Enhanced power quality using unified power flow controller systems

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Abstract. Electrical system frequently finds and issue due to unstable nature and power quality because of, in relation to great number of nonlinear charges. So, there is need to limit inside of these difficulties and produce fine voltage quality concerns. The Flexible Alternate Flow Transmission Systems (FACTS) are the framework made out of static gear works for the AC transmission of electrical energy. Unified Power Flow Controls (UPFC) are the excellent FACTS tools to attach series and shunt together and it could use for framing Power transmission sensitive and active power. Here in the paper, Unified Power Flow Control (UPFC) used to clear the voltage sink and Surge. Unified Control was developed and engineered using amplifiers and rectifiers. The real and reactive modifications in congruous control orientat ions at the receiver side. Use of Simulink of MATLAB checks quality of energy in the use of Unified Control.

1. Introduction
The low quality of energy impacts on all the kind of consumers. While the distribution systems are closer to the consumers, so the quality of power problems are depending on system of circulation. Voltage congruous & voltage sinks These are the 2 significant energy optimum values that impair system networks. Nonlinear charges act like primary Source of the congruous. There is short-term sink flow in the RMS voltage. In general, it can be discovered because of malfunctions (can be caused by variations in conditions such as lightning, storms, etc.) or because it involves big cars, e.g., engines, transformers or exemplifies dc. The voltage surge is the nominal voltage surge of RMS from 110% -180% for quarter time to one minute at power frequency. The result of malfunctions is voltage surges. Impacts constancy of voltage, performance or measurement in equipment of dim voltage and voltage and communication signals voltage and Surge in control devices [1]. The regulation and voltage stability are particularly crucial when the system discovers variations. Under this disturbance, the system should offer maximum load ratio. Unified control may be utilised to prevent the disruptive energy system and deliver maximum proportions of charges continuously [2].

2. Problems & Identification
Electrical power systems find interruptions frequently because of its unstable nature and quality of high-power are the huge problems cause of high number of non-linear-load. Therefore, there is a need to minimize power quality issues to limit these interruptions and improve its performance.
Flexible Alternative Current Transmissions (FACT) equipment are crucial like UPFC (Unified Power Flow Control) in put down the oscillations of power system and improvement in system dropping.

Causes of Poor Power Quality:
- Voltage Variation of voltage magnitude and frequency.
- Sudden increase in load or changes in size due to load, interruption, power electronics converter, inverter, lightning, etc.
- Differences in Frequency can come out of system dynamics or inject hormones.

3. UNIFIED POWER FLOW CONTROL

Study of basic concepts of UPFC.
- Finding the problems from conventional system by surveying literature.
- Design and study of power quality improv system in Electrical network.
- Analysis of the proposed topology on Sink and Surge condition.
- Study of the control strategies

4. UPFC Basic Structure

In three compensatory operations, namely voltages, inclination and impedance, the Unified controller operates concurrently by altering the line response and managing energy transfer in transmission and distribution networks. The UPFCs have a converter, shunt and serial converter on double power source. The converters work on the dc-link standard. Transformers have been connected by the shunt & switch sequence to the transmission network [3].

Figure 1 depicts the UPFC's basic anatomy. The shunt controller controls reactive power and provides the dc power required by combination converters, whereas in series with the transmission line, the serial converter regulates phase angle and voltage amplitude. Thus, the UPFC provides the line with voltage. The phase orientation and voltage magnitude of the output power fluctuate between 0 and 2, and between 0 and the default value. UPFC has two distinct control modes: the automatic voltage control and the VAR control. In first control mode, the reference input is inductive or capacity VAR, and the objective is to present line voltage at the critical link for a reference value in the automated voltage control mode [5].

\[ P = \frac{V_s V_R}{X} \sin(\alpha - \beta) \]  .... (1)

\[ Q = \frac{V_R}{X} (V_s - V_R) \]  .... (2)
5. Operation And Modelling of UPFC

5.1. Basic Principle of P & Q Control

In a multiple (We observe Figure 3 Ending Voltage, receiving end voltage and line voltage (or tie) Or two-bus AC hysteresis system) X impedance (ease, inductor). Illustration 4. Voltages throughout the system are displayed as a stage diagram with a transmission and \(|V_s| = |V_r| = |V|\). Transmitted Power \(P = P\left(P - \left(\frac{V_e^2}{X}\right) \sin \delta \right)\) and the reactive power \(Q = Q_e \left(Q - \left(\frac{V_e^2}{X}\right) (1 - \cos \delta)\right)\) provided towards the ends are shown plotted against angle \(\delta\).

**Figure 2.** General UPFC modes, (a) Regulation on voltage (b) Sweeping series

![Figure 2. General UPFC modes](image)

**Figure 3.** Simple two machine system

It is easy to find in figs. \(V_q + V_{pq}\) is the efficient transmission end voltage of the transmission line.

Thus, it is obvious that UPFC impacts on voltage along the transmission line (both its size and angle), therefore it is fair to anticipate that it can manage the magnitude and angle of \(V_{pq}\) realistically. The need for reactive force on the line in any angle from transmission to end.

\[V_{pq} = \Delta V + V_r + V_q\]  

\[Q_e \left(Q - Q_0(\delta) - 1\right)^2 + [P_0(\delta)]^2 = 1\]  

When \(V_{pq} = 0\) then

\[P = jQ_e = V_e \left(\frac{V_s - V_r}{jX}\right)\]  

When \(V_{pq} \neq 0\) then

\[P = jQ_e = V_e \left(\frac{V_s - V_r}{jX}\right) + \frac{V_{pq}^2}{-jX}\]  

Substituting

\[V_e = V_{e1/2} = V \left(\cos \frac{\delta}{2} + \sin \frac{\delta}{2}\right)\]  

\[V_e = V_{e1/2} = V \left(\cos \frac{\delta}{2} - \sin \frac{\delta}{2}\right)\]  

And

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

The following terms are available for obtained P and \(Q_e\)
$$P(\delta, \rho) = P_0(\delta) + P_{pq}(\rho) = \frac{v^2}{x} \sin \delta - \frac{v_{pq}}{x} \left( \cos \frac{\delta}{2} + \rho \right)$$ \quad \ldots \quad (10)

$$Q_r(\delta, \rho) = Q_{r0}(\delta) + Q_{pq}(\rho) = \frac{v^2}{x} \left( 1 - \cos \delta \right) - \frac{v_{pq}}{x} \left( \sin \frac{\delta}{2} + \rho \right)$$ \quad \ldots \quad (11)

6. Simulations And Results

UPFC’s capabilities should be evaluated by means of software simulation tools. For simulation purposes in this paper, MATLAB / Simulink is utilised. Three-component UPFC module: stable state model, dynamic model with parent controller. The analysis of the system is performed in this chapter when the UPFC is connected and not linked to the system. In the aforementioned system, there are different cases;

State of pre-default 0 < t: 2

In the incorrect field (error occurred within 2 to 3 seconds) 2 < t < 3

The line is restored. 3 > t

The behaviour of the line is examined as follows in view of these circumstances.

*The following is stated in the simulation of the UPFC test model:

Below are the feeder parameters that are simulated in the MATLAB.

Single phase Hz 230V, 50Hz

0.03 \(\Omega\) 1.067e-4 H Feeder parameters

13Kw RL Load

RL Charging 2 4KW

330e-6 Dc condenser connection

5.6e-3 filter inductance

Filter 5e-3 capacitance

![Figure 4. Proposed circuit without UPFC in sink mode.](image)

![Figure 5. Proposed circuit without UPFC in Surge mode](image)

6.1. System Voltage

This is the major controlling parameter; system voltage fluctuations should be modest if errors occur. If the compensating device is not used, system voltage will reach the critical value as seen in the
figure. Different devices and components linked to a given device have a dramatic decrease in voltage. There is a 45% voltage drop in this situation, which means that the performance is not adequate.

6.1.1 Load Voltage under the Sink Condition without UPFC System:
When new loads are introduced to the system, voltage sinks are produced inside the network. The celery state is seen in figs. The additional load will be introduced to the system within 0.3 seconds.

![Figure 6. Voltage across Load2 without UPFC under sink condition](image)

![Figure 7. Voltage across Load1 without UPFC under sink condition](image)

6.1.2 Load voltage under Surge condition without UPFC
When substantial charge is removed from the system as indicated in Figures 9 and 10, voltage surges enter the system.

![Figure 8. Load2 voltage without UPFC under Surge condition](image)

![Figure 9. Load1 voltage without UPFC under Surge condition](image)

6.2. Reactive Power Compensation
The reactive capacity relies on the system voltage. The reactive power must be fed into the system and vice versa if the system voltage falls. In this scenario, the reactive energy isn't injected and the system supports additional reactive energy to make up for the loss, which aggravates the disease more. Figure following shows the change in reactive power when the mistake occurs for 0.2-0.3 seconds. The growing reactive power value in a failure break shows that the system draws more reactive energy than the reactive power to correct its losses.

6.2.1 Real and Reactive powers under the Sink condition without UPFC system:
6.2.2 Real and Reactive capabilities under Surge state without UPFC

6.3. The simulation of UPFC testing model is given below

UPFCs based on rectifiers and inverters are utilised to alleviate different problems with the power quality, such as power sinks and surge systems. Without an integrated electric current controller, the test model in the MATLAB / Simulink environment is assessed.

The MATLAB/Simulink experimental model with UPFC is presented below

Figure 10. Reactive power without UPFC under sink condition

Figure 11. Active power without UPFC within sink condition

Figure 12. Active power without UPFC under Surge condition

Figure 13. Reactive power without UPFC under Surge condition

Figure 14. Proposed circuit with UPFC in sink mode
6.3.1 System Voltage

When UPFC is linked to the power system, the system voltage remains within defined limits. [4] When three phase faults occur, Figure 6 illustrates changes of system voltage. The figure shows clearly that when UPFC is linked to the systems, the intensity of the fault is decreased. The technology also reduces the current flow and the system may be guarded against overheating.[6-10] Now that UPFC is not connected, system voltage reduces to 25% of the usual value, which is practically half the prior situation. The simulation is performed for the most serious of failures, i.e. three-phase defects. This means that when critical conditions emerge, UPFC can sustain terminal conditions.

In the following figure, UPFC’s efficiency in the power system is indicated. UPFC can control and maintain the appropriate value w.r.t voltage, as shown in the figure. The sinks are generated at 0.3 sec and the network mitigates the voltage value of 0.4 sec UPFC.[11-14]

6.3.1.1 Load Voltage under Sink Condition with UPFC

![Load Voltage under Sink Condition with UPFC](image)

**Figure 17.** load-2 voltage with UPFC under sink mitigation condition

**Figure 18.** load-1 voltage with UPFC under sink mitigation condition
6.3.1.2 Load Voltage under Surge Condition with UPFC

Figure 19. Load-2 voltage with UPFC in Surge condition

Figure 20. Load-1 voltage with UPFC in Surge condition

6.3.2 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. Figure 22 shows the waveform for reactive energy. There can be seen in figure that there is a drop in reactive power, indicating that reactive energy is being introduced into the system.

The reactive power increased compared to the previous case.

6.3.2.1 Real and Reactive powers under Sink condition with UPFC

Figure 21. Active power with UPFC in sink condition

Figure 22. Reactive power with UPFC in sink condition
6.3.2.2  **UPFC real and reactive outputs under surge**

![Figure 23](image)

*Figure 23. Active power with UPFC in Surge condition*

![Figure 24](image)

*Figure 24. Reactive power with UPFC in Surge condition*

Comparison between results described below,

| Sr. No | States                  | Voltages (V) | Power Real (W) | Power Reactive (VAR) |
|--------|-------------------------|--------------|----------------|----------------------|
| 01     | No UPFC                 | 215.54       | 1778           | 2281                 |
| 02     | UPFC (open loop)        | 222.33       | 3394           | 5109                 |

6.4.  **Comparative analysis chart**

Figure 26 illustrates the chart of relative real power analysis.

![Figure 25](image)

*Figure 25: Real flow of energy with and without UPFC*

Figure 27 shows a comparative analytical chart for reactive power.

![Figure 26](image)

*Figure 26: Reactive flow of energy with and without UPFC*

Figure 28 illustrates the comparative study of charging voltages.

![Figure 27](image)

*Figure 27: Load tensions with and without UPFC*

7. **Conclusion**

The technology that has been developed to link UPFC to the electrical system's transmission line produces superior results than the existing technology power stabiliser and automated voltage
management. In order to explore series compensation and discrete blur compensation using serial control and shunt controller, we have performed computer simulations. Relative variation of reactive power support, terminal voltage and active power comparison studies. We have seen UPFC enhance momentary stability. Using UPFC, we get greater volatile stability than without UPFC.

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