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Power System Oscillation Damping using Coordinated Power System Stabilizer and STATCOM

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Abstract- When a power system experiences power oscillations brought on by a disturbance in the system, stability has been a fundamental problem in power system operation. Loss of synchronism and a catastrophic system collapse might result from power fluctuations. An effort must be made to dampen out power oscillation if the system is to remain stable despite a disturbance. Such oscillations are dampened using power system stabilizers (PSS), and the usage of flexible AC transmission system (FACTS) devices is recommended for increased damping efficacy. By reducing the oscillatory character of the system states, improvement in power system damping has been obtained. The primary purposes of the power system stability are to offer a dampening component when the machine's rotor speed deviation is in phase with it and to supply a stabilizing signal that compensates for oscillations in the excitation system's voltage error during dynamic/transient states. According to studies, power system stability is intended to offer more damping torque for various operating conditions, such as normal load and high load, which enhances the power system's dynamic stability. The simulation was run using PSCAD/EMTDC on a specific model system to demonstrate the viability of the suggested method.

Index Terms- Power system stabilizer (PSS), PSCAD/EMTDC, Power Oscillation, Heffron-Phillip's model, Fact Devices, etc

I. INTRODUCTION

Power system stability is defined as the property of a power system that enables it to remain in a state of operating equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to a disturbance.

Classification of Power System Stability:

1. Rotor Angle Stability
2. Voltage Stability
3. Frequency stability

Rotor Angle Stability

Rotor angle stability is the ability of interconnected synchronous machines of a power System to remain in synchronism after being subjected to a disturbance. Ability to maintain synchronism under large disturbances. Since disturbances are large, nonlinear differential equations cannot be linearized. It has to be solved numerically. It is difficult. However, we can use a graphical approach called Equal Area Criterion for analyzing the stability of a single machine connected to an infinite bus using the classical model.

Stability Phenomena

Stability is a condition of equilibrium between opposing forces. Under steady-state conditions, there is equilibrium between the input mechanical torques and the output electrical torque and the speed remain constant. If there is perturbation, the equilibrium will be upset. The change in electrical torque of a synchronous machine following a perturbation can be resolved as follows:

$$\Delta Te = TS\Delta\delta + TD\Delta\omega$$

Where,

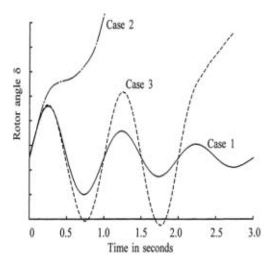
$TS\Delta\delta$ is the synchronizing torque component
TS is the synchronizing torque coefficient
$TD\Delta\omega$ is the damping torque component and
TD is the damping torque coefficient.

Small Signal (small disturbance) Stability Instability can be due to:

1. Steady increase in rotor angle due to lack of sufficient synchronizing torque.
2. Rotor oscillations of increasing amplitude due to lack of sufficient damping torque.

In today's practical power systems, small-signal stability is a problem of insufficient damping of oscillations.

Transient Stability

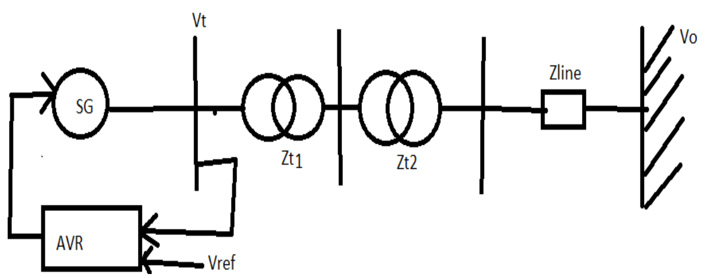


Rotor angle response to a transient disturbance

1) Case 1 - It is a stable case.
2) Case 2 - It is an unstable case. This form is called “first-swing” instability which is caused by insufficient synchronizing torque.
3) Case 3 - It is also an unstable case. This form occurs when the

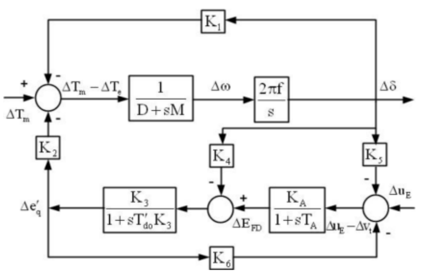
An accurate study of the power system is required to understand and forecast the behavior of a power system, as well as to assess its security and conduct additional research. The initial need for these investigations is knowledge of the parameters of various network elements. Synchronous generators, power transformers, transmission lines, loads, and other components are among them. Because synchronous generators are so important in power systems, modeling and identifying their characteristics has been and continues to be a fascinating and difficult study issue [4].

As a result, the Heffron-Phillips synchronous generator model is studied.9



Single machine infinite bus system

This approach is appropriate for tiny signal analysis in which linear approximation is beneficial. As a result, all of this model's input and output signals exhibit modest domain changes around the nominal illustrated by delta (Δ).



Block diagram of Heffron-Phillips model

II. PROBLEM DEFINITION

Power system stability has been a major concern in power system operation, when it is subjected to power oscillations caused by disturbance in a system. Power oscillations might cause loss of synchronism and eventful breakdown of the entire system.
To maintain the system stability even in case of disturbance, effort has been applied to damp out power oscillation. Power system stabilizer (PSS) is used to damp such oscillations, and flexible AC transmission system (FACTS) devices are advised for the improved damping performance.

III. PSCAD SOFTWARE

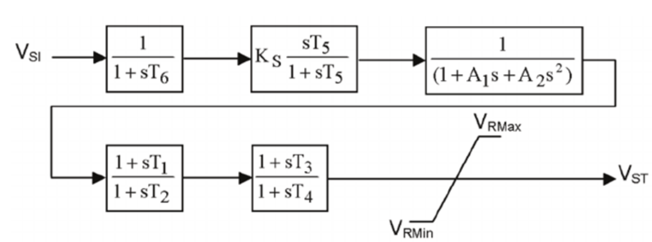
The electrical power systems in commercial and industrial buildings are planned and modeled by electrical power engineers using computer-aided design (CAD) software. [3].
PSCAD software is used by engineers who work on electrical power systems. energy systems by supplying a design foundation that enables power systems to be produced fast and enabling design engineers to analyze the integrity and safety of their design concepts, CAD tools boost the productivity, efficiency, and effectiveness of electrical system designers. With CAD software, businesses can design power systems more quickly than they could with traditional processes. [3].

IV. POWER SYSTEM STABILIZERS

The automated voltage regulator of a generator evaluates the improvement in system stability when a power system stabilizer is added. To reduce oscillation brought on by any disturbance, a PSS can provide an additional control signal to the speed governor and/or excitation systems of the electric generating unit. The stabilizer signal may be fed by one of the locally available signals, such as rotor speed, load angle, rotor frequency, and accelerating power. Power systems frequently include PSS, which reduces low-frequency oscillations. A PSS model may be seen as an extra control block that improves system stability. [2].
Through excitation control, power system stabilizers improve the damping of power system oscillations. Regular inputs to the stabilizers include:

- Shaft speed
- Terminal frequency
- Power

PSS1A - Single Input Power System Stabilizer



The PSS1A component used in the simulation is of IEEE model. The inputs given to this PPS1A model can be rotor speed i.e., W, Terminal voltage i.e., Vt and discontinuous controller reference Vk. The output of this PSS1A model is Vs, which may be rotor speed, terminal frequency, power or none.

TUNING OF PSS

- Through standard AVR control, the PSS modulates the field voltage to reduce power and speed oscillations.

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- Based on the specific generator, AVR settings, and system factors, the tuning research establishes the ideal

- PSS settings. For this investigation, specialized detailed models were used.

- To achieve the optimal damping in the PSS, tuning parameters such as gain K, washout time constant T, and lead lag block time constants T1, T2, T3, and T4 were changed.

- All of these variations were created through the approach of trial and error while using various parameters Values.

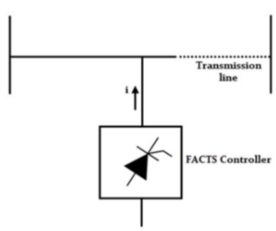
V. FACTS DEVICES

In order to increase system utilisation and power transfer capacity as well as the stability, security, reliability, and power quality of AC system interconnections, a new integrated concept called the Flexible AC Transmission System (FACTS) has been developed. It is based on power electronics switching converters and dynamic controllers. Intended to boost power transfer capabilities and improve controllability.

The following six categories can be used to classify FACTS controllers:

1) TCSC and SSSC.
2) Shunt regulators (such as SVC),
3) STATCOM and
4) Combination series shunt controllers, including UPFC and TCPS, and
5) Series-series controllers that are combined, such as IPFC [2].

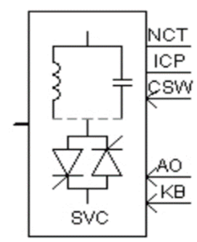
SHUNT CONNECTED CONTROLLERS ARE THE SORT OF FACTS DEVICE EMPLOYED IN THIS INSTANCE.



At the connecting point, these controllers pump a current into the system. A shunt controller uses or provides changeable reactive power to the power system if this current is in phase quadrature with the line voltage

VI. STATCOM

The static synchronous compensator (STATCOM) is a FACTS device that primarily controls reactive power and has a shunt connection. Inductive (lagging) and capacitive steady-state modes are available for the STATCOM (leading). STATCOMs are now widely accepted as a way to enhance the efficiency of electricity systems. The STATCOM consists of a single VSC and a shunt-connected transformer. The STATCOM feature is frequently used for reactive power compensation for voltage support and is analogous to that of a rotating synchronous condenser (RSC) or a static VAR compensator (SVC). The STATCOM does this by drawing (or injecting) a controlled reactive current from the line. Unlike a conventional static VAR generator, the STATCOM may additionally switch active power with the line through the charge and discharge of the DC link capacitor.

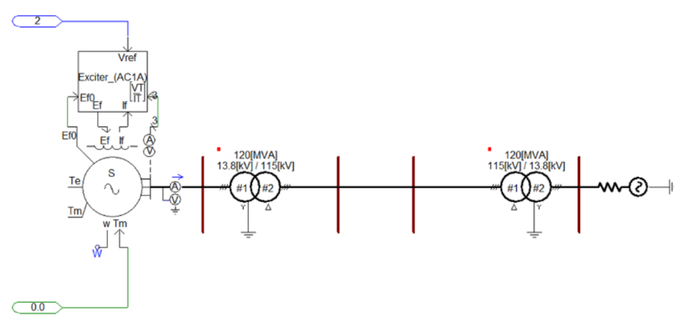


Static VAR Compensator model

The Elements of STATCOM are as follows:
1) A voltage source converter, or VSC
2) DC Capacitor
3) Inductive Reactance
4) Harmonic Filter

VII. Design and Outputs of the system

PSCAD simulation model of SYNCHRONOUS MACHINE.



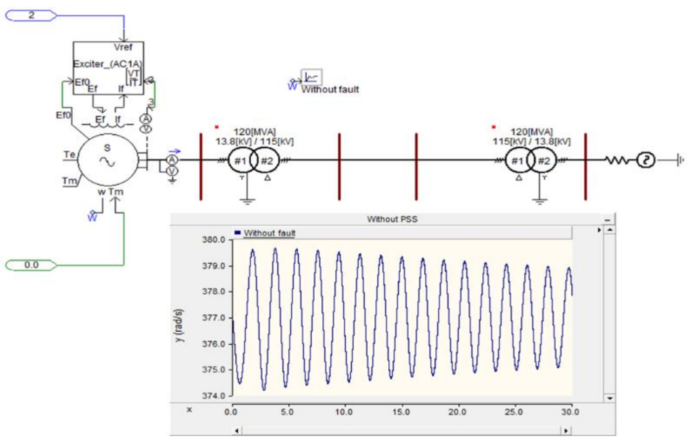
The simulation employs two transformers: a step-up transformer and a step-down transformer.

A step-up transformer is linked to the synchronous generator's output. A multimeter is attached between the synchronous generator and the step-up transformer to measure the instantaneous current and voltage. The ratings of the step-up transformer are of 120MVA, 60 Hz. The primary winding is of star type having a voltage of 13.8KV and the secondary winding is of delta type having a voltage stepping up from 13.8KV to 115KV.

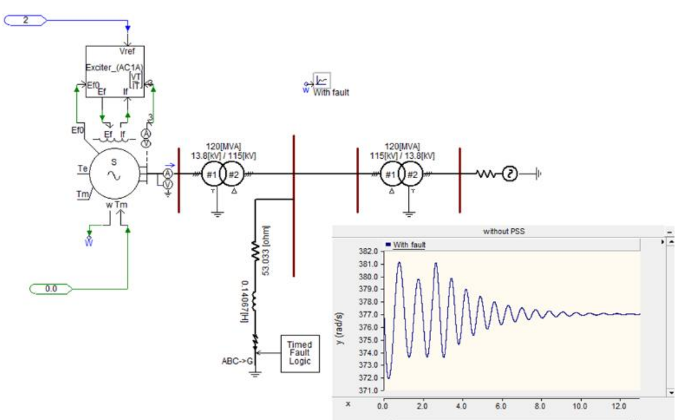
To this step-up transformer, a step-down transformer is connected having the ratings of 120MVA, 60 Hz. The primary winding is of delta type having a voltage of 115KV and the secondary winding is of delta type having a voltage stepping down from 115KV to 13.8KV.

At the end of this step-down transformer, an infinite bus is connected having the capacity larger than the synchronous generator. So, to measure the oscillations present in the stability of the rotor angle, the output of the stability of the rotor angle is fed as input the graph pane with a proper data label. Above in the model is given as W.

1. WITHOUT FAULT AND WITHOUT PSS



2. WITH FAULT AND WITHOUT PSS

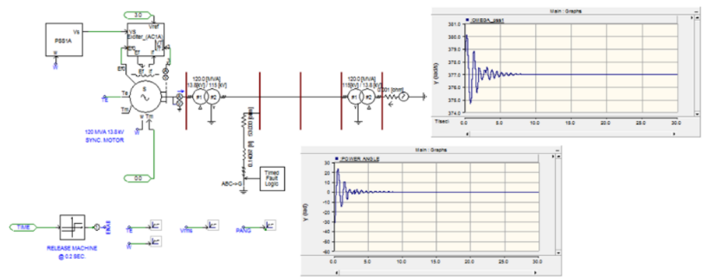


Time to apply fault – 2s, Duration of Fault- 2s.

3. WITH FAULT AND WITH PSS

The oscillations in the PSS with the defect are investigated using a specific graph, and it is discovered that the oscillations in the system are damping and stabilizing over time.

PSS-PSS1A, Time to apply fault – 2s , Duration of Fault- 1s, Gain- 1pu, T1-0.3S, T2-0.02S, T3-0.1S, T4-0.038S

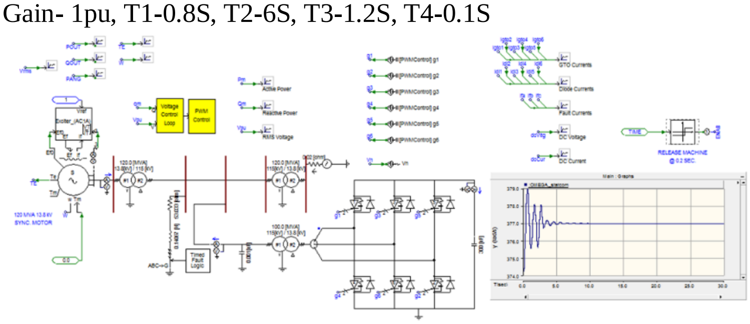


4. WITH FAULT AND WITH STATCOM

The model in the simulation consists of an exciter, synchronous generator, and 120MVA, 60 Hz step-up and step-down transformers sending power to an infinite bus through a single transmission circuit with STATCOM.

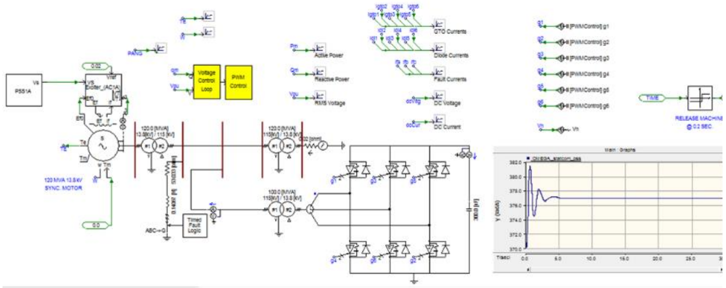
Consider the situation as it is now, with the problem and STATCOM. The oscillation in the STATCOM with the malfunction is initially investigated using a specific graph. The graph shows that the oscillations in the system are dampening and stabilizing with time.

PSS-PSS1A, Time to apply fault – 2s, Duration of Fault- 1s, Gain- 1pu, T1-0.8S, T2-6S, T3-1.2S, T4-0.1S



5. WITH FAULT AND WITH PSS & STATCOM

Electrical networks with poor voltage regulation and low power factor are frequently supported by STATCOMs. Voltage stability is the primary goal of STATCOM. A reactor encircles the voltage source of a STATCOM, a VSC-based device. Due to the fact that a DC capacitor serves as the voltage source, the STATCOM's active power capacity is slightly constrained. However, by installing an appropriate energy storage device across it, the DC capacitor's active power capability may be boosted.



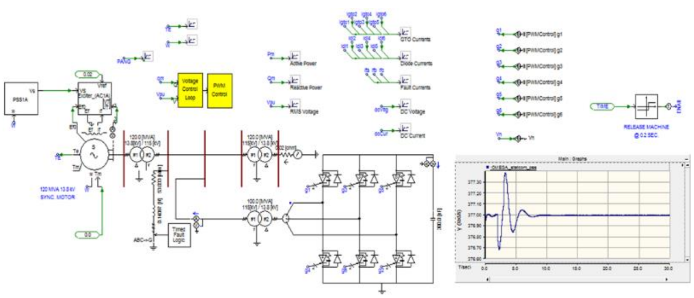
Consider the regular situation with the issue, as well as PSS and STATCOM. The oscillation in the PSS & STATCOM with the problem is first investigated using a specific graph. It can be seen from the graph that the system has oscillations that are dampening and stabilizing over time.

PSS-PSS1A, Time to apply fault – 2s, Duration of Fault- 1s, Gain- 1pu, T1-0.8S, T2-6S, T3-1.2S, T4-0.1S

VIII. RESULTS AND DISCUSSIONS

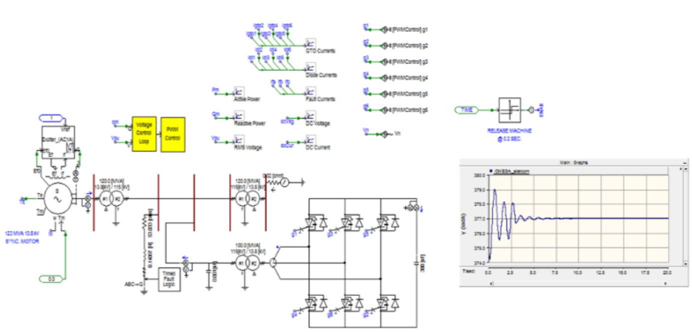
SYSTEM WITH PSS AND STATCOM

Time to apply fault-2s, Duration of Fault-1s



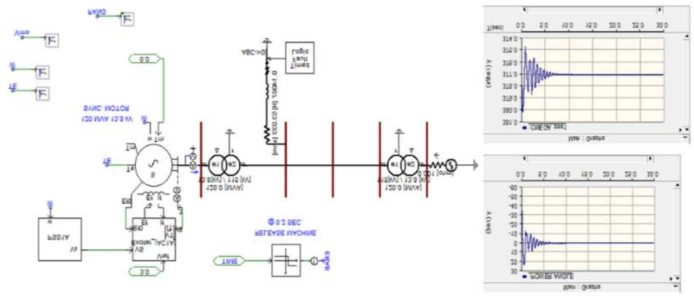
SYSTEM WITH STATCOM

Time to apply fault-2s, Duration of Fault-1s



SYSTEM WITH PSS

Time to apply fault-2s, Duration of Fault-4s



IX. FUTURE SCOPE

There hasn't been much research into the use of STATCOMs in SSO dampening. The majority of STATCOM control is done with traditional damping/lead-lag controllers. As a result, there are significant potential to create novel STATCOM control techniques for SSO damping. To assess the efficacy of STATCOMs for SSR/SSCI mitigation, researchers might focus on building adaptive damping controllers based on meta-heuristic and machine learning techniques. Furthermore, after successfully implementing coordinated control systems for rotor angle and voltage stability, further research into their application to SSO reduction is required. Coordinating multiple STATCOMs within wind farm clusters is a new aspect that is yet to be explored.

X. CONCLUSION

This research examines the use of STATCOM and power system stabilizers for maintaining system stability. In addition to reducing system oscillation, the power system stabilizer also reduces oscillation in real and reactive power, assuring a steady stream of power in the case of a disruption. To achieve enhanced power oscillation damping effects, the coordinated FACTS device may be taken into account and utilized.

XI. APPENDIX

Exciter Data	Vrmax=9.75, Vrmin=-7, Vfmax=5, Vfmin=-7, TR=0, KA=400, TE=1.0s, TA=0.02s, KE=1.0, TF=1.Os, KF=0.06

Generator Data	Ra=0.0036 ohm, Vs = 13.8 kV, fs = 60 Hz, T'd0 = 6.66 s, T'q0 = 0.44 s, Xd = 1.933 p.u., and Xq = 1.743 p.u. T"d0 =0.032s, T"q0 =0.057s, X"d=0.466 p.u., X"q=0.312 p.u., and X'd = 0.467 p.u.

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