VOLTAGE SECURITY IN FEEDERS BY UPFC

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ABSTRACT – *Economic, increasing demand and operational factors have forced the functioning of power system close to operating conditions. In this Online Voltage Security Assessment, it requires analysing the severity of voltage margins and accordingly acting to make the voltage level in the secured level utilising proper FACTS devices. Due to the complexity of the voltage behaviours, it still remains as an area where new improvements become essential. FACTS devices play vital role to secure voltage under all possible contingencies. Both real and reactive powers can either be absorbed or injected from or into the system with the help of UPFC modules.*

Index Terms – *Voltage Stability, Voltage Instability, Voltage collapse, Contingencies, FACTS concepts and devices, UPFC modules.*

1. Introduction

Voltage Stability is a major concern in power system operation since it has been the cause for many power blackouts [1] around the world. There has been a continually increasing interest and investigation into voltage stability. In [2]-[4], various methodologies for voltage stability analysis techniques have been discussed. The voltage stability evaluation determines if a given operating condition is voltage secure.

Furthermore it is desirable to know how far the system can move away from its current operating point and still remains secure [5]. To analyse the quasi steady state of the voltage, the system load is slowly increased along a certain direction to the point of voltage collapse. The P-V curve can be plotted and the distance from the base operating point to the critical collapse point, the load active power margin, gives the measure of proximity to voltage stability.

The voltage magnitude, Phase angle, real power, reactive power and the necessary parameters under consideration are given as the input and the contingency analysis is carried out.

The concerned credible contingency is given priority first. This method has been elaborated in [6]. After attaining the voltage based contingency ranking, the most severe contingency is analysed and the necessary FACTS controllers are activated, thus securing the voltage of the power system.

Flexible AC Transmission System enables the power system flexible with both the abrupt variations in load and the generating conditions [7]. FACTS Technology is not a single high power controller, but rather a collection of controllers which can be applied individually or in coordination with others to control one or more of the inter-related power system parameters. Flexible AC Transmission System Technology begins new chances for governing power and increasing the usable volume of current, as well as novel and improved lines. By giving further tractability, Flexible AC Transmission System Controllers can qualify a line to carry power nearer to its thermal rating.

2. Voltage Security

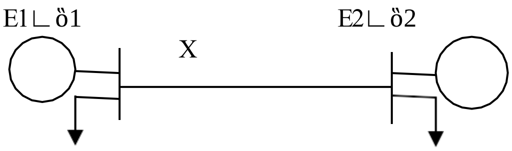
The ability of a system, not only to operate stably, but also to remain stable following credible contingencies or load increase is termed as voltage security. It can also be stated as the ability of the power system to maintain the voltage at all load points at an acceptable level. It often means the existence of considerable margin from an operating point to the voltage instability point following credible contingencies.

The power system is frequently subjected to disturbances and it is necessary to study the effect of these disturbances on the power system so that the system may be operated in a secure operating condition. For example, a generating unit may have to be taken off line because of some auxiliary equipment failure. By maintaining proper amount of spinning reserve, the remaining generating units can make up the deficit without causing any appreciable drop in frequency or need to shed any load.

Similarly, a transmission line may be damaged by a storm and taken out by automatic relaying. If the remaining transmission line in the system takes up the flows within their specified limits, the system remains in secure condition. Suppose if one of the remaining line becomes too heavily loaded, it may open due to relay action, thereby causing even more load on the remaining lines. This type of process is termed as cascading outages. If this continues, the entire system may completely collapse. This condition is referred as system blackout. To avoid these conditions, voltage security is continuously monitored and made secured using FACTS Controllers.

3. Facts Devices & UPFC

The Flexible AC Transmission System devices enable the transmission system flexible with change in load. FACTS devices like series controller, shunt controller, unified series-series controller, unified shunt-series controller, coordinated shunt-series controller etc alleviates the difficulties faced by transmission system, enhances the grid reliability, open new opportunities for power control and also control the line parameters. If the voltage is not compensated either by real power or by reactive power support, frequency will drop further and the system will collapse.



Let us assume the line has no active power loss and it is purely inductive. Changing E1 or E2 have much more influence on reactive power than the real power. By injecting voltage at right angle to the line current, by varying ȍ, we can control the active power flow. Hence it desirable, if the injected voltage is in series and its magnitude and phase angle of voltage are varied accordingly, we can control both the real power and reactive power. This concludes that the combination of line impedance control (series controller) and voltage regulation (shunt controller) can control both real and reactive power flow between the two systems. Such a FACTS Controller is Unified Power Flow Controller (UPFC).

Out of the four basic categories of FACTS controllers, combined shunt-series controllers make the transmission system more flexible and adoptable to changing load.

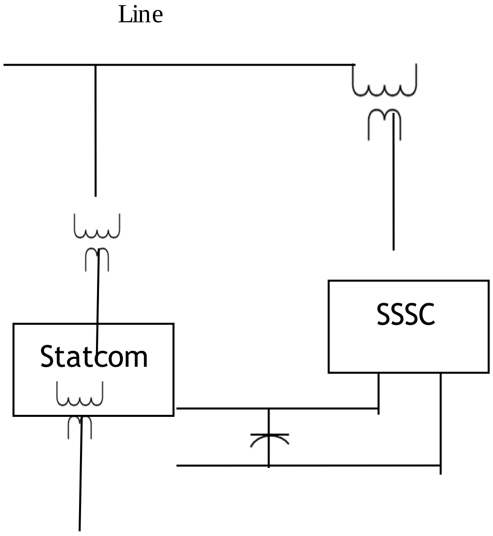
The schematic arrangement of the UPFC is shown above. A combination of static synchronous compensator (STATCOM) and a static series compensator (SSSC) which are coupled via a common dc link, to allow bidirectional flow of real power between the series output terminals of the SSSC and the shunt output terminals of the STATCOM, and are controlled to provide concurrent real and reactive series line compensation without an external electric energy source.

The UPFC, by means of angularly unconstrained series voltage injection, is able to control, concurrently or selectively, the transmission line voltage, impedance, and angle or, alternatively, the real and reactive power flow in the line. The UPFC may also provide independently controllable shunt reactive compensation.

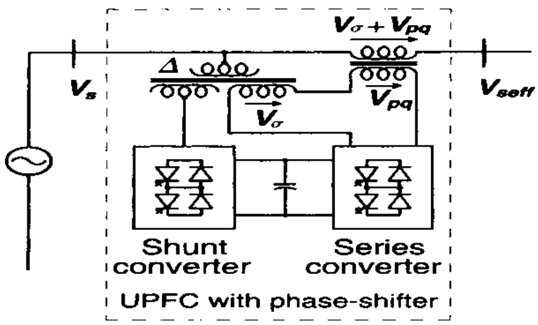
From the theoretical view point, the Unified Power Flow Controller is a general synchronous voltage source (SVS), denoted at the essential power system frequency by voltage phasor Vpq with governable magnitude and phase angle, in series with the transmission line, as demonstrated for the typical fundamental two machine system as shown above. In this functionally and restricted operation, which obviously comprises voltage and angle regulation, the synchronous voltage source normally contacts both reactive and real power with the transmission system. Since, as recognized earlier, a synchronous voltage source is able to produce only the reactive power replaced, the real power must be delivered to it, or engrossed from it, by a appropriate power supply or sink. In the Unified Power Flow Controller arrangement, the real power altercation is given by one of the end buses.

In the currently used applied execution, the UPFC consists of two voltage sourced convertors. These back to back convertors, branded “convertor 1 and convertor2”, are functioned from a common DC link delivered by a DC storage capacitor. This planning functions as an ideal AC to AC power convertor in which the real power can freely flow in either direction between the AC terminals of the two convertors, and each convertor can autonomously produce or engross reactive power at its own AC output terminal.

Convertor2 offers the main function of the UPFC by inserting a voltage Vpq with manageable magnitude and phase angle in series with the line via an insertion transformer. This injected voltage acts essentially as a synchronous AC voltage source, the transmission line current flows through this voltage source resulting in reactive and real power exchange between it and the AC system.



The reactive power exchanged at the AC terminal is generated internally by the convertor. The real power exchanged at the AC terminal is converted into DC power which appears at the DC link as a positive or negative real power demand.



The basic function of convertor1 is to supply or absorb the real power demanded by convertor2 at the common DC link to support the real power exchange resulting from the series voltage injection. This DC link power demand of convertor2 is converted back to AC by convertor1 and coupled to the transmission line bus via a shunt connected transformer.

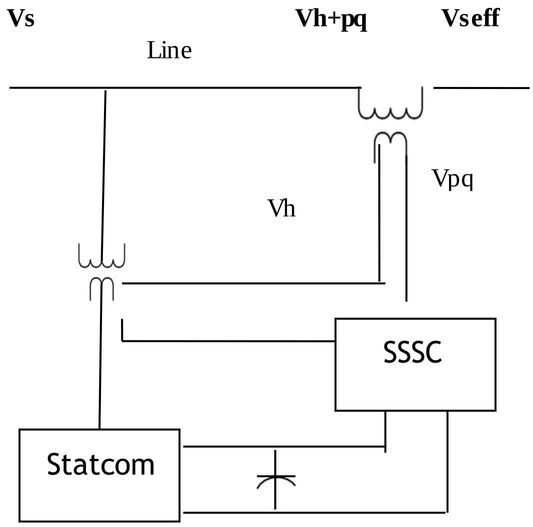
In addition to the real power need of convertor2, convertor1 can also generate or absorb controllable reactive power, if it is desired, and thereby provide independent shunt reactive compensation for the line. It is important to know that whereas there is a closed direct path for the real power negotiated by the action of series voltage injection thro convertors No1 & 2 back to the line the corresponding reactive power exchanged is supplied or absorbed locally by convertor2 and therefore does not have to be transmitted by the line. Thus, convertor1 can be operated at a unity power factor or be controlled to have a reactive power exchange with the line independent of the reactive power exchanged by convertor2. Obviously there can be more reactive power flow through the UPFC DC link.

The active power flow for the series unit (SSSC) is obtained from the line itself via the shunt unit STATCOM, the latter is also used for voltage control with control of its reactive power. This is a complete controller for controlling active and reactive power control through the line as well as line voltage control. Additional storage such as a superconducting magnet connected to the dc link via an electronic interface would provide the means of further enhancing the effectiveness of the UPFC. The controlled exchange of real power with an external source such as storage is much more effective in control of system dynamics than modulation of the power transfer within a system.

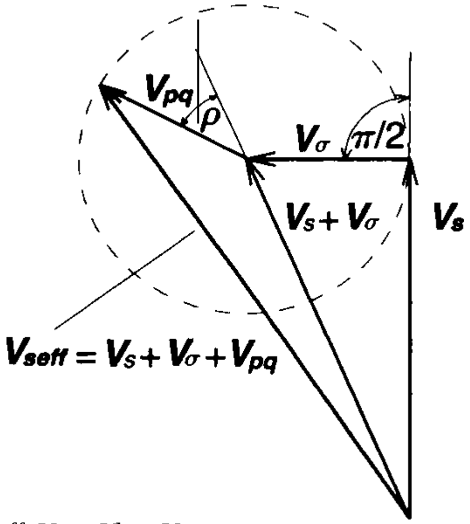
4. Problem Formulation

UPFC with a phase shifting transformer (Hybrid arrangement) has been chosen for voltage security control of the transmission line. The schematic arrangement is similar to that of UPFC a phase shifter has been included.

The Hybrid phase angle regulator is a combination of two or more different types of phase angle regulators to achieve specific objectives at a minimum cost. In this arrangement, the mechanical tap changer would provide the quadrature voltage injection as needed to maintain the required steady state power flow. The voltage source converter would provide superimposed dynamic phase angle control during and following system disturbances. This hybrid arrangement can be highly cost effective if the steady state flow control requires only relatively large, infrequent angular changes for an inter area tie or other line with inadequate dynamic stability for which a converter with relatively small rating could provide effective oscillation damping.



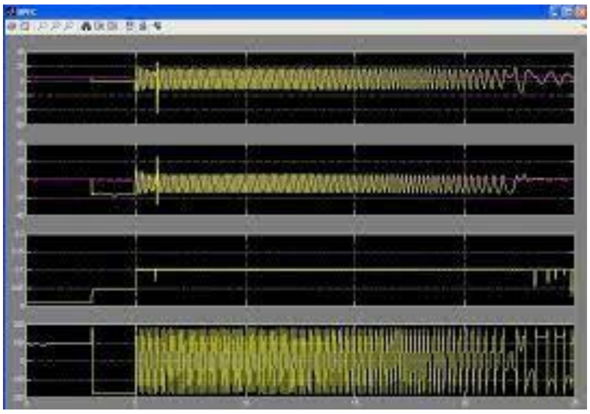
The phasor diagram of the above hybrid arrangement is shown here



Vseff=Vs + Vh + Vpq

The phase angle diagram has been shown above using Hybrid model of the UPFC controller. As explained above, the total injected voltage, used to control the power flow in the line is made up of two components, voltage component Vq, which is the fixed quadrature voltage provided by the shunt connected transformer to advance or retard the existing transmission angle by a fixed angle h, and voltage component Vpq, which is the controllable component provided by the UPFC.

The magnitude of Vpq is variable. The magnitude and angle of the controlled transmission voltage Vseff are obtained by vectorially adding the total injected voltage Vh+Vpq to the existing sending end voltage Vs.



The voltage injection of the UPFC is in a circular region around the end of the sending end transmission voltage phasor. This means that the UPFC voltage injection in general, results in an advance or a retard of the prevailing transmission angle. In other words, the UPFC has two equal half circle segments as operating regions, one characterised by the advancement, the other by the retardation of the effective transmission angle. Although this general capability of the UPFC may well be utilised in many practical applications.

There are other applications in which voltage injection resulting in unidirectional change, advancement, or retardation of the transmission angle is satisfactory, or in which unequal operating regions for advancement and retardation are preferred. If the attainable transmission angle is too small for the desired power transmission the UPFC would have to provide first an appropriate phase angle advancement to establish the correct steady state operating point around which the control of real and reactive power would be executed under the prevailing system conditions.

Another consideration in this application is that a significant portion of the UPFC rating may be used up for steady state angle control, which could be provided by more economical means.

The operating requirements for unequal operating range and steady state angular shift can be satisfied if the UPFC is combined with a phase shifting transformer providing fixed or selectable angle of advancement or retardation. The overall circuit arrangement includes the usual UPFC configuration with two coupling transformers, one connecting convertor one in parallel to the line and the other one, convertor tow in series with the line.

This arrangement in its simplest form, however, also includes an additional winding on the secondary convertor side of each phase of the shunt connected coupling transformer. The phase shifting could also be accomplished by a separate transformer. The transformer connection is such that the voltage obtained at the phases a, b, c of the secondary windings are in quadrature with the phase a, b, c primary voltages.

The hybrid arrangement within its operating region maintains the flexibility of functional control characterising the UPFC. For example, series reactive line compensation is accomplished in the phasor diagram. At this point the value of the series injected voltage is fixed and signal is set accordingly. Once the series transformer is in the line again, the UPFC can remain in voltage insertion mode or transition to any other desired post fault operating mode. To illustrate this capability the graph shows the UPFC returning to the pre fault operation mode (automatic power flow control) and the referred values attained.

5. Application

The above discussed Hybrid model of UPFC has been modelled and simulated using Fuzzy controller in Matlab. Various possible voltage levels lying in the operating regions with different magnitudes and angles are fed as input and checked for its operation. The disturbances created are rectified accordingly by either absorbing power from the source or injecting power into the source. In addition to this, a practical value available in the feeder of Athipattu feeder, Chennai, Tamil Nadu Electricity Board has also been checked for the viability of the operation of the Hybrid model of UPFC.

6. Conclusion

In this research, an optimal voltage control by Hybrid model of UPFC has been designed in Fuzzy using Matlab and checked for its viability by various voltage levels including one practical voltage from the Athipattu feeder of Tamil Nadu Electricity Board. This research leads to the scope of improving the quality of voltage of the power transmission lines to a greater extent.

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