The impact of FACTS facilities during short-circuit in power system

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Abstract — **The present article is focused to impact of FACTS systems and their utilization for improvement of transient stability during set short-circuit. This article consists of simulations of SVC, STATCOM, TCSC and UPFC systems of a practical representation in NEPLAN software. This paper is focuses on implementing FACTS devices and is compared to different types of controllers. The modeling of the elements in the NEPLAN program shows the regulator's response to voltage and active and reactive power at the short-circuit. The final chapter is dedicated on the recommendation of the practice use of FACTS devices in power transmission system that can help to operate the power flow, stabilize voltage oscillations and improve the transient phenomena.**

Keywords: FACTS, transient phenomenon, controller, short-circuit, dynamic stability

I. Introduction

The operation of each FACTS system is different, and therefore, when it is installed, it will be determined in advance what type of controller is to be dealt with in order to provide the most optimal solution to the individual problems in a given line or node, whether global or local. In almost any case, any version that is suitably set up for a given network greatly improves the quality of either transmission or transients and the stability of electricity.

This scheme examined transient phenomena (dynamic stability) adjusted to 3-phase short-circuit and subsequently observed power system oscillation using flexible devices with and without the use of it.

The application of FACTS systems is mainly limited by the investment costs due to power semiconductor devices and the overall complexity of the technology structure. However, due to their high reliability and efficiency, the return on these devices exceeds the costs associated with their purchase and installation [1], [15].

Using the NEPLAN computational program, a simple diagram (Figure 1.) was constructed to observe transient events with the implementation of FACTS systems and to compare their response and ability to regulate voltages and power flows with the best possible ability to maintain system stability. In the given scheme, disturbances are defined, where the line "LINE23" is disconnected at 0.2 s from both nodes and in the node "BUS3" at a time of 0.1 s a three-phase short-circuit with a duration of 0.1 s is set (thus up to 0.2 s).

In the following subchapters, the individual effects of the controllers will be graphically presented, starting with a system where the generator is not using flexible systems (only the wake-up controller is used) and then compared with individual FACTS devices (SVC, TCSC, STATCOM with UPFC - in this order). Each of the waveforms shows the time on the x axis (from 0s to 5s) and the y-axis shows the bus voltages and active and reactive power on the generator in proportional units. All elements of the FACTS system will connect to a node called "BUS4".

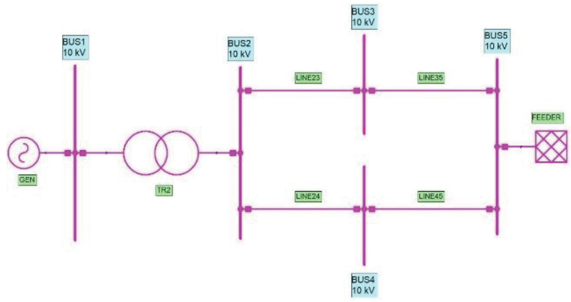

Figure 1. Fundamental scheme

The scheme consists of a generator, a transformer, a series-parallel line and a feeder. All of these elements are enough to keep track of dynamic influences, stability, and voltage fluctuations in a variety of unwanted phenomena in the system. In our case, disconnecting the line and applying a three-phase short circuit in the node can be observed in the oscillations of the voltage and power, thereby evaluating why it is necessary and advantageous to use the control FACTS devices [3],[9].

II. Simplified model of simulation of dynamic phenomena without and with using exciter in NEPLAN programme

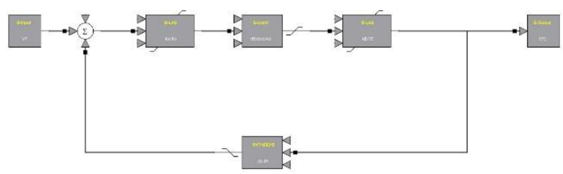

Figure 2. Controller exciter

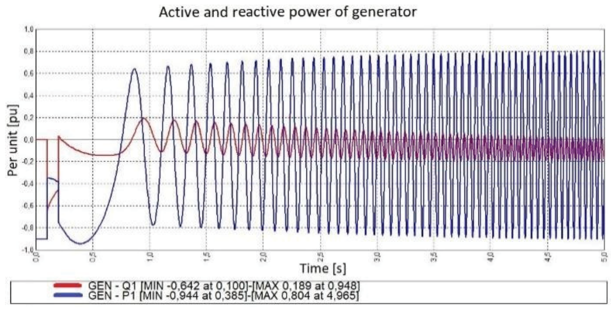

Figure 3. Without exciter P, Q

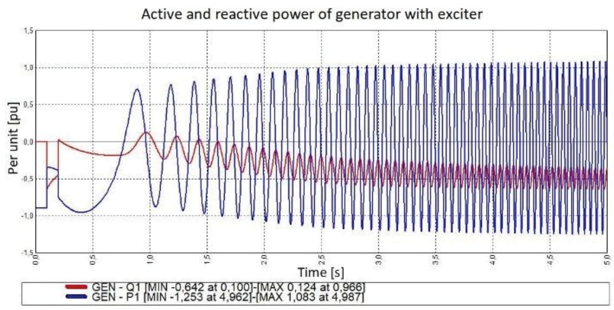

Figure 4. With Exciter P, Q

Figure 3. and Figure 4. shows the active (blue wave) and reactive (red wave) waveforms of the generator without and using the exciter controller. From the waveforms it can be seen that with the set failure, the generator has grown to the point that it has not been able to stabilize itself to a constant power value. The generator has dropped out of synchronism while the amplitude of the oscillation increases with increasing time - generator shutdown is required (power supply stabilization). The exciter response can also be noted by the fact that the reactive power oscillation has stabilized at a lower value (without amplitude change) compared to the non-exciter generator [5],[6].

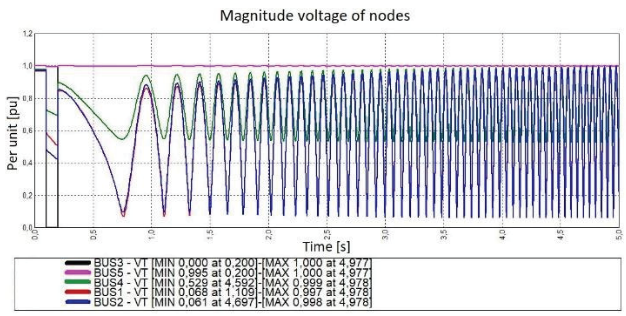

Figure 5.Voltage without exciter

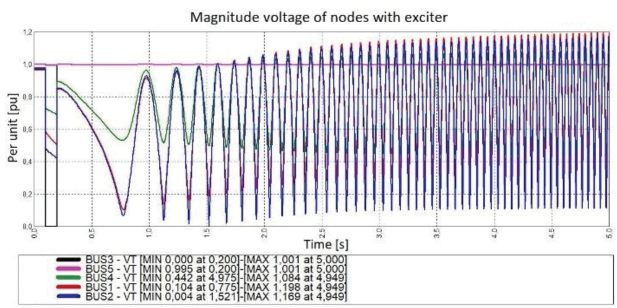

Figure 6. Voltage with exciter

Disconnection of the line "LINE23" and the formation of a three-phase short-circuit on the bus "BUS3" due to large currents and interaction of the entire system oscillated the voltage as shown in Figure 5. and Figure 6. As a result of the exciter controller, the voltage fluctuations at the "BUS1" generator outlet were shifted (similar to reactive power) above 1 p.j. and similarly they could not stabilize. The voltages "BUS5" have almost constant value throughout the monitored time. This is due to the fact that "FEEDER" is considered to be a so-called. a hard network - a network capable of delivering any amount of power without much voltage change (used to calculate and simulate waveforms for NEPLAN). Thus, we can conclude that the driver cannot stabilize and compensate for the serious failure and is not sufficient to stabilize and regulate the dynamic events in the system [4], [22].

III. DYNAMIC MODEL OF SVC CONTROLLER

The main purpose of the SVC regulator is to increase the transmission capacity of the power system. This can be achieved if voltage is provided (by stabilizing it) and by increasing system stability boundaries. In order to stabilize the voltage at the receiving end of the transmission line and to contribute to the improvement of transient stability, the SVC essentially functions as a voltage regulator. While reactive power changes to reduce and quickly damp oscillations during voltage fluctuations, and especially after major bus failures [10], [19], [20].

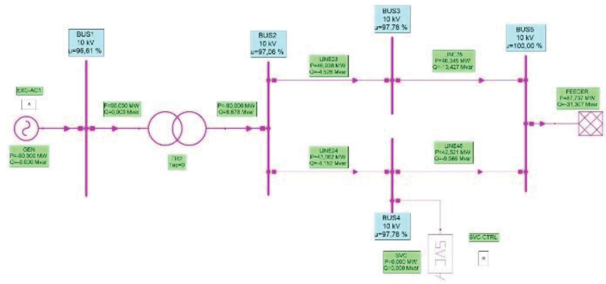

Figure 7. Model with SVC

The FACTS system technology, called SVC, is placed in the model in the "BUS4" node, with each FACTS element having its own controller, which controls the individual parameters for power transmission based on inputs and outputs. It is a modern trend that SVC controllers have also been widely used to control offtake in industry or household to improve a power factor [7].

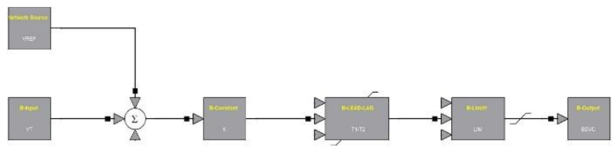

Figure 8. Controller of SVC system

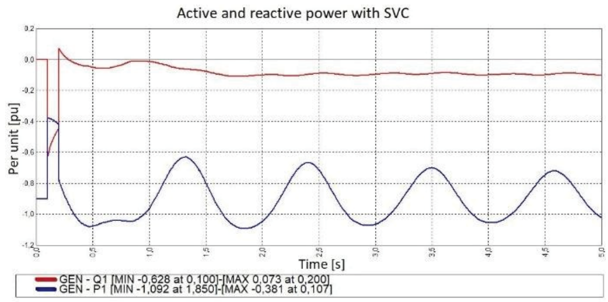

Figure 9. Active and reactive power with using of SVC system

In Figure 9. we can observe the response and influence of the controller and SVC system on generator performance compared to its use or using other FACTS systems (listed in other subchapters). The reactive power the SVC was able to stabilize to an almost constant value while the active power settled at low oscillations, which no longer set a constant value with the controller.

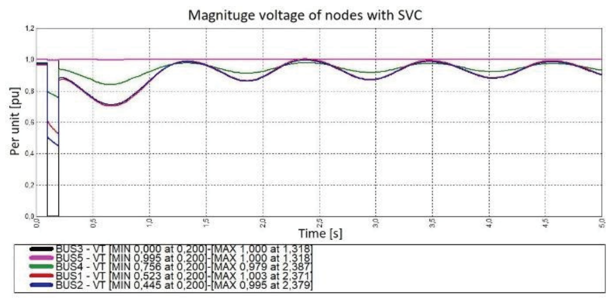

Figure 10. Magnitude voltage with using of SVC system

The SVC system greatly influenced the voltage fluctuations in all system nodes except the "BUS3" fault and the "BUS5" hard network node. Voltage fluctuations were managed by SVC to much lower values, which the network can handle much better, thereby delaying system disruption, disconnecting power supplies, or preventing generator outage from synchronism [17].

IV. DYNAMIC MODEL OF TCSC CONTROLLER

For studies of dynamic stability and oscillation events, a TCSC device may be represented by a variable reactance that is modeled as a variable reactance at a base frequency due to failure and during frequency variation - the frequency remains constant.

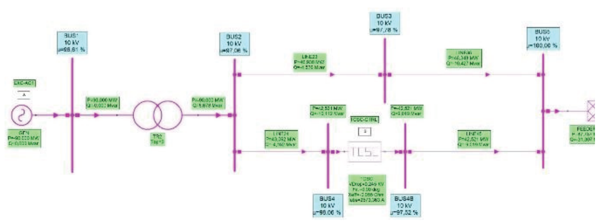

Figure 11. Model with TCSC device

Each of the FACTS devices is designed for the purpose of controlling or controlling the parameters in the system. Thus, the regulator may have entered different input values (voltage, current, power, etc.), which it monitors during operation and thereby controls the output value by means of the members included in the diagram, which may also differ from other regulators (susceptance - change of admittance, inductance - impedance change and others) [18].

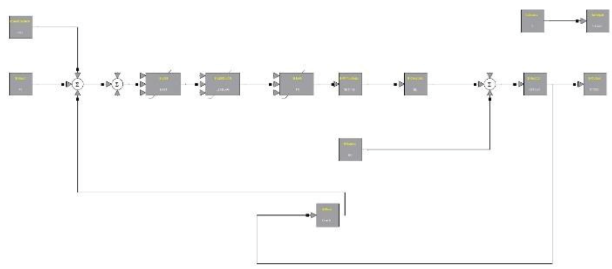

Figure 12. Controller of TCSC system

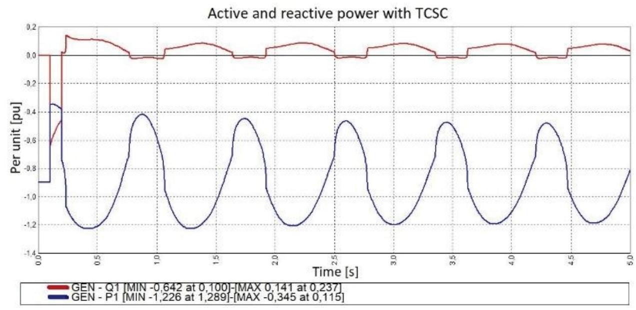

Figure 13. Active and reactive power with using of TCSC

On the curves of active and reactive power of the generator of Figure 13. we can also observe a marked improvement in performance oscillation compared to a non-FACTS-based scheme. Compared to the SVC system, the module thus failed to stabilize TCSC reactive power without oscillations. From the graph (red waveform) we can see when the regulator has turned the controller on and off to achieve the best possible power transmission operation by the power system [11].

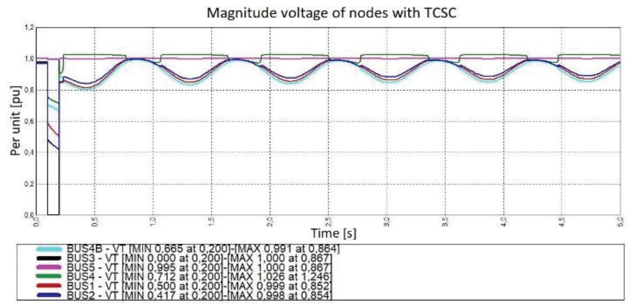

Figure 14. Magnitude voltage with using of TCSC system

Switching on the TSCS module also affected the voltage that the controller was able to settle for minimal fluctuation to ensure its subsequent amplification amplitude as was the case without using a FACTS device. When switching the semiconductor elements in the TCSC, the voltage variation in the "BUS4" node was changed step by step when the oscillations and voltage oscillations were changed due to the impedance change (see Figure 14) [12].

V. DYNAMIC MODEL OF STATCOM CONTROLLER

Dynamic models of STATCOM devices are based on dynamic SVC systems, the difference being that each of them is constrained by a different value. STATCOM is restricted by current (between IC max and IL max) while SVC is limited by susceptance (between BC and BL) [23].

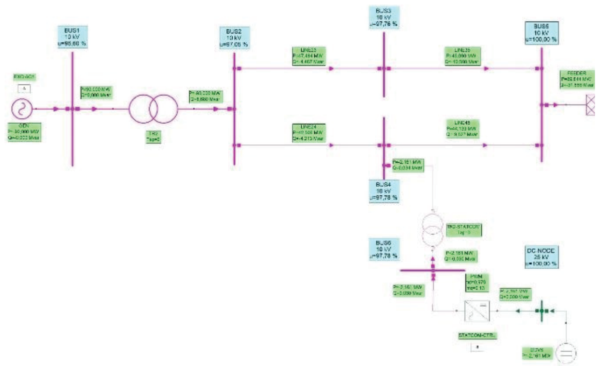

Figure 15. Model with STATCOM device

Each FACTS system has its own controller structure and is, in a way, unique in design and control of given parameters in a system or compensated area. The same technology of a given type of FACTS system can have many designs with a different controller control principle. It means different concurrency of input and output information - another mathematical model of the controller diagram. While the output of them is always connected and it is connected to the switching and switching control pulses of semiconductor components [14].

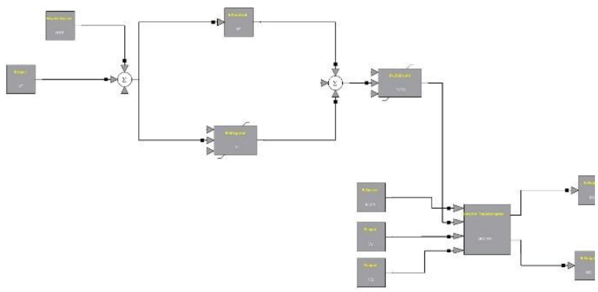

Figure 16. Controller of STATCOM system

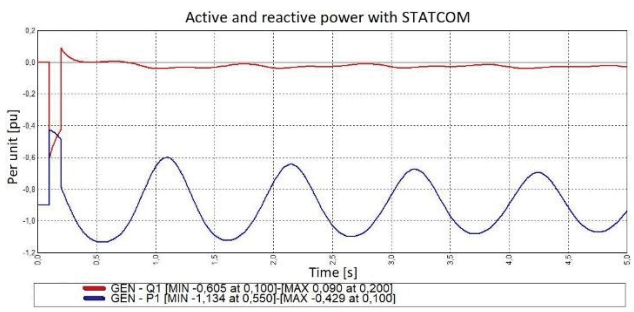

Figure 17. Active and reactive power with using of STATCOM system

As with previous simulations of FACTS controllers used to improve system stability and dynamics, STATCOM technology is able to similarly regulate and reduce voltage and active and reactive power oscillations even when using other equipment designs. From the graphs shown in Figure 17. and Figure 18. we can observe the influence of the STATCOM controller system, which has stabilized the reactive power to almost constant value, and the active power has substantially reduced the amplitude of the oscillations and limited their rapid step changes as opposed to without the FACTS controllers [16].

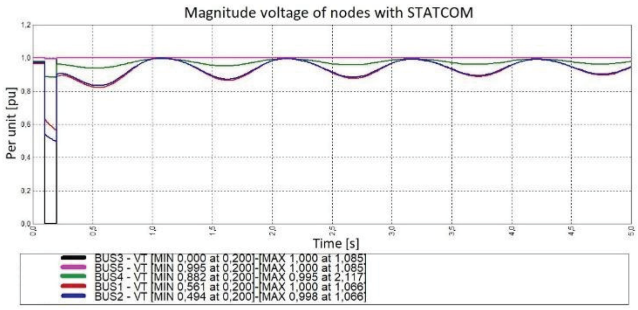

Figure 18. Magnitude voltage with using of STATCOM system

VI. Dynamic model of UPFC controller

The UPFC is a combination of serial and parallel controlled compensation. The UPFC system may appear to be interconnected two known as devices, namely STATCOM and SSSC interconnected via VSC converters with a DC link. This device can independently control both active and reactive power transmitted by the transmission line.

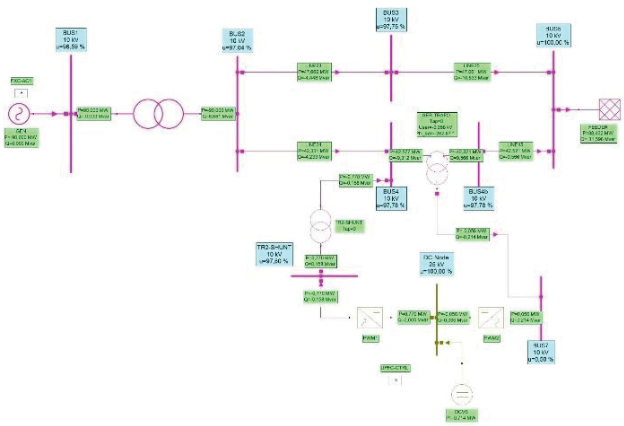

Figure 19. Model with UPFC device

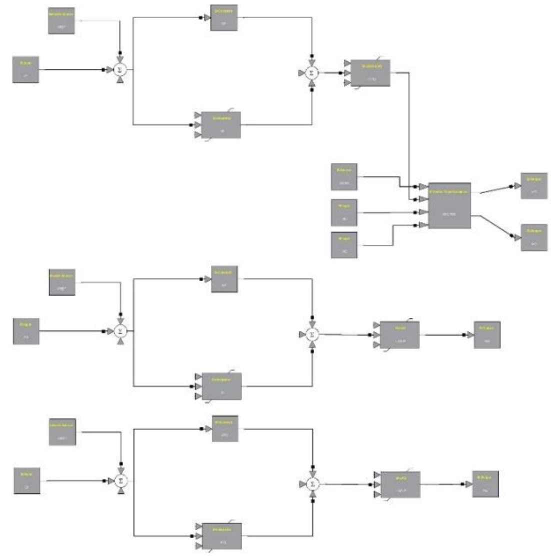

Figure 20. Controller of UPFC system

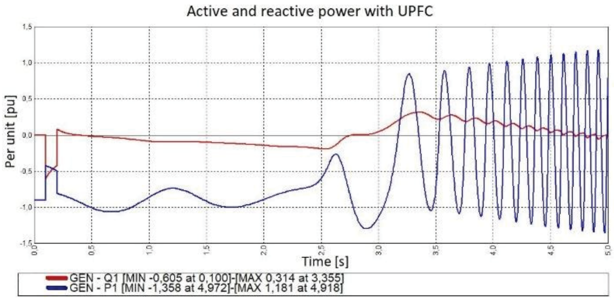

Figure 21. Active and reactive power with using of UPFC system

In Figure 21. and Figure 22. we can see the response of the UPFC system controller, which failed to compensate for the failure, stabilize or mitigate the effects of oscillation of power, voltage, and other system parameters. By approximately 2.9 seconds when the first greater active power oscillation was generated, the controller was unable to stabilize this oscillation. As a result, the amplitude of power and voltage increased with increasing time and would oscillate until the local area in the network or the entire system was broken down. In this case, we can say that the synchronous generator has dropped out of synchronism and the UPFC controller has failed to improve the power transmission in the system.

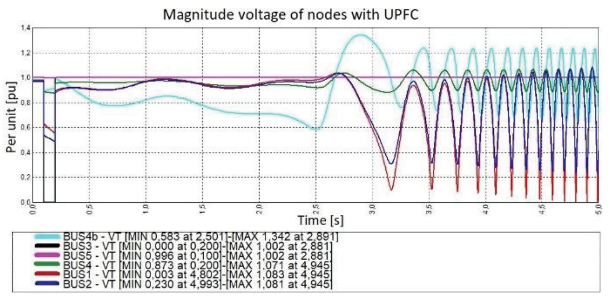

Figure 22. Magnitude voltage with using of UPFC system

CONCLUSION

From the individual developments and research on the impact of FACTS devices in this model, we can evaluate that in the vast majority of these devices are able to greatly ensure the improvement and reliability of the power system. Each device has its own controller and its design and location is suitable for various applications that need to be solved for their installation. This is an analysis for the purpose of applying the device to the system, and which of the electricity quality indicators need to be improved or optimized at a given location. It can be a power factor improvement, reactive power compensation, node voltage stability, increased transmission capacities, and especially the fastest possible dynamic events in various failures, resulting in rapid assistance for synchronous generators and preventing their outage from synchronism. Through FACTS systems, we can manage power flows, ensure continuous production, transmission and supply of electricity, and thus strengthen the whole system as a whole, thereby avoiding blackouts or even a major problem such as the aforementioned "Blackout" systems [13], [21], [24].

Due to the rapidly evolving demand for electricity, it can be stated that FACTS systems will be largely implemented in different locations, whether transmission or distribution systems. However, before they are put into practice, an analysis is needed to address what equipment is best suited to the issue and to which part of the network to use the selected system to make it as reliable as possible to optimize electricity transmission [1], [2], [8], [25].

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