Simulation of Domestic Utility to Improve the Voltage Stability using AI Controller

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Abstract— **The power system has been operating near its voltage uncertainty point due to an increase in demand (mainly reactive load) and a lack of appropriate production. Voltage stability prior to voltage breakdown has been an intriguing study topic for many researchers. As a result, several voltage stability indices have been proposed as a way to gauge how far the power system is from experiencing a voltage breakdown. Hence the proposed framework employs the fuzzy based controller to UPFC SVC to stabilize the voltage in the domestic application by testing on IEEE 30 bus and the simulation is carried out in the MATLAB 2019 Simulink. The results show the system can be adopted for the real time applications.**

Keywords— Voltage stability, Fuzzy, UPFC, simulink, IEEE 30 bus.

I. INTRODUCTION

The entire economy is now largely driven by the global power grid. In today's world, power systems are operating close to their limits because of the constant growth in demand. Constraint violations and voltage collapse are mostly caused by voltage instability. The stability of the voltage is linked to the regulation of reactive power, which is regulated. Reactive power flow is more dynamically controlled by FACTS, thanks to its enhanced transmission system flexibility [1]. There is a need to find the accurate place of power system variation and it can be rectified by placing the FACTS, it can be in the transmission line or in the buses. Control is delegated to the power electronic equipment. Flexible AC Transmission System is the controller's full name. These controllers have the potential to save operating costs and improve the dependability of a power system. Static VAR compensator (SVC), unified power flow controller (UPFC), thyristor-controlled series capacitor (TCSC), static synchronous series compensator (SSSC), and static synchronous compensator (STATCOM) are some of the five FACTS devices (UPFC). They all have their own advantages and disadvantages.

If they can fulfil the specified voltage stability criteria using the most advantageous FACTS devices, they are valuable from a utility perspective. For voltage stability analyses, several papers [2][3][4] use just AC equations. As a result, the DC components of FACTS devices may not be viable. With shunt correction, it is possible to evaluate the voltage stability of the system. For the SVC and STATACOM the IEEE-14 bus has been connected to link the devices.

II. LITERATURE SURVEY

They suggest a transmission line capacity increase for IEEE 14-bus networks by locating and sizing UPFCs in the most optimum locations and dimensions. Now a days a requirement is such that the demand from the load need to be fulfilled by without changing the transmission line capacity considering this as the research gap there is a need to increase the loading factor linearly from 1.25 to 1.50 of the base case value of 1.0 enables this method's dynamic and practical usage to be achieved. To find the power flow for every increment of load the Newton-Raphson method is employed. The Grey Wolf Optimization (GWO) methodology is used to find the best position and size for the UPFC. The results of the simulation reveal that the suggested strategy is effective and appropriate for increasing transmission capacity and delaying or eliminating the upgrade of transmission lines.[1]

They suggests the usage of a Thyristor Controlled Phase Shifting Reduce the fault currents and pre-fault bus voltage using a transformer (TCPST). Mathematical models for TCPST-equipped power systems were created methodically. When TCPST injects a series voltage that reduces the pre-fault bus voltage, the amount of series reactance plays a crucial role in determining the short circuit current. TCPST decreases the overall fault current of the system in comparison to the total fault current of the system prior to TCPST installation. TCPST is assessed using the phase fault to determine its success in the suggested technique. [2]

In this study, new modulated power filter compensator (MPFC) systems for smart grids are described in an effort to improve their efficiency and stability. A one-of-a-kind tri-loop dynamic error driven inter linked modified PID controller is responsible for operating the MPFC. In order to effectively increase power quality (PQ), voltage stability, power factor correction, and transmission line loss reduction, each of the Matlab digital simulation models that make up the proposed MPFC system have been subjected to extensive testing. The FACTS-based method that has been suggested can easily be modified and expanded to include distributed and dispersed renewable energy interface and utilization systems in order to meet a variety of specific stabilization and compensation requirements, as well as voltage control and efficient utilization needs. In this study, new modulated power filter compensator (MPFC) systems for smart grids are described in an effort to improve their efficiency and stability. A one-of-a-kind tri-loop dynamic error driven inter linked modified PID controller is responsible for operating the MPFC. In order to effectively increase power quality (PQ), voltage stability, power factor correction, and transmission line loss reduction, each of the Matlab digital simulation models that make up the proposed MPFC system have been subjected to extensive testing. The FACTS-based method that has been suggested can easily be modified and expanded to include distributed and dispersed renewable energy interface and utilizations systems in order to meet a variety of specific stabilization and compensation requirements, as well as voltage control and efficient utilizations needs. [3] UPFC embedded power systems load flow analysis is given a novel and efficient technique. According to two fundamental UPFC control techniques, an analogous network may be simply generated and utilised for load flow analysis of the original system, which includes UPFCs. The load flow solution is used to establish the control parameters of each UPFC. Using the ETAP software, the analysis is completed (electrical transient analyzer program). The usual methods of load flow analysis are therefore fully included into this method. The efficiency of this strategy is tested using IEEE 14 and New England 39-bus systems.[4]

III. VOLTAGE STABILITY

Reactive power imbalance is the most common cause of voltage instability. Voltage instability. The amount of reactive power supply that a bus in the power system is able to get from the system is directly proportional to the amount of load that bus can carry inside the system. When a system is approaching either its maximum loads or its voltage breakdown, there is a significant increase in the amount of power that is lost due to both actual and reactive power losses.

Therefore, in order to satisfy the demand, supports for reactive power must be located locally and in adequate quantities. [5-7]. The concept of FACTS encompasses many different things, including the adaptability of AC transmission systems, the flow of reactive power, bus voltages, and transmission line impedance.[8]

The categorization of the FACTS follows the format shown in the figure 1 below:

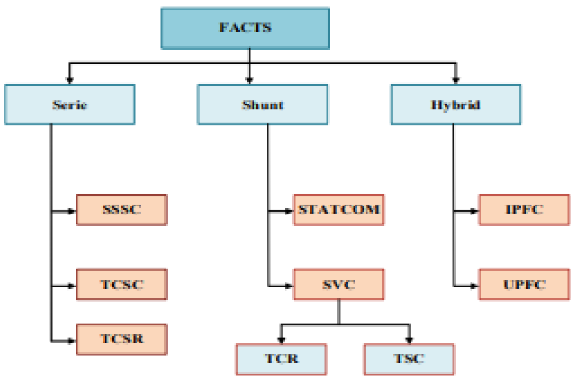

Figure 1: Classification of the FACTS

A. *Thyristor Controlled Series Capacitor (TCSC)*

This is the simplest TCSC module, which includes a TCR and a capacitor. A TCSC is made up of one or more modules.. For protection of the capacitor, in between the transmission lines the MOV (metal oxide varistor) is placed, as well as a TCR (thyristor valve) branch, which is connected to the MOV in parallel with the capacitor. The capacitor bank and the thyristor valve are both bypassed by mechanical breakers. All three bank disconnect switches are closed and the circuit breaker is open during normal operation. In order to disconnect the TCSC, the bypass circuit breaker must first be switched on, and then the bypass switch must be activated. In the event that the capacitor is activated or the bypass circuit breaker is activated, the dampening circuit is employed to restrict the current. When the TCR is off, just the bare minimum in series compensation is accomplished and the design is as shown in the below figure 2,

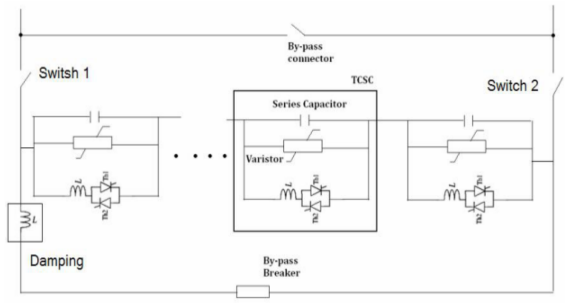

Figure 2: Thyristor Controlled Series Capacitor (TCSC)

The reactive and active power is given by below equations,

$$P_i^F = V_i^2 \, \Delta \, G_{ij} - V_i V_j \left[\Delta G_{ij} \cos\left(\theta_i - \theta_j\right) + \Delta B_{ij} \sin\left(\theta_i - \theta_j\right) \right]$$

$$Q_i^F = -V_i^2 \, \Delta \, B_{ij} - V_i V_j \left[\Delta G_{ij} \sin\left(\theta_i - \theta_j\right) + \Delta B_{ij} \cos\left(\theta_i - \theta_j\right) \right] \quad (1)$$

B. *Static Series Synchronous Compensator (SSSC):*

This FACTS controller, like a STATCOM or an SVC, may be thought of as a more sophisticated version of a controlled series compensation. The SSSC is a series connection FACTS controller that is dependent on the voltage source controller (VSC). To begin with, SSSCs eliminate bulky passive components (such as capacitors and reactors), whereas TCSCs do not. They also have improved technical characteristics (such as inductive and capacitive operation modes), as well as symmetrical capability in both inductive and capacitive operating modes (such as DC port connection availability).

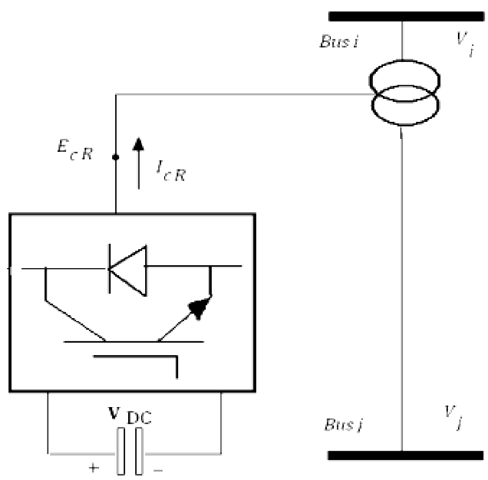

Figure 3: Schematic diagram of SSSC

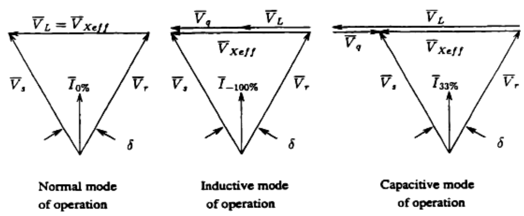

Figure 4: Modes of operation by considering inductor and capacitor.

The figure demonstrates the phasor diagrams for a fundamental power transmission system consisting of an SSSC that operates in both the inductive and capacitive modes. We call a transmission line that transmits electricity from one end to the other with an inductive reactance XL and no compensation a steady-state transmission line. Effective reactance has a voltage imprint identical to the voltage drop over an uncompensated line since series compensations have no impact.

IV. PROPOSED MODEL

A. Static VAR compensator(SVC)

To support voltage, it is a vital component of reactive compensation. SVC is a shunt variable susceptibility model. To maintain a certain voltage, the reactive power of the device may be changed [9] and the structure is as shown in the below figure 5,

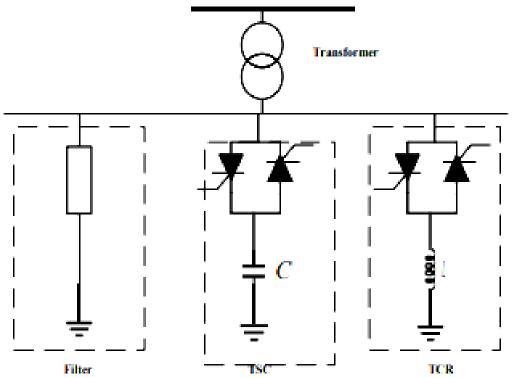

Figure 5 : Structure of SVC

B. Unified Power Flow Controller (UPFC)

A block schematic of the UPFC [10] may be shown in Figure 3. This device is the most powerful and adaptable of all of them. Adjustments may be made to the line impedance, phase angle, and bus voltage in order to manage the flow of power. Because of the limited energy storage capacity of the DC connection, the shunt converter has to generate active power or draw active power from the system at a rate that is equivalent to that of the series converter. Power flow control flexibility is increased since the reactive power of the two converters may be independently adjusted.

The analysis of the UPFC controller is applied on the IEEE-30 bus and the implementation details is as shown in the below figure 6.

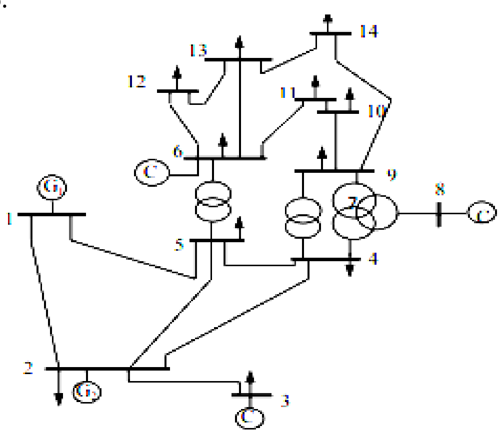

Figure 6: IEEE-14 single line bus structure.

C. Design of the fuzzy logic for the UPFC

"Fuzzy control systems" refers to control systems that use fuzzy logic to assess analogue input values, rather than classical or digital logic, which works on just one of two discrete values: "1" and "0." (True or false, respectively). Machine control makes extensive use of fuzzy logic. Fuzzy logic refers to things that can't be described in terms of "true" or "false," but rather are referred to as "partially true." Genetic algorithms and neural networks may be able to solve the same problem with the same accuracy as fuzzy logic, but fuzzy logic has a distinct advantage because the fuzzy rules may be described in language that human operators can comprehend, which makes it possible to include the operators' prior expertise into the design of the controller. Allows us to automate processes that have previously proven effective for people.

Proposed system has the two inputs and has the forty nine rules are designed to predict the change. The structure of the fuzzy is as shown in the below figure 7,

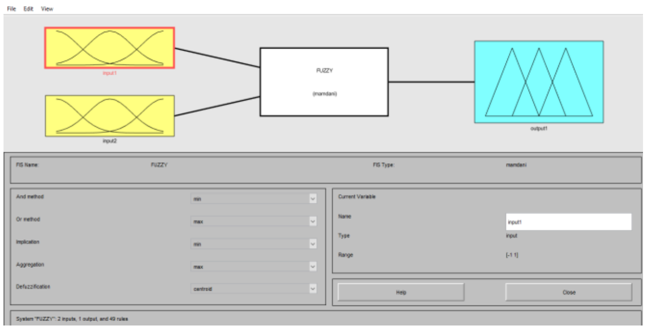

Figure 7: Fuzzy design

The membership design for the first input is as shown in the below figure 8,

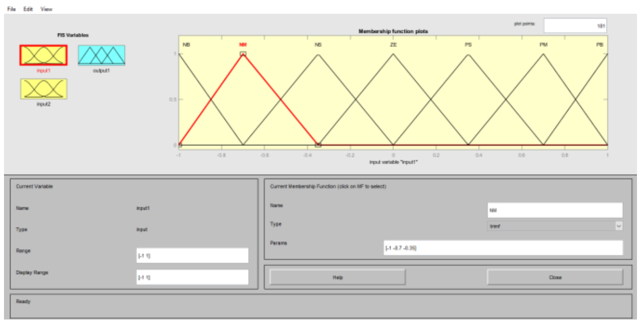

Figure 8: Membership functions for input1.

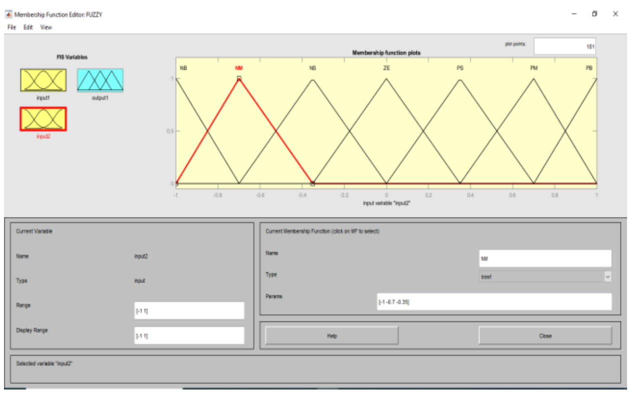

Figure 9 : Membership function for the input2

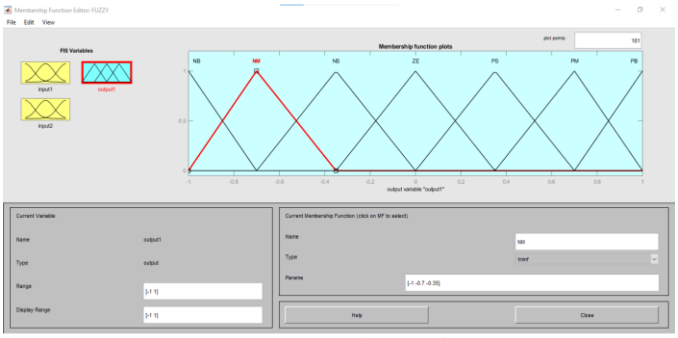
Figure 10: Membership function for output

For designing the rules the and logic is employed such that if both the input are high the output will be appearing, weights of the model is assigned to one and the instance of the rules is as shown in the below figure 11,

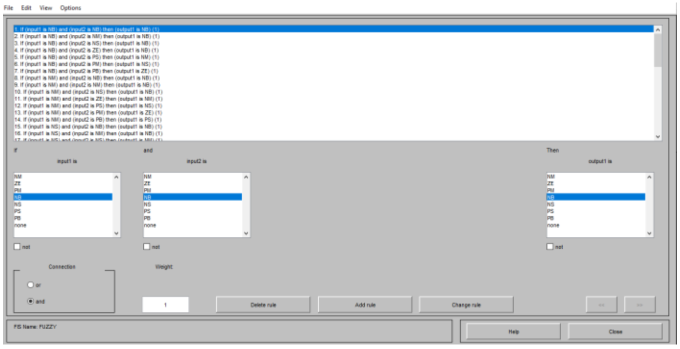
Figure 11: Framed rules for the proposed model.

V. RESULT AND DISCUSSION

A simulated three-phase failure at bus 14 and an increase the demand for the load by 25%, the influence on voltage stability of the test network of the installation of UPFC and SVC, respectively, without any alteration to the network architecture. Between buses 1 and 2, we will join SVC and UPFC at bus 9. SVC has a power dimension of 60 MVAR or less. Up to 200 MVAR of UPFC capacity.

This section is divided into two sections, with FACTS and without FACTS employed on the circuit.

A. Without facts

Case 1: Consider the disruption caused by a three-phase bolted failure on bus 14 for 100 milliseconds. If there is a direct short circuit somewhere in the system, the voltage drop might continue until it approaches the very lowest level that is permissible. Once a few well-dampened oscillations, voltage recovers to its original value after a problem is cleared. In the figure 12 below, you can see how the voltage on bus 2 has changed in real time. Because of its position.

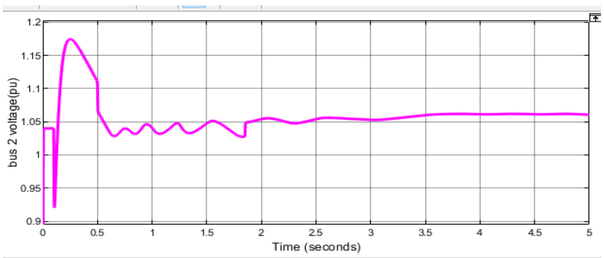

Figure 12 : Without employing FACTS the magnitude of the voltage at Bus 2.

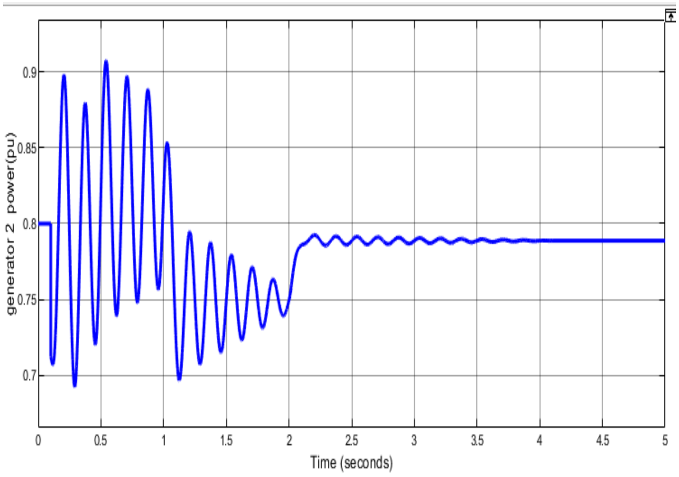

Figure 13: Without employing FACTS the magnitude of the voltage at Bus 14.

As a result of the same failure, we were able to track the changes in the power produced by two different machines, G1 and G2. After a problem is cleared, G1 and G2's peak electrical output is around 0.5 and 0.9 kilowatts, respectively.

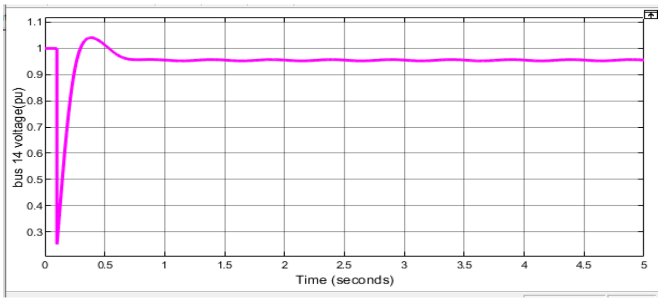

Figure 14: Considering the machine G1, the temporal evolution of the generated power without using the FACTS

Case 2: Increase the load requirements by 25 percentage:

The simulating has a 25% increase based on the findings of the bus 14 short circuit. The time development of voltages on bus 1 with and without FACTS is shown in the figure 15 below. A significant voltage loss occurred at several buses as the load increased.

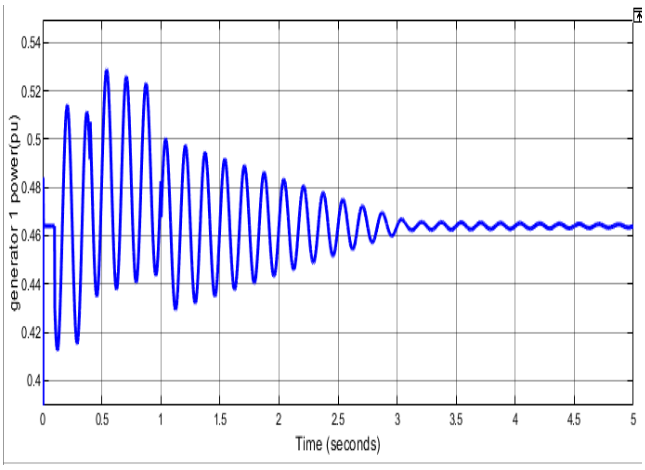

Figure 15 : Considering the machine G2, the temporal evolution of the generated power with using the FACTS

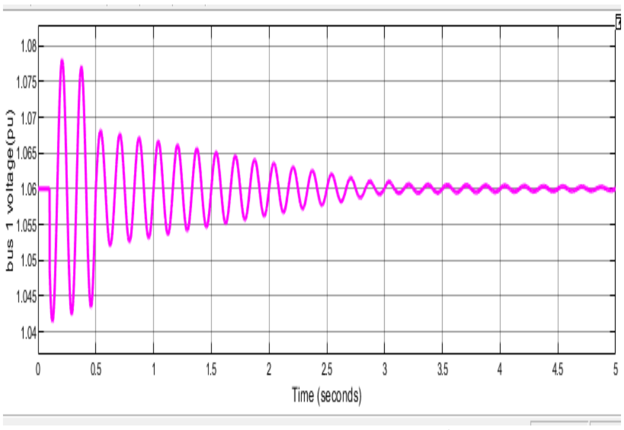

Figure 16: With employing FACTS the magnitude of the voltage at Bus 1.

B. Using UPFC fuzzy on the circuit.

The same two case scenario is employed while implementing the model,

Case 1: Case 1: Consider the disruption caused by a three-phase bolted failure on bus 14 for 100 milliseconds. The voltage drop may continue until it reaches the bare minimum allowable if there is a direct short circuit in the system. Once a few well-dampened oscillations, voltage recovers to its original value after a problem is cleared. In the figures 17 below, you can see how the voltage on bus 2 has changed in real time. Because of its position, the voltage on bus 2 has improved somewhat despite the presence of SVC. UPFC, on the other hand, has a well-dampened voltage magnitude development.

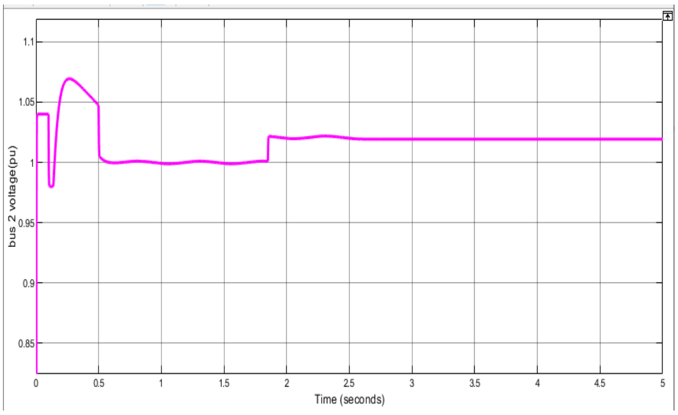

Figure 17: With employing FACTS the magnitude of the voltage at Bus 2.

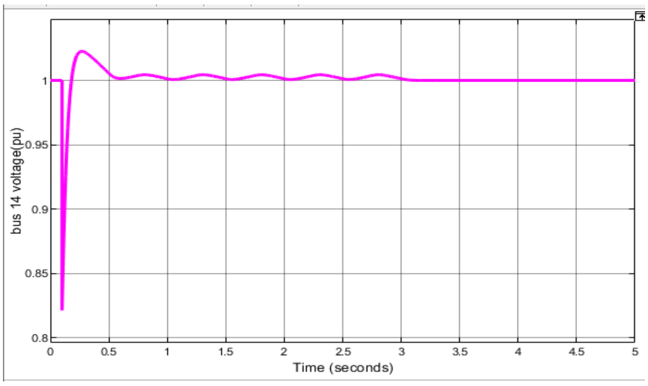

Figure 18 : Considering the machine G1, the temporal evolution of the generated power with using the FACTS

As a result of the same failure, we were able to track the changes in the power produced by two different machines, G1 and G2. After a problem is cleared, G1 and G2's peak electrical output is around 0.5 and 0.9 kilowatts, respectively.

In comparison to SVC, the incorporation of UPFC has greatly improved the dampening of power oscillations and it is illustrated in the below figures 19,20,

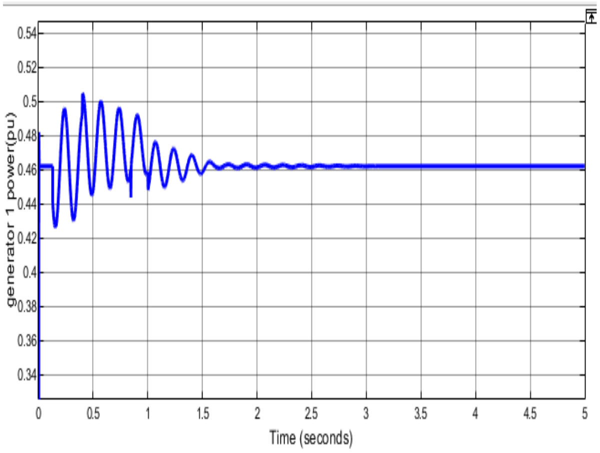

Figure 19: Considering the machine G2, the temporal evolution of the generated power without using the FACTS

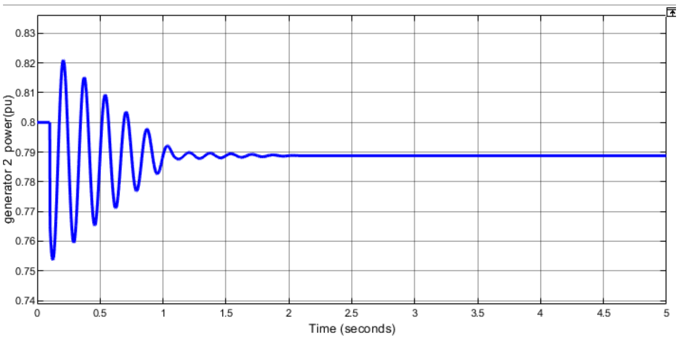

Figure 20 : Considering the machine G1, the temporal evolution of the generated on bus-14.

Case 2: Increased in the load requirements by 25 percentage: The simulating has a 25% increase based on the findings of the bus 14 short circuit. The time development of voltages on bus 1 with and without FACTS is shown in the figure 21 below. A significant voltage loss occurred at several buses as the load increased

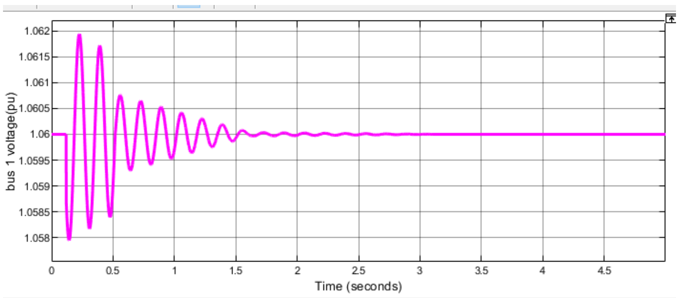

Figure 21: With employing FACTS the magnitude of the voltage at Bus 1.

VI. CONCLUSION

This study suggests employing FACTS devices like the UPFC and SVC to increase voltage stability. The IEEE 14-bus system's response to various disturbances is examined. In order to evaluate the contribution of the gadgets, comparison research is carried out. The results of the simulations show that the SVC's capacity to maintain voltage stability is wasteful. That is why UPFC with the fuzzy logic device has been shown to be better and more durable in improving power system dependability quickly. For a power system with large dimensions and practicality, the suggested solution is ideal.

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