International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 4 Issue 4, June 2020 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

A Review on Optimization of Coordinated Control Plan for PSS and STATCOM Devices to Improve Power System Oscillation

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ABSTRACT

This thesis work introduces the control of the coordinates of PSS and STATCOM to damp the inter-field oscillations of the multi-machine system. In previous eras, PSS was used as a local controller in multi-machine systems to dampen such oscillations between fields. Reactive FACTS devices, such as synchronous static compensators (STATCOM) are taken into account and evaluated for their design of a damping controller. STATCOM is a reactive power compensator based on a voltage source converter that uses electronic power devices with stop capacity as switching devices. Its main function is to support the voltage of the bus from which it is connected to the system by providing a quick response to the delivery or absorption of reactive power. In order to dampen the power oscillations, the power oscillation damping function (POD) must be used, in which its output is summed with the voltage reference at the input of STATCOM.

KEYWORDS: *POD, Inter-area oscillation, Power System Stabilizer, STATCOM*

How to cite this paper: Gautam Kumar | Prof. Govind Prasad Pandiya "A Review on Optimization of Coordinated Control Plan for PSS and STATCOM Devices to Improve Power System Oscillation" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-4 | Issue-4, June 2020, pp.114-118, URL: www.ijtsrd.com/papers/ijtsrd30901.pdf

IJTSRD30901

I. INTRODUCTION

Due to the ever increasing demand for electricity, power supply systems work very close to their stability limit. The continuous increase in load is also a kind of disturbance. In this case, modern power supply systems are more likely to reach stressful conditions than in the past. Under such conditions, the occurrence of errors and eventualities can lead to vibrations with negative or poor damping, which have dangerous effects on the power grid. With the increasing power requirements of this modern era, negatively damped low frequency vibrations between zones or poorly damped vibrations are becoming a major problem for network engineers.

The conventional method of damping or decaying these types of intermediate range vibrations for a negative or low damping ratio uses a conventional method. In this conventional method, we used a power system stabilizer (PSS) on each generator, and the control signal for this PSS is a separate generator signal called the local signal. However, this type of controller may not always be able to dampen such vibrations between zones because there is no global observation.

Due to technological advances in power electronics, the trend is increasing to use FACTS devices in power supply systems for both transmission and distribution levels. When FACTS and WASM (Wide Area System Monitoring and Control System) technologies are used together, they can help improve the stability performance of power systems. In this study, the STATCOM, a FACTS controller connected in the shunt and based on a variable reactive current, is used to control the current flow of the connecting line between two zones of an electrical study system.

II. OBJECTIVES OF THE RESEARCH

The main objective of this research includes the following prospects:

A. Design a STATCOM FACTS device based power system stabilizer to damped out the inter-area oscillations and improves the power system stability.
B. Develop a multi-machine SIMULINK models for the Kundur two-area four-machine power systems with STATCOM FACTS device to validate the expected results.

III. LIMITATIONS OF THE RESEARCH

The following are the limitations of the research.

A. Out of various FACTS devices only STATCOM used in this research work.
B. Optimized location of FACTS devices and Feedback signal for FACTS controller not taken in this work

Test system used as a Kundur's two-area four machine power system

IV. LITERATURE REVIEW

Various related literature such as IEEE transactions, other journals and proceedings of various national and international conferences were reviewed

Weiss [2015] constructed a reduced-order model of the Western Electricity Coordinating Council (WECC) power system using mathematically derived parameters from real Synchrophasors data. These parameters include inter and intra-area impedances, inertias, and damping factors for aggregate synchronous generators representing five geographical, and yet coherent, areas of WECC. Wide-area feedback is taken from supplementary POD controller. The objective is to damp the inter-machine oscillation modes of the reduced-order model, which in the full-order system corresponds to inter-area oscillations. The controller input is chosen via statistical variance analysis, and its parameters are tuned to improve the damping factors of the slow modes. The model is implemented in a real-time digital simulator, and validated using a wide range of disturbance scenarios. The closed-loop system is observed to be highly robust to all of these disturbances as well as the choice of operating points. Detailed experimental analyses of the capacity of the STATCOM to satisfy the damping specifications of supplementary control are also presented via multiple contingencies. The results are promising in aiding damping of inter-area modes in WECC, especially at a time of increasing penetration of wind and other renewable resources. *In this work, researcher also used STATCOM FACTS device to damp out the inter-area oscillations.*

Pan [2015] explores the electric torque analysis (ETA) method in the two machine system and the criteria of stability. An online coordination scheme of SVC-based Wide-Area Damping Controller (WADC) to maximize the damping ratio of the inter-area mode with the transient stability constraints is presented. The scheme is treated as an optimization issue and a Plant Growth Simulation Algorithm (PGSA) is employed to search for the optimal controller parameters. A 2-area 4-machine Kundur's benchmark system is used to verify the effectiveness and advantages of the proposed scheme for online applications. *In the research work of this dissertation Kundur's two area four machines system is also taken as a study power system for prosed controller.*

Pradhan [2015] proposed a wide area damping controller, used global signal as a feedback for FACTS or HVDC to damp out the inter-area oscillation. According to author of this paper, global feedback signals may have better damping effect than local feedback signal. But, in this paper, a composite control strategy is used, which uses both local and global signal to damp out or supress the local mode oscillation or inter-area oscillation and improved robustness. *In this dissertation work wide area signal (speed deviation of gen-2 and gen-4) is taken as a control signal for proposed controller.*

Khadanga [2015] proposed a novel approach to enhance the power system stability to damp out the negative damping or weak damping inter-area oscillations including signal delay effect by using coordination control of PSS and SSSC and the parameters of the proposed controller optimised by Gravitational Search Algorithm (GSA), GA and PSO and Compare these results with hybrid of PSO and GSA. To validate this research work, author include various time-delay in controller signal and given both in single machine as well as multi- machine power system under different loading condition and system configuration. Form the results it can be easily observed that, the proposed hybrid PSO-GSA controller, easily damp out the negative as well as weak damping power system oscillations over a wide range of disturbance. *In this research work researcher used coordination control of STATCOM and PSS.*

Yao [2014] proposed a new approach for the synthesis of Wide Area Damping Controller (WADC) for FACTS devices considering the adverse effect time delay of wide area signal. In this paper researcher introduces the delay margin as an additional performance index. For feedback input signal researcher used the geometric measure method and phase compensation part of the WADC designed by residue method. The delay margin is calculated by a Lyapunov stability criterion and LMIs based on the reduced-order model of large-scale power system excluding the WADC. The gain of the controller is the key parameter related to delay margin. *In this dissertation, researcher does not consider the delay adverse effect, but designed a WADC based on FACTS device (STATCOM) with supplementary POD controller.*

Padhy [2014] Network uncertainties, such as time-varying delays, packet losses, packet disorder, seriously deteriorate the performance and stability of any network based control system. To address this issue, a systematic approach has been suggested in this paper to compensate for the network latency in the application of synchrophasors assisted wide area control for the Static Synchronous compensator (STATCOM). The power oscillation modes are estimated online in presence of packet drop in a communication network. The modes are monitored through a modified Extended Kalman Filter (MEKF) approach. The time delay has been compensated by predicting the dynamics of the delayed measurement signal. A network control system model has been developed incorporating the Phasor Measurement Units (PMUs), event driven communication network and network buffers to mimic the response of a real time communication based control. The wide-area stabilizing controller has been designed based on Takagi-Sugeno (TS) fuzzy approach. The performance of the proposed delay compensation scheme has been tested on 39-bus New England system. *In this research work, STATCOM FACTS device has been used without communication delay.*

Wivutbudsiri [2014] present a robust controller for power system damping improvement, with Thyristor Controlled Series Capacitor (TCSC) based on fuzzy logic control design and controlled signal obtained from Phasor Measurement Units (PMUs).In this paper author placed, two PMUs at the generator buses which is located at far away in different areas. As a result of this, weak or low frequency inter-area oscillation can be detected more obviously. The control signal obtained by Phasor Measurement unit is used as feedback input for proposed TCSC damping controller. The fuzzy controller designed for TCSC is based on PMUs wide area signal. Author, simulated some results to validate the effectiveness of proposed controller and also compared their results for conventional lead-lag damping controller. From simulation results it is reveal that, a significant improvement of damping performance and robustness can be obtained by

using fuzzy controller. *In this research work STATCOM FACTS device is used.*

Laopromsukon [2014] proposed the application of a Static Synchronous Series Compensator (SSSC) with Fuzzy Logic Controller (FLC) to damp out the inter-area oscillations from power system. The proposed FLC is applied to SSSC and effeteness of controller tested on Kundur's two-area four-machine power system. From the simulation results, it can be concluded that the proposed control method can improve the stability and robustness of a wide-area power system better than the conventional lead-lag controller. *In this dissertation work STATCOM is used as a controller to increase the damping of low frequency oscillations in a wide-wide area power system.*

Yao [2014] proposed a new approach for WADC controller using FACTS devices, considering the effect of communication delay in wide area signals. The proposed approach select the feedback signal by using geometric measure method and phase composition block design by residue method for WADC. The delay margin is calculated by a Lyapunov stability criterion and LMIs based on reduced-order model of large-scale power system excluding the WADC. The gain of WADC is the key factor related to the delay margin and damping performance: the increase of the gain of WADC will reduce the delay margin while increasing the damping ratio of the critical inter-area oscillation mode. *In this dissertation researcher optimized the parameters of PSS so that controller provide a satisfactory damping performance without a delay margin.*

Zhang [2013] demonstrated design of wide area power system damping controller by considering resiliency either in communication system or physical system to counter act communication failure. In the paper the location of SVC has been selected to strongly influence the relevant inter-area mode of oscillations by computing bus participation factor at nominal operating condition of the power system. *In this paper lead-lag compensator based PSS has been used as wide area damping controller.*

Modi [2011] demonstrate the three different approaches for feedback signal selection for power system wide area damping controller to damp out the inter-area oscillations with negative damping ratio or low damping ratio. These three methods are: residue, controllability/observability, and hankel singular value approach. Out of these methods residue and hankel value based signal selection are based over controllability/observability approach. Further researcher found that residue and hankel value based method signal selection performs similarly in small two-area power system. However, hankel value based signal selection performs outstanding in medium scale system. *In this research work of thesis, researcher used hit and trail method for input signal to the controller.*

Panda [2007] present the single machine infinite bus with TCSC to improve the power system stability and the parameters of the proposed controller are optimised by Genetic Algorithm. This paper also indicates the concept of the damping controller for the power system stability improvement and soft computing technique is used to tune the controller parameters**.** *In this research work the STATCOM and PSS has been applied to Kundur two area four machine power systems to improve the system performance.*

V. CONCLUSION

In this article, the researchers developed a FACTS damping controller to dampen vibrations between the zones of a large power system using the STATCOM POD controller. Some simulation results are performed to verify the efficiency of the proposed controller for small disturbances. The results of the simulation show that the proposed control effectively dampens the vibrations between the zones

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