Performance Enhancement of Electrical Transmission Parameters through UPFC Simulation in MATLAB

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***Abstract*— A Unified Power Flow Controllers (UPFC) are a powerful energy management tool that effectively regulates both reactive and active power in electrical transmission lines. They can be employed as a shunt and series compensator. Reducing voltage sag and swell is the main objective of UPFC in order to improve power system stability. Its circuit architecture combines an inverter and a rectifier to enable dynamic control of power flow. Through real-time voltage control, UPFC is implemented in a MATLAB/Simulink ecosystem to improve power quality. The analysis of response to frequency, voltage deviations, or reactive power support in the simulation results confirms UPFC's capacity to suppress fluctuations. UPFC guarantees quick stabilization in the event of system errors or disruptions, much surpassing systems without it. By reducing voltage level and reactive power variability, this study demonstrates how well UPFC maintains power system stability, optimizes voltage control, and increases energy transmission efficiency.**

Keywords: UPFC,FACTS,MATLAB etc.

I. INTRODUCTION

The ongoing liberalization of power networks around the world may present new technological challenges for researchers or the power sector in addition to offering consumers better service and less expensive electricity. Adequate Available Transfer Capacity (ATC) is necessary for free access to transmission networks in a deregulated environment in order to ensure economic transactions. However, the transmission facility owner or system operator may not be able to centrally manage the major ATC-improving techniques of rearranging active electric power production, changing the final power of generators, changing the taps within an on-load tap the changer, as well as conventional methods in a privatized electrical power market. While new transmission lines can still be built, there are more stringent environmental laws and often social concerns as well. With the development of new topologies and the availability of fully controlled semiconductor components which include the Insulated Gate Bipolar The transistor (IGBT) and the Gate Turn-off Thyristor (GTO), the most powerful and versatile class of FACTS devices to date has been produced by combining multiple compensators, or combined compensating components. The renowned Unified Power Flowing Controller (UPFC) and Interline Power flowing Controller (IPFC) are among its delegates. The current generation of FACTS gadgets is the last one. It is commonly recognized that buses and densely laden lines with comparatively low voltages are elements that severely restrict.

1. The power system, which is often mechanically controlled, connects generating units to load centers via high-voltage electric transmission lines.

2. Distribution, transmission, and generation comprise its three subsystems. Until recently, a single entity managed all three systems in a particular area, providing electricity at predetermined rates.

3. The Unified Power Flow Controllers (UPFC) is a unique configuration of two SVSs, one linked in parallel with the ac system & the other connected in shunt, with shared dc terminals. This is a series-shunt controller example.

Unrestricted framework movements at low frequencies have been possible with the development of the interconnection of massive electric force frameworks, requiring only a few cycles per second. The main source of these low recurring motions is the framework's mechanical method's lack of dampening.Because power swaying is a special feature, it's important to monitor the disgruntled machine's accelerates and decelerating swings and modify the applied compensation. In order to achieve intensity framework adaptability, the Flexible AC Transmission A framework (FACTS) concept uses strong state regulators to quickly and reliably control intensity framework boundaries that affect the power stream in the transmission channel, specifically voltage, impedance, and stage point.

Linked together A multipurpose Flexible AC Transmission system (FACTS) controller called the Power Flow Control (UPFC) creates new opportunities for force control and increasing the current lines' useful limit. To lessen the motions of the mechanical modes, a UPFC beneficial damping control has been added to the the UPFC control mechanism. UPFC damping regulators are demonstrated in an efficient four-option approach. However, the benefits of these UPFC dampening regulators are intended based on apparent working conditions and are not affected by line loadings or framework functioning conditions. The control structure differs for the various UPFC control signal options due to the regulator gains. Continuous execution is unyielding due to the widely different control structure for the determination of control signals, even if dampening of low recurrence motions may be one of the alternative elements in the multifunctional UPFC depending on its other important control responsibilities. In order to dampen magnitude frameworks electrically driven motions, this study suggests a versatile fluffy forecasting framework (ANFIS) base UPFC helpful dampers regulator. The UPFC control sign has the damping capacity placed on it. The adaptable fluffy regulator is obtained by integrating the fluff derivative structure into the framework of flexible networks.

Through reproductions on a transformed Philips-Hefron representation of a force frame with UPFC, the proposed ANFIS-based damping regulator implementation is examined for the four choices made by UPFC control signals that rely on the voltage phase and equalization record in the UPFC setup and switched converters. The results of reenactments, which demonstrate the regulator's ability to dampen motions across a broad range of loading scenarios and system values with the four an alternative UPFC controller signal choices, support the viability of this controller when contrasted with constant gain lowering controllers created using the phase repayment technique at specific operating points.Applying this method to a multi-machine electric system and validating the suggested controller's robustness using non-linear simulation.

II. PROBLEM IDENTIFICATION

Because of its dynamic nature, electric power systems frequently experience disruptions. A series conversion and a shunt conversion are the two converters for voltage sources that UPFC provides. Therefore, these interruptions must be minimized and power quality issues must be addressed in order to improve its performance. In order to reduce power system oscillations and enhance system damping, Flexible Altering Current Transmission (FACTS) devices, such UPFC, are becoming more and more significant.

Causes Of Poor Power Quality:

• Variations in the voltage's frequency and magnitude.
• A sudden increase or decrease in load, power electronics converters, inverters, lightning, and other factors can cause a change in magnitude.
• Frequency variations may result from out-of-system dynamics or the introduction of harmonics.

III. METHODOLOGY

A. Overview

Two voltage-supply (VSI) inverter share a single dc store capacitor coupled to the power network via coupling transformer make up the fundamental parts of UPFC. One VSI is connected to the power grid by a shunt transformer, while the other two are connected via a series transformer. Fig. 1 displays an average UPFC function diagram. In order to regulate both the reactive and active electrical currents on the power system, a symmetrical three-phase voltage system (Vse) with a configurable magnitude as well as phases The series inverter injects the angle parallel to the line. As a result, this inverter and the line will exchange both reactive and active electricity. In order to maintain a constant voltage across the capacitor that stores Vdc, the shunt converter is designed to demand the dc terminal energy either positive or negative from the line. Therefore, the losses created by the inverters & their transformers alone make up the net true energy that the UPFC absorbs from the line.

In this instance, the shunt inverter functions as a STATCOM, producing or consuming reactive power to control the connection point's voltage level. However, in order to control the current flow and, consequently, the electrical flow on the electric system, the series inverter functions as an SSSC, producing or absorbing reactive powerThere are several ways that the UPFC can function. To be more specific, the shunt inverter works by injecting a regulated current, Ish, into the power transmission line. There are two modes for controlling the shunt inverter. A. VAR Controlling Mode: The reference input is either a both capacitive and in variable requirement. A shunt conversion controller transforms the var references into an appropriate reverse current request and modifies the inverter's gating to ascertain the amount of current needed. A feedback signal that represents the dc bus the voltage, Vdc, also happens to be necessary for this control mode. B. Automated The voltage control option automatically regulates the shunt inverter's reactive current to maintain the power supply voltage at the connecting point at the reference value. The sending end bus, which supplies voltage signals that feedback to the transformer's parallel coupling, is utilized in this control mode.

B. Basic Structure of UPFC

By altering the line's reactance and managing the power flow in both transmission and distribution lines, UPFC simultaneously serves three compensation functions: voltage, phase angle, and impedance. UPFC offers voltage source converters in both series and shunt configurations. A common dc link unites these converters. Shunt or series transformer are used to connect converters to the transmission line [3].

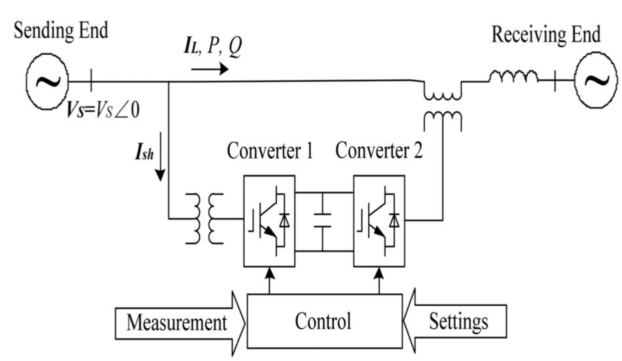

Fig. 1: basic structure of UPFC

Fig. 1 depicts the UPFC's basic anatomy. While series converters manage the phase angle also magnitude of voltage in parallel with the transmission line, shunt controllers control reactive power and supply the dc power required for combined converters. The UPFC essentially introduces the power line and voltage. Regarding the terminal voltage, the phase angle and voltage magnitude can vary from 0 to 2π, and from 0 to a specified maximum value, respectively [4]. VAR control and automatic voltage control are the two UPFC modes that are available. The automatic voltage control mode's goal is to keep line voltage at the point where it links to the value of the reference, while the first control mode uses an inductive or capacitive reference input [5]. The actual and receptive energies that a unified power controller regulates are determined by the following formulas,

$$P = \frac{V_S V_R}{v} \text{Sin } (\alpha \qquad (1)$$

$$Q = \frac{V_R}{v} (V_S - \qquad (2)$$

C. Operation and Modelling of UPFC

Initially, the Unified Electricity Flow Controllers (UPFC) was suggested for dynamic compensation and true-to-time regulation of AC transmission networks.A gate thyristor valve is used to treat the two switching converters that make up the integrated flow controller as voltage sorter inverters. These inverters—designated "VSC1" and "VSC2"—use a common dc link that the dc storage resistor provides. The AC power Converters in this configuration allows actual power to freely flow in any direction between the AC terminals. Reactive power can be generated separately by both inverters and concurrently absorbed by each inverter at its respective AC output terminal. UPFC's series converter transforms real power with a transmission line because it can inject voltages with varying amplitude and phase angle. using series transformers. Nevertheless, in practice, UPFC (both conversions) cannot be provided and absorbed in a steady condition (except from energy intended to offset losses). As a result, the shunt branch must compensate the chain branch for any actual power that it draws or supplies and damages. Condenser kn t an is at constant voltage when the power posture is not maintained. The reactive power is freely converted using the shunt branching mechanism.

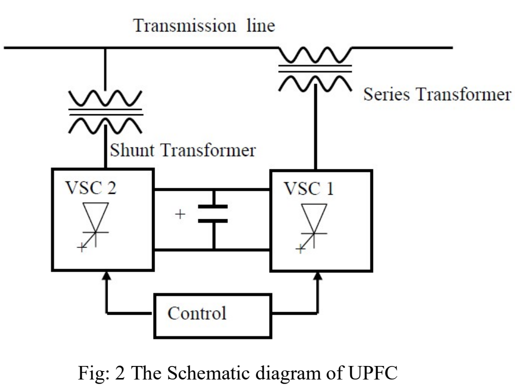

Fig: 2 The Schematic diagram of UPFC

By infusing Vpq (0≤ Vpq≤ Vpq maximum) the angle of phase ρ (0≤ρ ° 360 °) using controllable scales at low frequency energy injection, VSC 2 performs the primary function of the UPFC. Line from should be inserted. change.

Synchronous AC voltage is thought to originate from this injection voltage. Currently, the transmission line passes through this voltage source, causing a shift in both reactive and actual power within it and the AC machine. The inverter and the real authority exchanges above the AC terminal (also known as the insert transformer terminal) assist in converting the AC energy to DC power, which then manifests as either favorable or adverse real electrical demands in the DC link. . The electrical power inverter was internally created at the AC terminal. The function of converter 1 is to supply or absorb the actual power that conversion 2 asks over a simple DC link.

With the aid of a shunt-connected transformer, the DC link's power is transformed into AC and supplied to the transmission line. VSC 1 offers independent reverse reactive balancing for the line by producing or absorbing adjustable reactive power if responsive power is needed. The opposite of inverters 1 and 2 take the "direct" route to the real electrical power via the series volt injection action when the reactive impulse is transferred or absorbed from the local inverter. 2 and as a result, the line does not release reactive energy. Consequently, the rectifier 1 can be managed to regulate a reactive power transformation along the line separate from the reactive electrical power transferred by the inverter, or it may work in a unified voltage factor. This indicates that the UPFC is not experiencing a constant flow of reactive current. From the perspective of traditional power transmission, which relies on reactive serial compensation, shunt compensation, and phase shifts, the UPFC is the only device which can perform all of these tasks and, by adding injected voltages, accomplish numerous control targets. Does it? Figure 3 uses the phasor representation to show the fundamental UPFC strength flow control function, with the proper magnitude as well as phase angle matched to the voltage at the termination V0.

D. Basic Principle of P & Q Control

Figure 3 illustrates a two-machine (or two-bus AC inertia) system with end voltage sending, the receiving voltage VR, and line (or tie) resistance X (considered as an inductor for simplicity). Figure 4. A phase diagram displaying the system's voltage transmissions with transmission and │Vs│ = │Vr│ = │V│.

Transmitted Power P= $P(P - \left(\frac{V^2}{X}\right) \text{si}$ and the reactive power Q =Qs= $Q_r(Q - \left(\frac{V^2}{v}\right)(1 - \text{c}$ provided at the line's ends are displayed plotted against the angle δ.

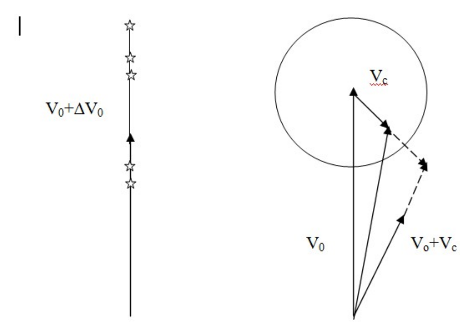

Fig 3 fundamental UPFC control operation. (a) Control of Voltage (b) Compensation in Series.

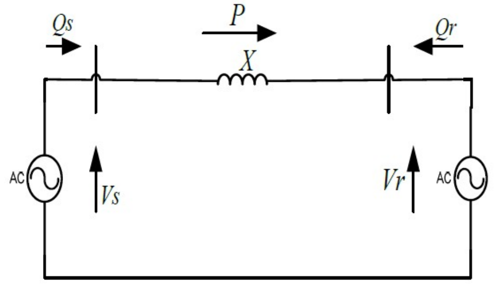

Fig 4 basic two-machine setup

Figs are an easy way to find it. The effective communication end voltage is determined by the transmission line as Vs + Vpq. It is reasonable to believe the fact that UPFC can actually change the Vpq's magnitude and direction because it clearly affects the voltage across the line of communication (both of which its size and angle). The line's reactive force requirement at any angle of transmission between the point of emission and ending.

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

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

When Vpq=0 then

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

When Vpq≠0 then

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

Substituting

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

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

And

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

The expressions below are derived for P and Qr

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

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

IV. Simulations and Results

It is necessary to use simulation software tools to evaluate UPFC's capabilities. The simulation in this work is done using MATLAB/Simulink. The UPFC module is composed of three components: the stable state model, the dynamic model, and its parent controller. The electrical system is analyzed in this chapter both with and without the UPFC connected to the system.

The system mentioned above has a number of cases;

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

Case 2: Iincorrect placement (mistake happened in 2–3 seconds) 2 <t <3

Case 3: The line is restored. 3> t

Given the aforementioned situations, the line's behavior is being examined in the following ways.

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

The following is a list of the feeder's parameters that MATLAB simulates.

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

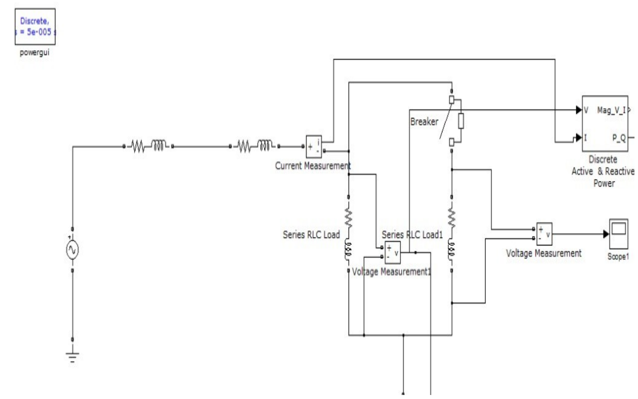

Fig.5. Proposed circuit without UPFC in sag mode.

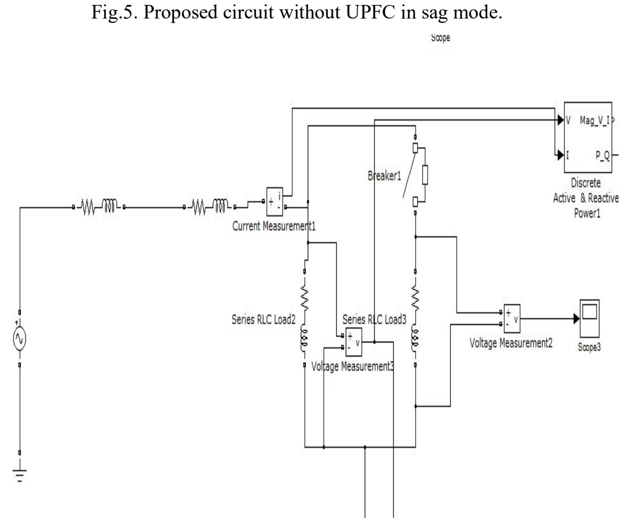

Fig.6. The suggested circuit in swell mode without UPFC

System Voltage

This is the primary parameter that needs to be managed; if there is an error, the system voltage should only slightly vary. As seen in the figure, the system voltage reaches a critical value when the compensating device isn't in use. The performance of multiple devices and components coupled to a single device is diminished by a sudden reduction in voltage. Because of the 45% voltage loss in this instance, the performance is unsatisfactory.

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

When more loads are added into the system, the network experiences voltage sags. Figs are used to show the state of the celery. As seen in Fig., the additional load is introduced to the network in 0.3 seconds.

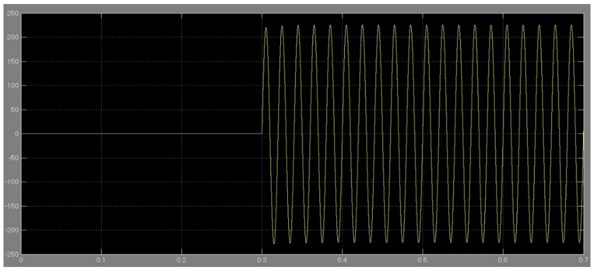

Fig.7. Voltage across Load2 without UPFC under sag condition

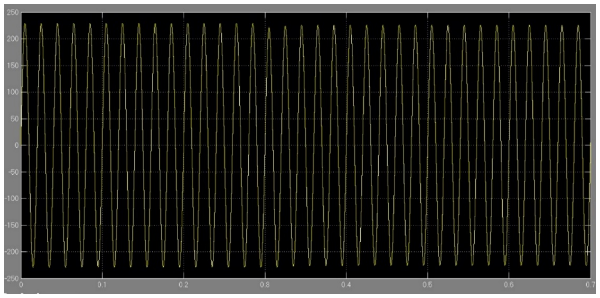

Fig.8. Voltage across Load1 without UPFC under sag condition

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

When a large load is removed from the system, voltage surges enter the system, as seen in Fig.

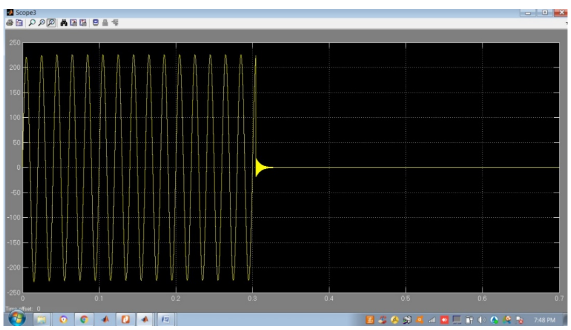

Fig.9. Load2 voltage without UPFC under swell condition

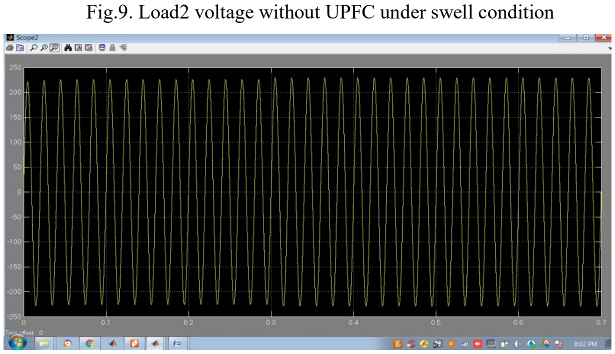

Fig.10. Load1 voltage without UPFC under swell condition

- **Reactive Power Compensation**

Reactive power determines the system voltage. Reactive power has to be added to the system if the voltage in the system falls, and vice versa. Reactive power is not injected in this instance since compensation is not provided, and the system requires additional reactive energy to make up for the loss, which makes matters worse. Fig. 4 illustrates the change in power response when the error happens across a time span of two to three seconds. The system is drawing more active energy to make up for the deficit than to provide the reactive power, as evidenced by the rising reactive power value during a fault break.

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

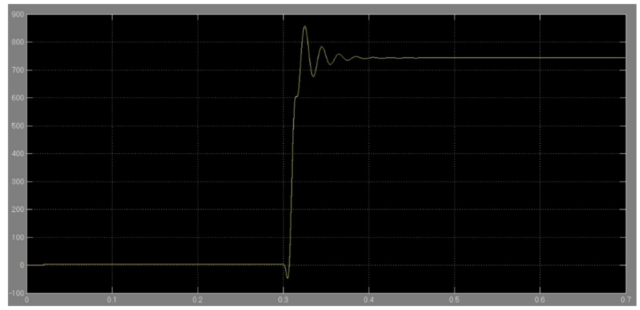

Fig.11. Reactive power without UPFC under sag condition

Fig.12. Active power without UPFC under sag condition

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

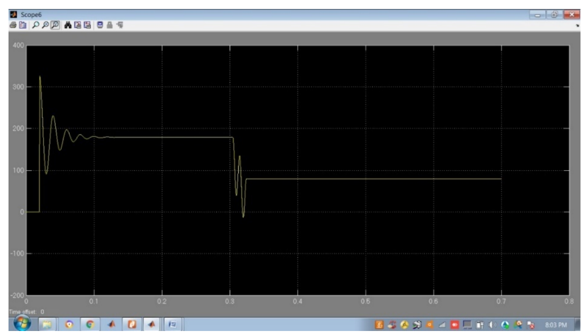

Fig.13. Active power without UPFC under swell condition

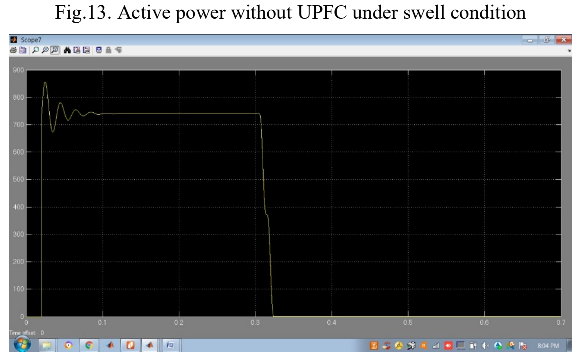

Fig.14. Reactive power without UPFC under swell condition

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

This project uses UPFCs based on rectifiers and inverters to lessen a variety of power quality problems, including voltage sags or swelling. Without an integrated current controller, the test model is examined in the Matlab/Simulink environment. Below is a test model using UPFC in MTALAB/Simulink.

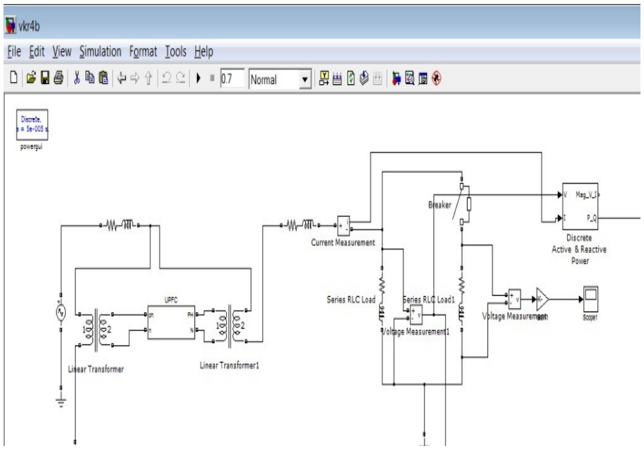

Fig.15. Proposed circuit with UPFC in sag mode

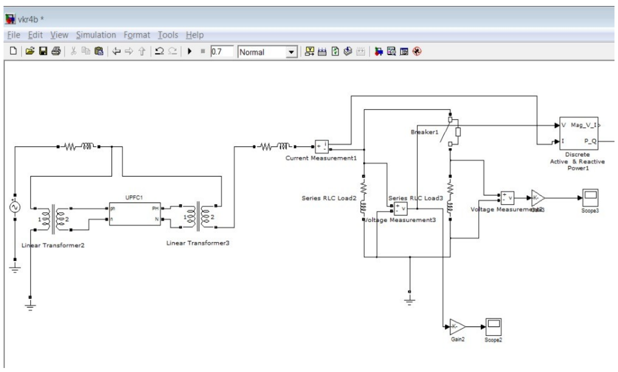

Fig.16. Proposed circuit with UPFC in swell mode

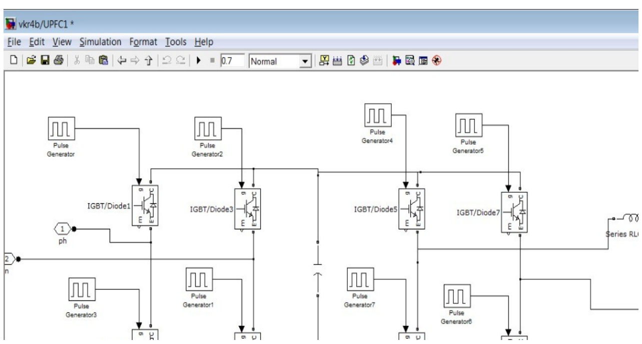

Fig.17. UPFC design rectifier inverter circuit

- **System Voltage**

When UPFC is linked to the power system, the system power is kept within the specified bounds. When a three-phase failure occurs, the system voltage changes are seen in Fig. 6. It is evident from the graphic that when UPFC is linked to the system, the fault's intensity decreases. Additionally, the system's current draw is decreased, and it can be shielded from overheating. Now, when the UPFC is disconnected, the system voltage falls to 25% of its typical value, or about half of what it was before. Three-phase defects, which are the most severe, are the subject of the simulation. This suggests that in the event of a critical scenario, UPFC can sustain the terminal conditions.

Fig. shows how effective UPFC is in the electricity grid. As shown in Fig., UPFC can regulate and maintain the voltage at a consistent value. At 0.3 seconds, sags are created, and when UPFC is added to the network, it reduces them at 0.4 seconds.

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

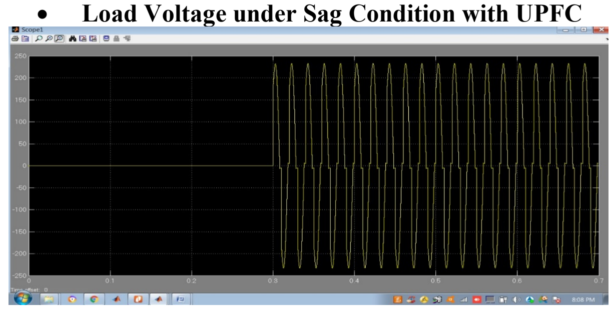

Fig.18. load2 voltage with UPFC under sag mitigation condition

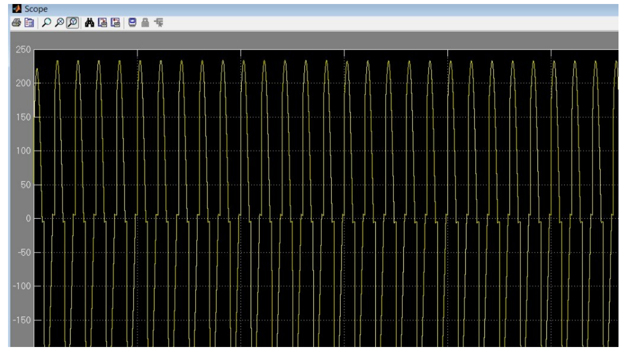

Fig.19. load1 voltage with UPFC under sag mitigation condition

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

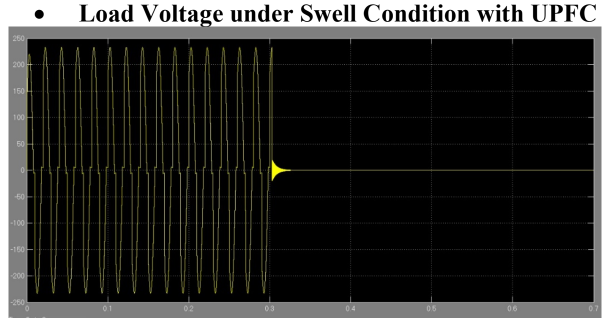

Fig.20. Load2 voltage with UPFC in swell condition

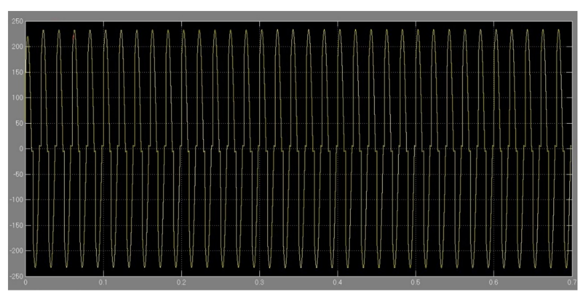

Fig.21. Load1 voltage with UPFC in swell condition

- **Reactive Power Support**

As previously stated, reactive energy must be supplied to raise the system voltage if it falls to a specific level. One type of reactive power storage media is UPFC. In the event that a fault-like disturbance causes the voltage to drop, it supplies reactive power to an electrical system. The reactive energy waveform is displayed in Fig. 7. Reactive power is decreasing, as can be seen in the image, suggesting that receptive energy is entering the system.

Reactive power rose in comparison to the earlier instance.

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

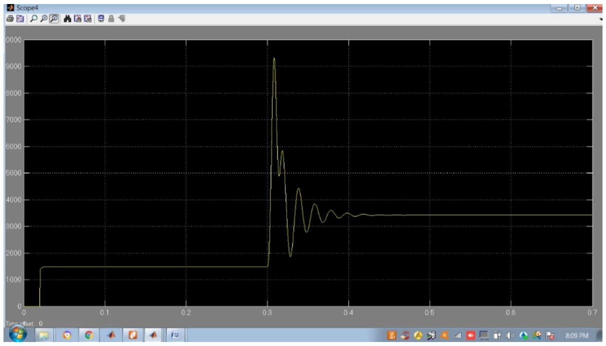

Fig.22. Active power with UPFC in sag condition

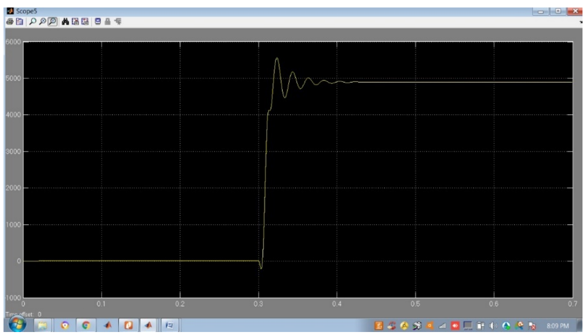

Fig.23. Reactive power with UPFC in sag condition

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

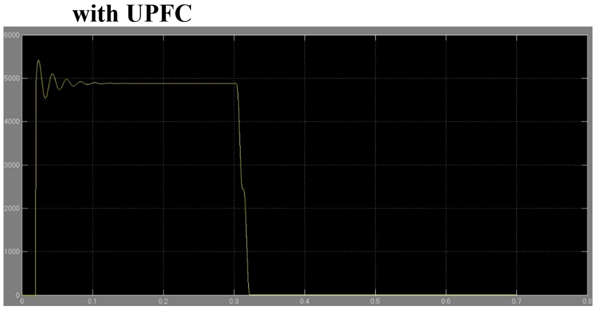

Fig.24. Active power with UPFC in swell condition

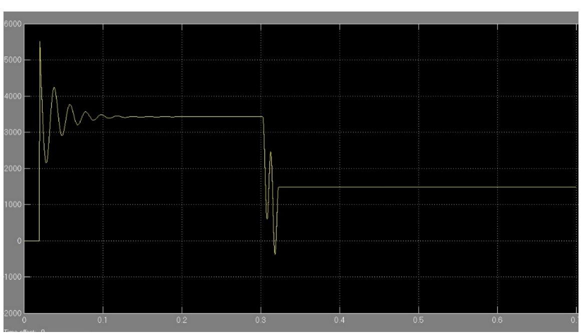

Fig.25. Reactive power with UPFC in swell condition

*C. **Comparison between results described below,***

S.NO	condition	Load voltages (V)	Real Power (W)	R p (
01	Without UPFC	225.54	1878	2
02	With UPFC	232.33	3594	5

- ***Graph of comparative analysis***

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

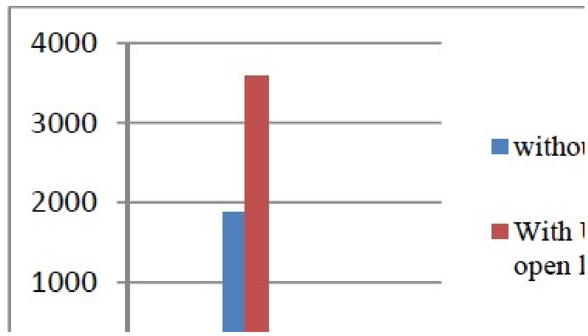

Fig. 26: Real power flow without and with UPFC

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

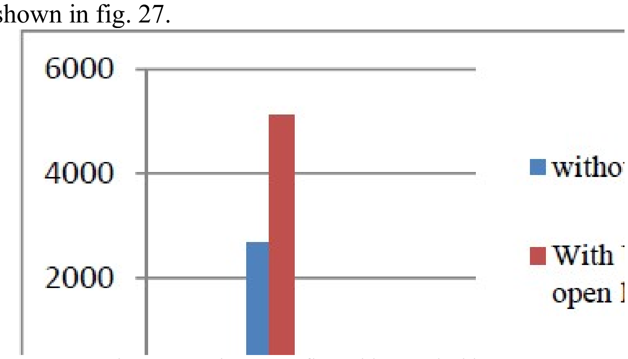

Fig. 27: Reactive power flow without and with UPFC

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

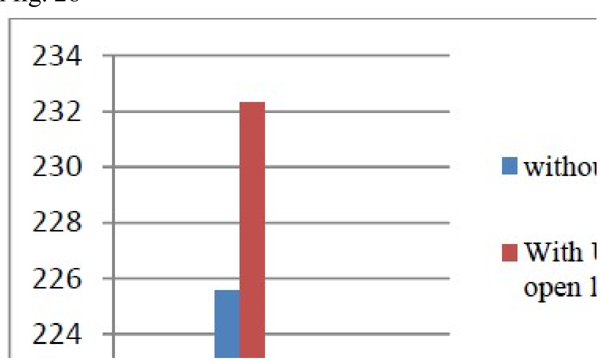

Fig. 28: Load voltages without and with UPFC

- It is preferable to preserve the line impedance, phase angle, and voltage magnitude in power system transmission. Thus, the idea of energy control or volt injection is used to regulate the power flowing from one side to the other.When t comes to organizing and maintaining power systems, UPFCs are quite helpful, according to system modeling and outcomes analysis.
- With a short observing time, low signal-to-noise ratios, and less complexity, the suggested approach algorithm performs exceptionally well in a variety of channel situations. taken into account. Two variable voltage sources are used to model the UPFC; the series inverter is denoted by Vser and the shunt inverter by Vsh. Both compensation voltages produced by each UPFC inverter are represented by two perpendicular components, one in quadrature and the other in phase with the rest of the bus voltage. Signals produced and obtained by laboratory equipment are used to confirm the integrity of the suggested algorithm, and the outcomes of the experiments closely match those of computer simulations.

V. CONCLUSION

MATLAB/Simulink has been used to implement the suggested system. A unified power flow management device has been constructed over an AC transmission line in the proposed flexible current transmission system architecture. This has been proved to be quite effective and efficient. The reference reactive power can be matched by the implemented system model. For improved AC power transmission system, this characteristic of the implemented model allows for stable voltage, regulates reactive power, and impedance.

The UPFC to the electrical system's transmission line performs better than the outdated automatic voltage controller and power system stabilizer methods. To investigate the discrete baffle compensation and series compensation provided by shunt and series controllers, we ran comprehensive computer simulations. relative variance based on comparisons of active power, terminal voltage, and reactive power support. We observed an improvement in the use of UPFC for momentary stabilization. Using UPFC improves our volatile stability performance compared to not using it.

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