference input is inductive or capacitive VAR request and maintain line voltage at the connection point to a reference value is the aim of automatic voltage control mode [5]. The real and reactive powers controlled by unified power flow controller are determined by the following equations,

$$P = \frac{V_S V_R}{X} \operatorname{Sin}(\alpha - \beta) \quad (1)$$

$$Q = \frac{V_R}{X}(V_S - V_R) \quad (2)$$

C. Operation and Modelling of UPFC

The Unified Power Flow Controller (UPFC) was originally proposed for true-to-time control and dynamic compensation of AC transmission systems.The integrated current controller consists of two switching converters, which are treated as voltage sorter inverters using a gate thyristor valve. These inverters, identified as "VSC1" and "VSC2", operate on the common dc link provided by the dc storage capacitor. With this arrangement the AC power converter in which the actual power flows freely between the AC terminals in any direction. Both inverters and each inverter can generate independently and simultaneously absorb the reactive power at their own AC output terminals. Since UPFC's series converter can inject voltage with variable magnitude and phase angle, it converts real power with the transmission line. With the help of series transformers. However, UPFC (both converters) cannot be supplied or absorbed in a stable state in reality (except for energy designed to compensate for losses). Therefore, the shunt branch is required to pay compensation (for any real power drawn / supplied and damaged by the chain branch. When the power balance is not maintained, the capacitor kn t a is at a constant voltage. The shunt branch system freely converts the reactive power.

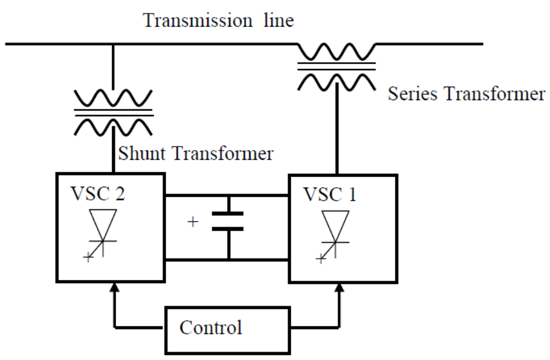

Fig: 2 The Schematic diagram of UPFC

VSC 2 provides the main function of the UPFC by injecting Vpq (0≤ Vpq≤ Vpq max) and phase angle ρ (0≤ρ ° 360 °) with controllable magnitudes, at low frequency frequency injection. Insert with line from. Transformer.

This injection voltage is considered to be the source of synchronous AC voltage. The transmission line present day flows through this voltage supply, ensuing in a real and reactive power change between it and the ac machine. The real power exchanges at the AC terminal (i.e. at the terminal of the insert transformer) and the inverter help to convert the AC power to DC power, then DC power appears as positive or negative real power demand in the DC link. . The inverter of reactive power is generated internally at the AC terminal. The function of converter 1 is to supply or absorb the actual power requested by converter 2 via a simple DC link.

The power of the DC link is converted to AC and with the help of shunt-connected transformer , it connected to the transmission line . VSC 1 can also produce or absorb controllable reactive power if reactive power is required, so it provides independent shunt reactive compensation for the line. When the reactive energy is exchanged or absorbed by the local inverter, the inverse inverters 1 and 2 are the “direct” path to the actual power by the series voltage injection action. 2 and therefore the reactive energy does not flow from the line. Therefore, the inverter 1 can be operated in a unified power factor or controlled to maintain a reactive power conversion along the line independently from the reactive power exchanged by the inverter. This means that there is no continuous reactive current flow through the UPFC. Unified current controllers from the standpoint of conventional power transmission based on reactive series compensation, shunt compensation and phase changes, UPFC is the only device that can accomplish all these functions and thereby achieve multiple control targets by adding injected voltages. Does. The basic UPFC power flow control function is illustrated in Fig.3, using the phasor representation, with the appropriate amplitude and phase angle to the terminal voltage V0.

D. Basic Principle of P & Q Control

Consider fig.3 End voltage sending, receiving end voltage VR and line (or tie) impedance X (for simplicity, considered as inductor) are shown in a two-machine (or two bus AC inertia) system. Fig. 4. The voltage transmissions of the system are shown as a phase diagram with transmission and │Vs│ = │Vr│ = │V│.

Transmitted Power P= $P(P-\left(\frac{V^2}{X}\right)\sin\delta$ and the reactive power Q =Qs= $Q_r(Q-\left(\frac{V^2}{X}\right)(1-\cos\delta)$ supplied at the ends of the line are shown plotted against angle δ.

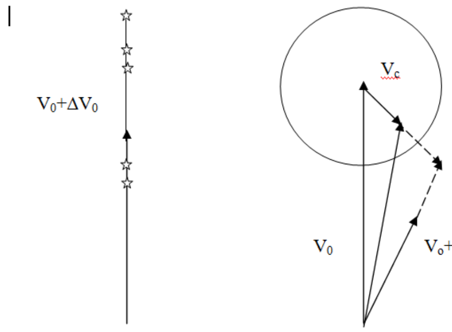

Fig 3 Basic UPFC control function. (a)Voltage Regulation (b) Series compensation.

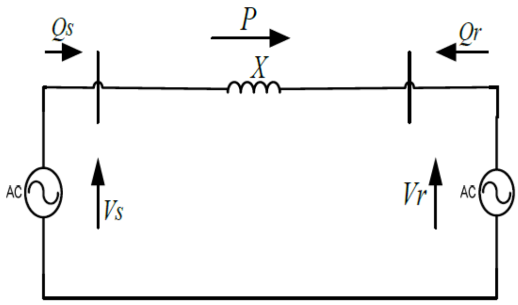

Fig 4 Simple two machine system

It can be easily found in figs. The transmission line sees Vs + Vpq as the effective transmission end voltage. Therefore, it is clear that the UPFC affects the voltage across the transmission line (both its size and angle) and therefore it is reasonable to expect that it can realistically control the size and angle of the Vpq. The reactive force demand of the line at any transmission angle between the sending and ending.

$$V_{pq}=\Delta V+V_{\sigma}+V_q \tag{3}$$

$$Q_r\{Q_{ro}(\delta)-1\}^2+\{P_0(\delta)\}^2=1 \tag{4}$$

When Vpq=0 then

$$P=jQ_r=V_r\left(\frac{V_s-V_r}{jX}\right)^* \tag{5}$$

When Vpq≠0 then

$$P=jQ_r=V_r\left(\frac{V_s-V_r}{jX}\right)^*+\frac{V_rV_{pq}}{-jX} \tag{6}$$

Substituting

$$V_s=Ve^{j\delta/2}=V\left(\cos\left(\frac{\delta}{2}\right)+\sin\frac{\delta}{2}\right) \tag{7}$$

$$V_r=Ve^{-j\delta/2}=V\left(\cos\left(\frac{\delta}{2}\right)-\sin\frac{\delta}{2}\right) \tag{8}$$

And

$$V_{pq}=V_{pq}e^{-j\left(\delta/2+\rho\right)}=V_{pq}\left(\cos\left(\frac{\delta}{2}+\rho\right)-\sin\left(\frac{\delta}{2}+\rho\right)\right) \tag{9}$$

The following expressions are obtained for P and Qr

$$P(\delta,\rho)=P_o(\delta)+P_{pq}(\rho)=\frac{V^2}{X}\sin\delta-\frac{V_{pq}}{X}\left(\cos\frac{\delta}{2}+\rho\right) \tag{10}$$

$$Q_r(\delta,\rho)=Q_{ro}(\delta)+Q_{pq}(\rho)=\frac{V^2}{X}(1-\cos\delta)-\frac{V_{pq}}{X}\left(\sin\frac{\delta}{2}+\rho\right) \tag{11}$$

IV. SIMULATIONS AND RESULTS

There is a need to assess the capabilities of UPFC through simulation software tools. MATLAB / Simulink is being used for simulation purposes in this work. UPFC module with three components: stable state model, dynamic model with its parent controller. In this chapter, the analysis of the electrical system takes place when the UPFC is connected to the system and not connected.

There are various cases in the above system;

Case 1: Pre-fault state 0 <t: 2

Case 2: In the wrong position (error occurred within 2 to 3 seconds) 2 <t <3

Case 3: The line is restored. 3> t

In view of the above cases, the behavior of the line is being investigated as follows.

A. The simulation of test model without UPFC is expressed below

The parameters of the feeder which is simulated in the MATLAB are listed below.

Single phase source 230 V,50 HZ

Feeder parameters 0.03 Ohm,1.067e-4 H

RL Load 1 3KW

RL Load 2 4KW

Dc capacitor link 330e-6

Inductance of filter 5.6e-3

Capacitance of filter 5e-3

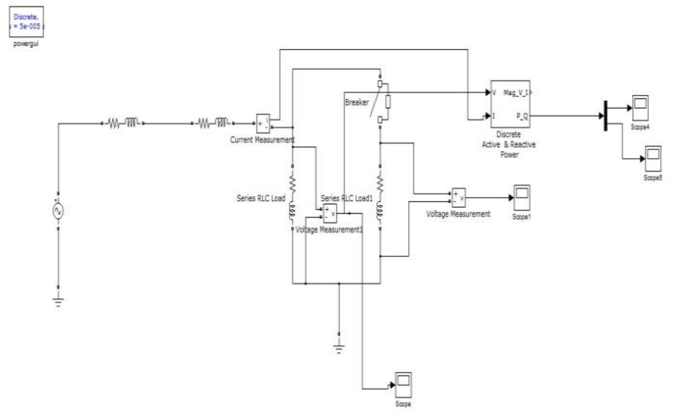

Fig.5. Proposed circuit without UPFC in sag mode.

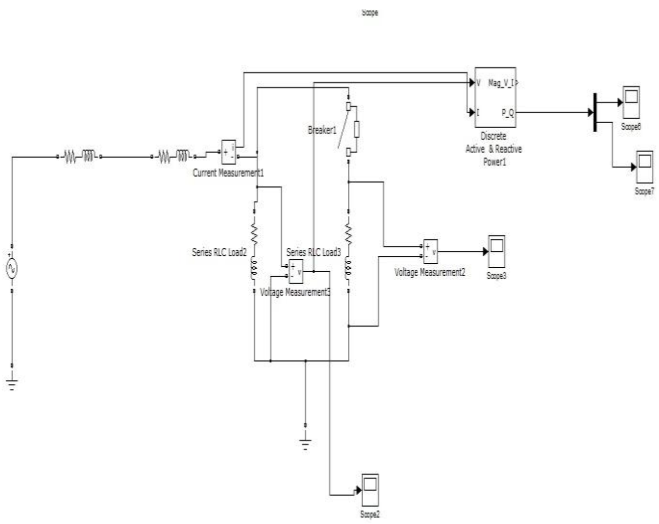

Fig.6. Proposed circuit without UPFC in swell mode

System Voltage

This is the main parameter to be controlled; There should be minimal changes in system voltage if there is any error. When the compensation device is not in use the system voltage goes to a critical value as shown in the figure. A sharp drop in voltage reduces the performance of various devices and components connected to a single device. In this case there is a 45% voltage drop, so the performance is not satisfactory.

- **Load Voltage under Sag Condition without UPFC**

Voltage sags are generated in the network when additional loads are added to the system. The condition of the celery is displayed in figs. The extra load is added to the system in 0.3 seconds as clearly shown in Fig.

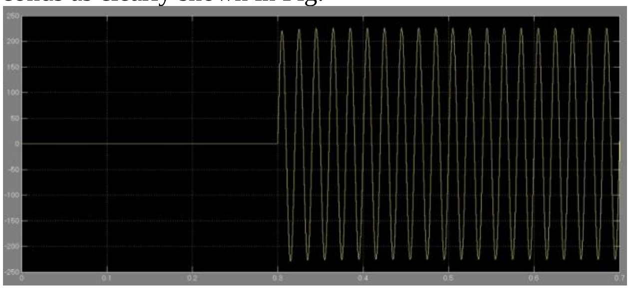

Fig.7. Voltage across Load2 without UPFC under sag condition

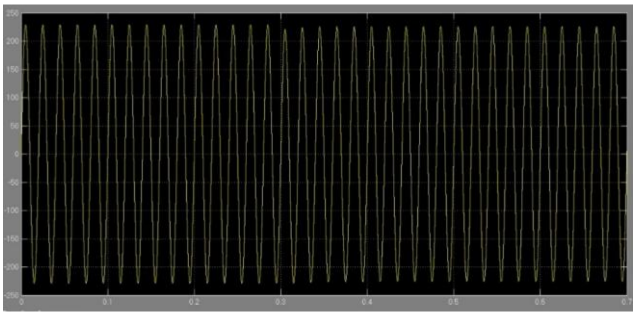

Fig.8. Voltage across Load1 without UPFC under sag condition

- **Load voltage under Swell condition without UPFC**

Voltage swells entered in the system when heavy load is disconnected from the system as shown in Fig.

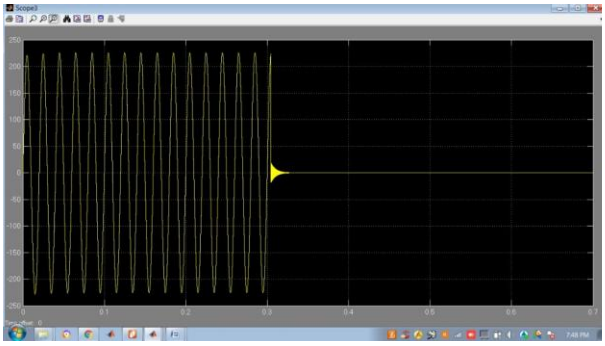

Fig.9. Load2 voltage without UPFC under swell condition

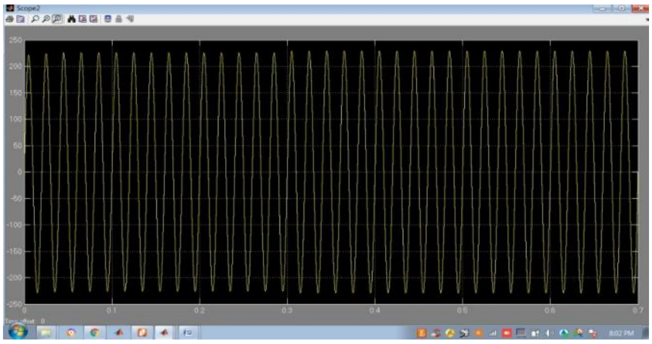

Fig.10. Load1 voltage without UPFC under swell condition

- **Reactive Power Compensation**

The system voltage depends on the reactive power. If the system voltage drops, the reactive power must be injected into the system and vice versa. In this case, because the compensation is not paid, the reactive energy is not injected and the system supports more reactive energy to compensate for the loss, which further aggravates the situation. The variation in reactive power when the error occurs over a period of 2-3 seconds is shown in Figs. 4 shows. The increasing value of the reactive power during a fault break indicates that the system is pulling more reactive energy to compensate for its losses than to give the reactive power.

- **Real and Reactive powers under Sag condition without UPFC**

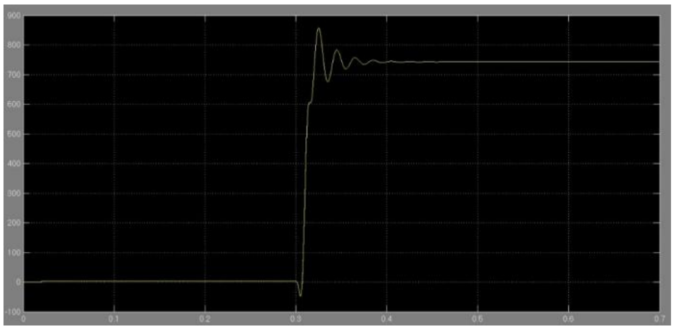

Fig.11. Reactive power without UPFC under sag condition

Fig.12. Active power without UPFC under sag condition

- **Real and Reactive powers under Swell condition without UPFC**

Fig.13. Active power without UPFC under swell condition

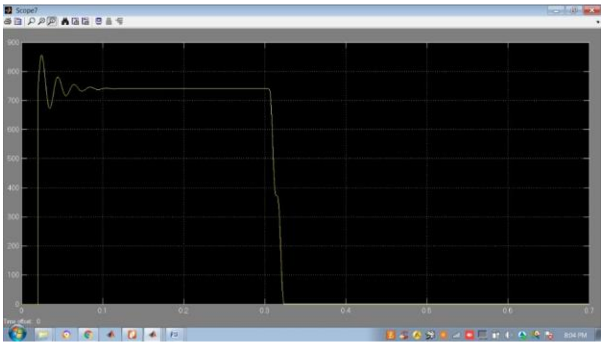

Fig.14. Reactive power without UPFC under swell condition

B. *The simulation of test model with UPFC is expressed below*

In this project, rectifier and inverter based UPFCs are used to reduce various power quality issues such as voltage sags and swelling. The test model in the Matlab / Simulink environment is analyzed without an integrated electric current controller. Test Model with UPFC in the MTALAB /Simulink is preform below.

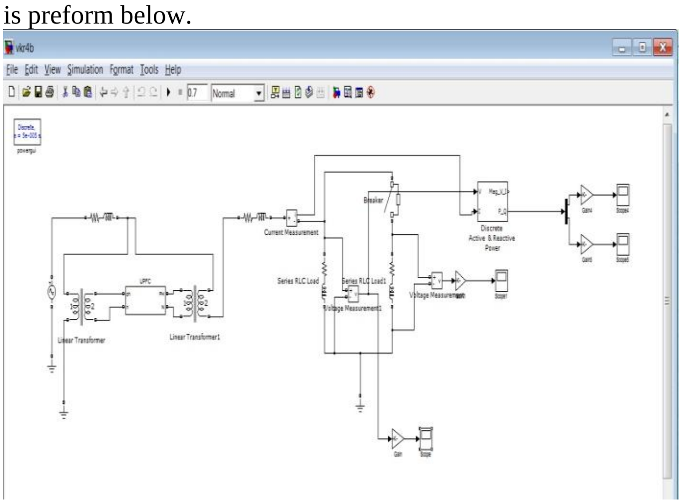

Fig.15. Proposed circuit with UPFC in sag mode

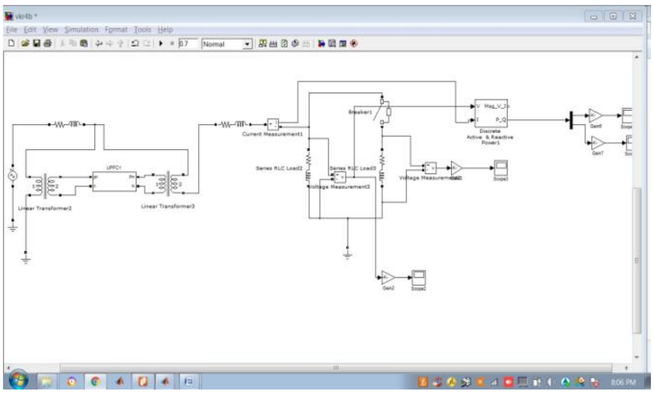

Fig.16. Proposed circuit with UPFC in swell mode

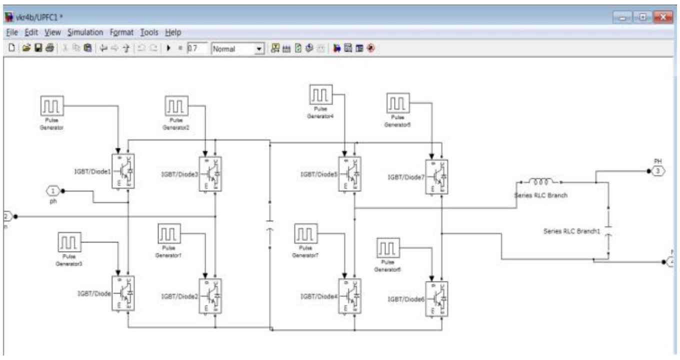

Fig.17. UPFC design rectifier inverter circuit

- **System Voltage**

The system voltage is maintained within prescribed limits when UPFC is connected to the power system. Fig. 6 shows the system voltage variations when three phase fault occurs. From the figure, it can be clearly seen that the intensity of the fault is reduced when UPFC is connected to the system. The current drawn by the system is also reduced and system can be protected from over-heating of the system. The system voltage now drops to 25% of the normal value, which is almost half of the previous case when UPFC is not connected. The simulation is done for the severest of the faults i.e., three phase faults. This implies that UPFC can maintain the terminal conditions when critical condition arises.

The effectiveness of UPFC in the power system is expressed in Fig. UPFC has the ability to control and retain the voltage constant w.r.t proper value as described in Fig., at 0.3 sec sags are produced and at 0.4 sec UPFC is introduced in the network mitigates it.

- **Load Voltage under Sag Condition with UPFC**

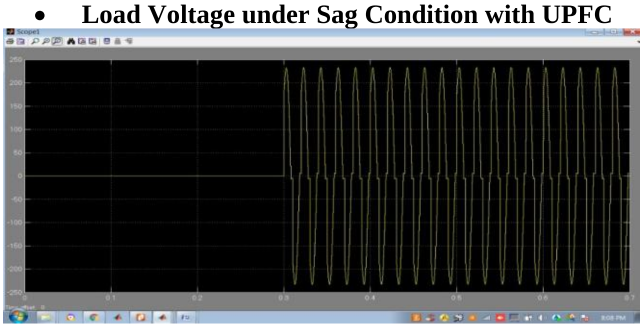

Fig.18. load2 voltage with UPFC under sag mitigation condition

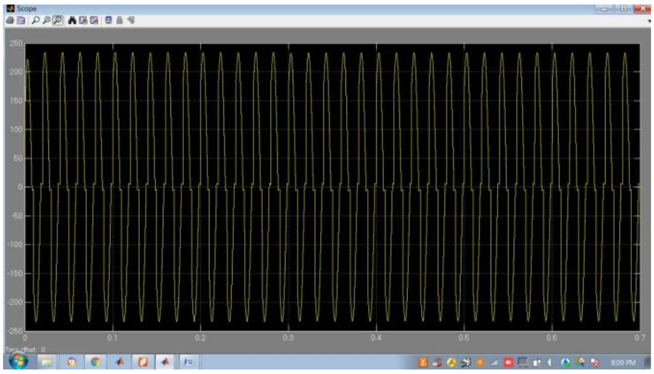

Fig.19. load1 voltage with UPFC under sag mitigation condition

- **Load Voltage under Swell Condition with UPFC**

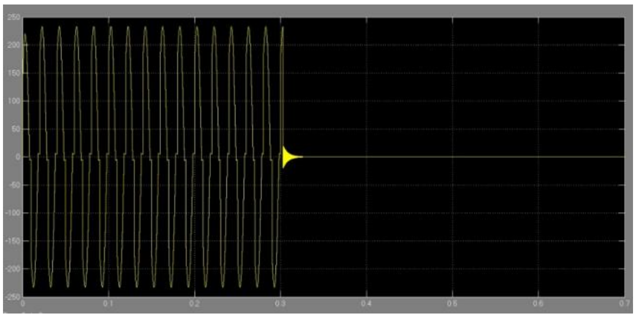

Fig.20. Load2 voltage with UPFC in swell condition

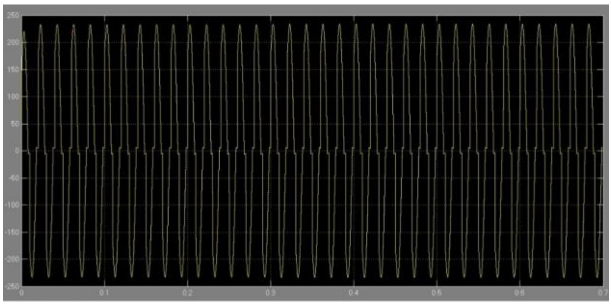

Fig.21. Load1 voltage with UPFC in swell condition

- **Reactive Power Support**

As mentioned above, if the system voltage drops to a certain value, reactive power must be injected to increase the voltage. UPFC is a reactive power storage medium. It provides reactive power to the electrical system when the voltage drops due to a fault-like disturbance. Fig. 7 shows the waveform for reactive energy. From the figure, it can be seen that there is a decrease in reactive power, indicating that reactive energy is being introduced into the system

The reactive power increased compared to the previous case.

- **Real and Reactive powers under Sag condition with UPFC**

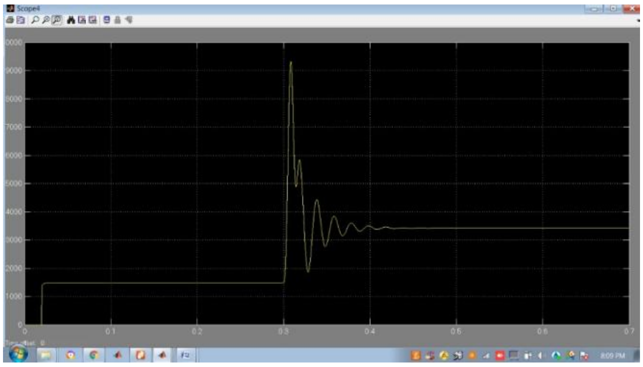

Fig.22. Active power with UPFC in sag condition

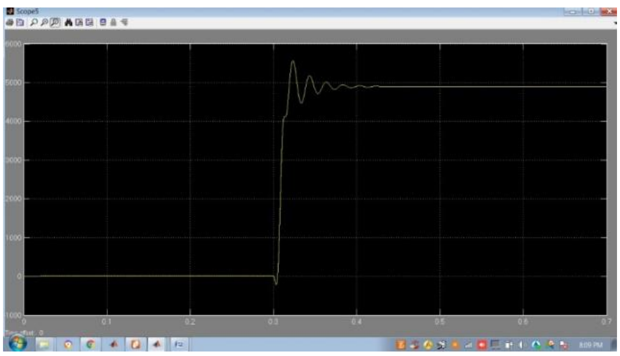

Fig.23. Reactive power with UPFC in sag condition

- **Real and Reactive powers under Swell condition with UPFC**

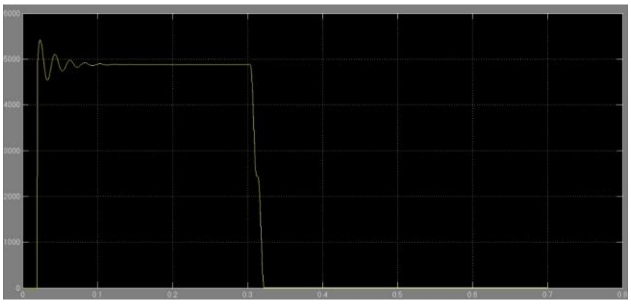

Fig.24. Active power with UPFC in swell condition

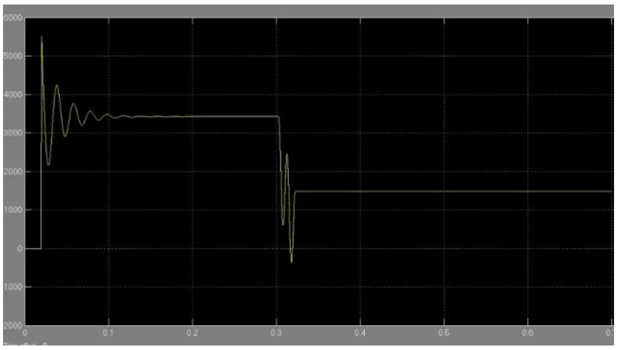

Fig.25. Reactive power with UPFC in swell condition

C. *Comparison between results described below,*

S.NO	condition	Load voltages (V)	Real Power (W)	Reactive power (VAR)
01	Without UPFC	225.54	1878	2681
02	With UPFC (open loop)	232.33	3594	5129

- *Graph of comparative analysis*

Graph of comparative analysis for real power is shown in fig. 26.

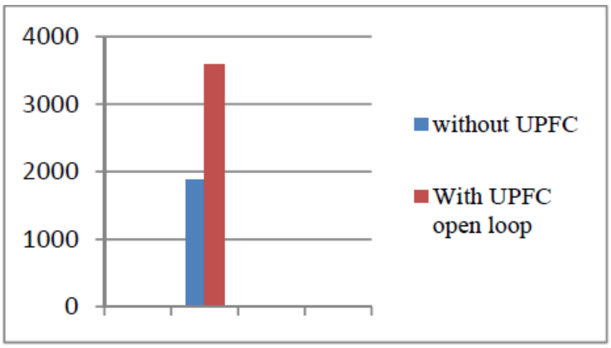

Fig. 26: Real power flow without and with UPFC

Graph of comparative analysis for reactive power is shown in fig. 27.

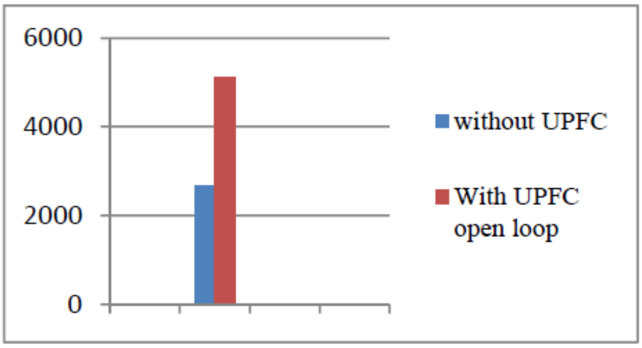

Fig. 27: Reactive power flow without and with UPFC

Graph of comparative analysis for load voltages is shown in fig. 28

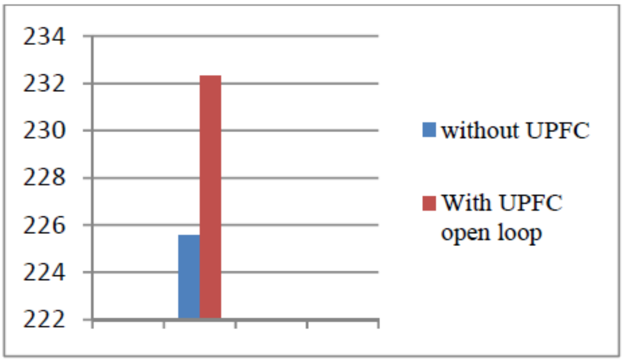

Fig. 28: Load voltages without and with UPFC

- In power system transmission, it is desirable to maintain the voltage magnitude, phase angle and line impedance. Therefore, to control the power from one end to another end, this concept of power flow control and voltage injection is applied .Modeling the system and studying the results have given an indication that UPFC are very useful when it comes to organize and maintain power system.
- The proposed method algorithm provides a very good performance under various channel conditions, with a short observation time and at low signal-to-noise ratios, with reduced complexity. considered. The UPFC is modeled as two controllable voltage sources; Vser represents the series inverter and Vsh represents the shunt inverter . Two perpendicular components: one in-phase with the system bus voltage and the other in quadrature are used to represent both compensation voltages generated by each inverter of the UPFC The validity of the proposed algorithm is verified using signals generated and acquired by laboratory instrumentation, and the experimental results show a good match with computer simulation results.

V. CONCLUSION

The proposed system has been implemented using MATLAB/ Simulink. In proposed Flexible alternating current transmission system model model, Unified power flow control device has been implemented over AC transmission line. This is found to be so efficient and effective. The implemented system model is able to match set reference reactive power. With this feature the implemented model enables stable voltage, control over reactive power, and impedance for better AC power transmission system.

The UPFC to the transmission line of the electrical system gives better results than the old techniques power system stabilizer and automatic voltage controller. We made extensive computer simulations to study both series compensation and discrete baffle compensation given by series controller and shunt controller. Relative variation from comparative studies of reactive power support, terminal voltage and active power. We saw that momentary stability UPFC usage has improved. We get better volatile. stability performance using UPFC than without UPFC

REFERENCES

[1] Samiksha Thakare ; M. Janaki ; R. Thirumalaivasan, "Improvement in Power Flow Control and Voltage Regulation using UPFC", IEEE 2019 Innovations in Power and Advanced Computing Technologies (i-PACT).

[2] Swati Bhasin ; Annapurna Bhargava ; Sandeep Verma ; Vandana Chaudhary, Comparative Simulation Studies for Hybrid Power Flow Controller and UPFC based Controller for SMIB System," 2019 2nd International Conference on Power Energy, Environment and Intelligent Control (PEEIC) IEEE Xplore DOI: 10.1109/PEEIC47157.2019.8976670.

[3] Hyun-Jun Lee ; Young-Doo Yoon "Single-phase UPFC Topology with Autotransformer Structure for Smart Grid 2019 10th International Conference on Power Electronics and ECCE Asia (ICPE 2019 - ECCE Asia) IEEE Xplore

[4] Muhammad Noman Iqbal ; Anzar Mahmood ; Adil Amin ; Hirra Arshid, "Voltage Regulation and Power Loss Minimization by Using Unified Power Flow Control Device," 2019 International Conference on Engineering and Emerging Technologies (ICEET) IEEE Xplore DOI: 10.1109/CEET1.2019.8711866

[5] Salah Kamel ; Yousry Ibrahim ; Ahmed Rashad ; Loai S. Nasrat. "Performance Enhancement of Wind Farms Integrated with UPFC Using Adaptive Neuro-Fuzzy Inference System" 2019 International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE) IEEE Xplore DOI: 10.1109/ICCCEEE46830.2019.9070833

[6] Abhilash Sen ; Atanu Banerjee ; Haricharan Nannam investigated in "A Comparative Analysis between UPFC and DPFC" 2019 IEEE International Conference on Intelligent Techniques in Control, Optimization and Signal Processing (INCOS) IEEE Xplore.

[7] .Liang Zhang ; Bin Zhou ; Peng Li ; Yubo Yuan ; Jingnan Xu ; Xiangping Kong. He "Impact Evaluation for Distance Protection of Southern Suzhou 500kV UPFC," IEEE Xplore: 16 September 2019 DOI: 10.1109/ICIEA.2019.8834339

[8] Smitkumar D. Choudante ; A. A. Bhole, "A Review: Voltage Stability and Power Flow Improvement by Using UPFC Controller," IEEE Xplore: 08 November 2018 DOI: 10.1109/ICCPEIC.2018.8525161

[9] Sauvik Biswas ; Paresh Kumar Nayak "Superimposed Component-Based Protection Scheme for UPFC Compensated Transmission Lines "Publisher: IEEE,"EXPLORE 2018

[10] Hong Ji ; Jian Ling ; Chunhua Yu ; Jun Xu "Parameter Tuning of UPFC Supplementary Damping Controller Considering Communication Latency IEEE Xplore: 31 December 2018 DOI: 10.1109/CICED.2018.8592511

[11] Parvez Ahmed and S. N. Verma, "Modelling and Simulation of Hybrid Power Flow Controller for Improving the Performance of Power System", International Journal of Engineering Reasearch & technology (IJERT), vol. 4, no. 06, June 2015.

[12] Garima Aggarwal, Lini Mathew and S Chatterji, "MATLAB/SIMULINK BASED SIMULATION OF AN HYBRID POWER FLOW CONTROLLER", International conference on Advanced Computing & Communication Technologies IEEE, vol. 10, pp. 4799-4910, 2014.

[13] Arup Ratan Bhowmik and Champa Nandi, "Implementation of Unified Power Flow Controller (UPFC) for Power Quality Improvement in IEEE 14-Bus System", International Journal of Computer Technology and Applications, no. 6, pp. 1889-1896, Nov-Dec 2011.

[14] T. Bruckner, S. Bernet, and H. Guldner, “The active NPC converter and its loss-balancing control,” IEEE Trans. Ind. Electron., vol. 52, no. 3, pp. 855–868, Jun. 2005.