POWER OSCILLATION DAMPING USING FOR THE CONTROL OF MULTI MACHINE AND BUS SYSTEM

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Abstract: This project proposes a novel objective function and algorithm to obtain a set of optimal power system stabilizer (PSS) parameters that include a feedback signal of a remote machine and local and remote input signal ratios for each machine in a Multi-machine power system under various operating conditions. A novel function called the damping scale is proposed and formulated as an objective function to increase system damping after the system undergoes a disturbance. The control performance is evaluated and compared with other control schemes using eigen value analyses and nonlinear time-domain simulations over a wide range of operating conditions, for example, severe system faults, outage contingencies, load/generation shedding, and line tripping. Additionally, three existing objective functions of the damping factor, damping ratio, and a combination of the damping factor and damping ratio were analyzed and compared with the proposed objective function. In this project we propose a method to identify the dynamic behavior using SA algorithm. The various coefficients obtained from SA global optimization problem are given as an input to the controller block. The paper presents a supplementary VSC-HVDC Power Oscillation Damping (POD) controller based on wide area measurement signals (WAMS). The parameters are obtained through the SA algorithm. The effectiveness and robustness of the proposed approach over a wide range of loading is tested under various conditions and disturbances.

INTRODUCTION

1.1 POWER SYSTEM STABILIZATION CONCEPTS

Low frequency oscillations are observed when large power systems are inter connected by relatively weak tie lines. These oscillations may sustain and grow to cause system separation if no adequate damping is available with the advent of Flexible AC Transmission System (FACTS) technology, shunt FACTS devices play an important role in controlling the reactive power flow in the power network and hence the system voltage fluctuations and stability . Series capacitive compensation was introduced decades ago to cancel a portion of the reactance line impedance and thereby increase the transmittable power. Subsequently, with the FACTS technology initiative, variable series compensation is highly effective in both controlling power flow in the transmission line and in improving stability.

1.2 STRUCTURE OF PSS

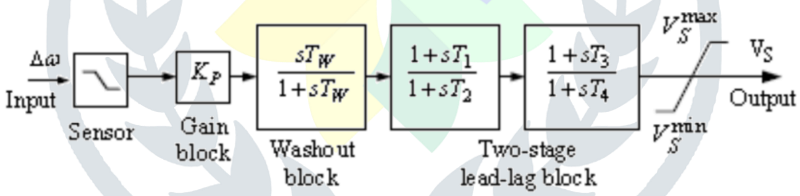


Fig 1.1: Structure of PSS

1.3 MULTI MACHINE POWER SYSTEM

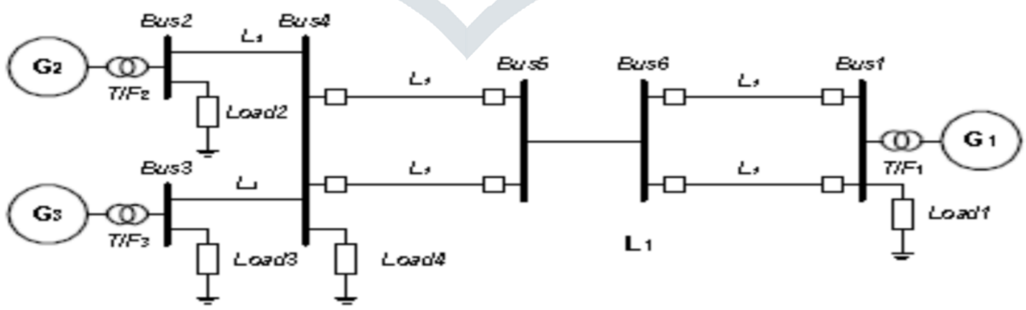


Fig 1.2: Multi Machine Power System

1.4 LOW FREQUENCY OSCILLATIONS IN POWER SYSTEM

Small oscillations in power systems were observed as far back as the early twenties of this century. The oscillations were described as hunting of synchronous machines. In a generator, the electro-mechanical coupling between the rotor and the rest of the system causes it to behave in a manner similar to a spring-mass-damper system which exhibits oscillatory behaviour following any disturbance from the equilibrium state.

Small oscillations were a matter of concern, but for several decades power system engineers remained preoccupied with transient stability. That is the stability of the system following large disturbances. Causes for such disturbances were easily identified and remedial measures were devised. In early sixties, most of the generators were getting interconnected and the automatic voltage regulators(AVRs) were more efficient. With bulk power transfer on long and weak transmission lines and application of high gain, fast acting AVRs, small oscillations of even lower frequencies were observed. These were described as Inter-Tie oscillations. Sometimes oscillations of the generators within the plant were also observed. These oscillations at slightly higher frequencies were termed as Intra-Plant oscillations.

The combined oscillatory behaviour of the system encompassing the three modes of oscillations are popularly called the dynamic stability of the system. In more precise terms it is known as the small signal oscillatory stability of the system.

A power system is said to be small signal stable for a particular steady-state operating condition if, following any small disturbance, it reaches a steady state operating condition which is identical or close to the pre-disturbance operating condition."

The oscillations, which are typically in the frequency range of 0.2 to 3.0 Hz., might be excited by disturbances in the system or, in some cases, might even build up spontaneously.

These oscillations limit the power transmission capability of a network and, sometimes, may even cause loss of synchronism and an eventual breakdown of the entire system. In practice, in addition to stability, the system is required to be well damped i.e. the oscillations, when excited, should die down within a reasonable amount of time.

Reduction in power transfer levels and AVR gains does curb the oscillations and is often resorted to during system emergencies. These are however not feasible solutions to the problem.

The stability of the system, in principle, can be enhanced substantially by application of some form of close-loop feedback control. Over the years a considerable amount of effort has been extended in laboratory research and on-site studies for designing such controllers.

There are basically three following ways by which the stability of the system can be improved,

(1) Using supplementary control signals in the generator excitation system.
(2) Making use of fast valving technique in steam turbine.
(3) Impedance Control-resistance breaking and application of the FACTS devices, etc.

The problem, when first encountered, was solved by fitting the generators with a feedback controller which sensed the rotor slip or change in terminal power of the generator and fed it back at the AVR reference input with proper phase lead and magnitude so as to generate an additional damping torque on the rotor. This device came to be known as a Power System Stabilizer (PSS).

Damping power oscillations using supplementary controls through turbine, governor loop had limited success. With the advent fast valving technique, there is some renewed interest in this type of control.

There can also be other kinds of controls applied to the system for counteracting the oscillatory behaviour - for instance FACTS devices can be fitted with supplementary controllers which improve the system stability.

Power system stabilizers are now routinely used in the industry. However, the complex, constantly changing nature of power systems has severely restricted the efficacy of these devices.

1.5 FIXED PARAMETER CONTROLLERS

Over the years, a number of techniques have been developed for designing PSSs and other damping controllers. Some of these stabilizing methods have been briefly described in this section. The main motivation for including this rather brief exposition of the existing techniques is to introduce the need for the application of robust control techniques in power systems. Some of references cited here include a more comprehensive coverage of the topic.

1.5.1 CONVENTIONAL STABILIZERS

The earlier stabilizer designs were based on concepts derived from classical control theory. Many such designs have been physically realized and widely used in actual systems.

These controllers feedback suitably phase compensated signals derived from the power, speed and frequency of the operating generator either alone or in various combination as input signals so as to generate an additional rotor torque to damp out the low frequency oscillations.

The gain and the required phase lead/lag of the stabilizers are `tuned' by using appropriate mathematical models, supplemented by a good understanding of the system operation.

The principles of operation of this controller are based on the concepts of damping and synchronizing torques within the generator. A comprehensive analysis of these torques has been dealt with by deMello and Concordia in their landmark paper in 1969. These controllers have been known to work quite well in the field and are extremely simple to implement. However, the tuning of these compensators continues to be a formidable task especially in large multimachine systems with multiple oscillatory modes. Larsen and Swann, in their three part paper, describe in detail the general tuning procedure for this type of stabilizers.

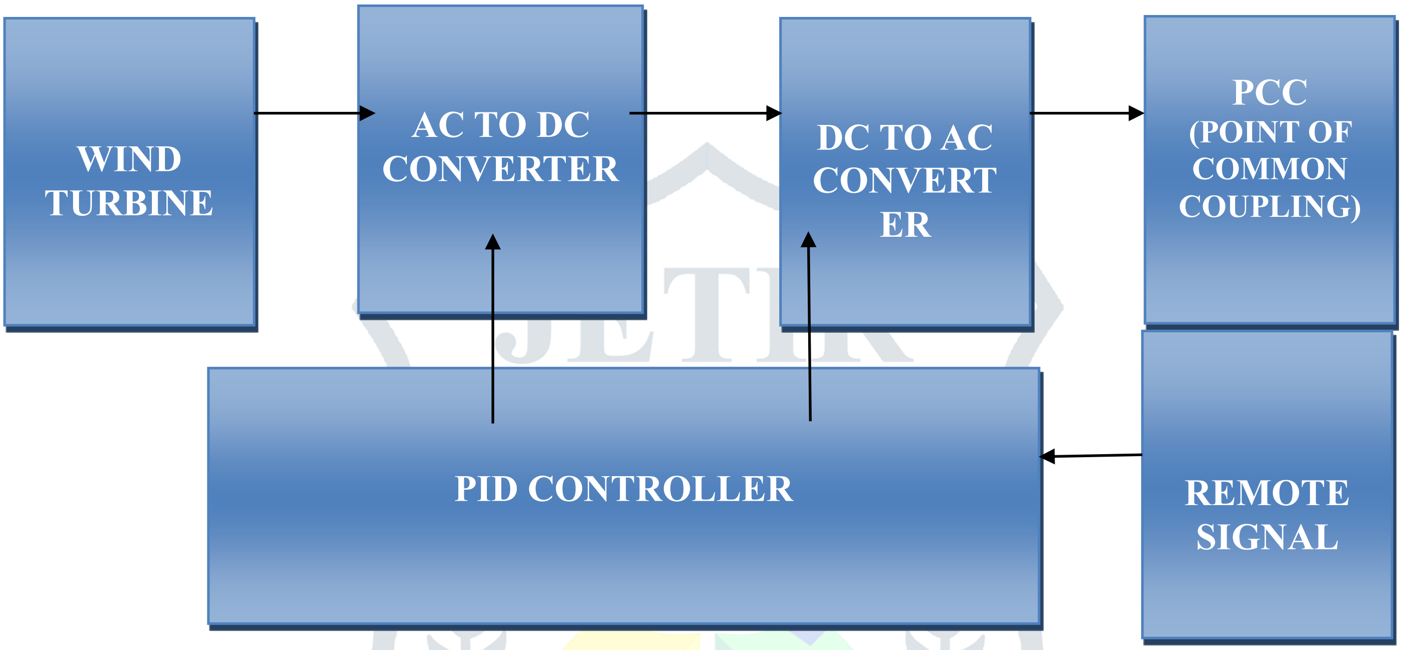
PSS design using this method involves some amount of trial and error and experience on part of the designer. Further these controllers are tuned for particular operating conditions and with change in operating conditions they require re-tuning. Robustness issues are also not adequately addressed in this classical setting. The problem associated with these controllers is more fully described later in this chapter.

1.5.2 OTHER FIXED PARAMETER CONTROLLERS

There have also been numerous attempts at applying various other control strategies -in particular -modal control and LQ optimal control techniques for designing damping controllers. These attempts exemplify the growing preference for algorithmic controller design methods as opposed to the classical intuitive ones. They call for a lesser amount of engineering judgement and experience on part of the designer. The ill-suitedness of the quadratic performance index used in LQR/LQG to the problem has motivated researchers to define alternative performance indices which aptly capture the magnitude of system damping. Such indices can be optimized using standard numerical optimization techniques.

These techniques have the advantage of being straight forward and algorithmic with little ambiguity in the recommended procedure. A few extensions of these methods tried to incorporate some robustness by optimizing some additional index such as eigen value sensitivities. Sensitivity minimization in this form, though, quite helpful as a means of providing robustness in the absence of better methods is essentially a qualitative approach and hence does not guarantee performance preservation in the face of modal inaccuracies.

3.2 BLOCK DIAGRAM



3.3 BLOCK DIAGRAM DESCRIPTION

3.3.1 WIND TURBINE

A wind turbine is a device that converts kinetic energy from the wind into electrical power. A wind turbine used for charging batteries may be referred to as a wind charger. The result of over a millennium of windmill development and modern engineering, today's wind turbines are manufactured in a wide range of vertical and horizontal axis types. The smallest turbines are used for applications such as battery charging for auxiliary power for boats or caravans or to power traffic warning signs. Slightly larger turbines can be used for making contributions to a domestic power supply while selling unused power back to the utility supplier via the electrical grid. Arrays of large turbines, known as wind farms, are becoming an increasingly important source of renewable energy and are used by many countries as part of a strategy to reduce their reliance on fossil fuels.

3.3.2 AC TO DC CONVERTER

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. The process is known as rectification. Physically, rectifiers take a number of forms, including vacuum tube diodes, mercury-arc valves, copper and selenium oxide rectifiers, semiconductor diodes, silicon-controlled rectifiers and other silicon-based semiconductor switches. Rectifiers have many uses, but are often found serving as components of DC power supplies and high-voltage direct current power transmission systems. Because of the alternating nature of the input AC sine wave, the process of rectification alone produces a DC current that, though unidirectional, consists of pulses of current. Many applications of rectifiers, such as power supplies for radio, television and computer equipment, require a steady constant DC current (as would be produced by a battery). In these applications the output of the rectifier is smoothed by an electronic filter (usually a capacitor) to produce a steady current.

3.3.3 DC TO AC INVERTER

A power inverter, or inverter, is an electronic device or circuitry that changes direct current (DC) to alternating current (AC).The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry. The inverter does not produce any power; the power is provided by the DC source. A power inverter can be entirely electronic or may be a combination of mechanical effects (such as a rotary apparatus) and electronic circuitry. Static inverters do not use moving parts in the conversion process.

3.3.4 PCC

PCC = Point of Common Coupling (or Point of Common Connection). The PCC is a point in the electrical system where multiple customers or multiple electrical loads may be connected. According to IEEE-519, this should be a point which is accessible to both the utility and the customer for direct measurement. Although in many cases the PCC is considered at the metering point, service entrance or facility transformer, IEEE-519 states that “within an industrial plant, the PCC is the point between the non-linear load and other loads.

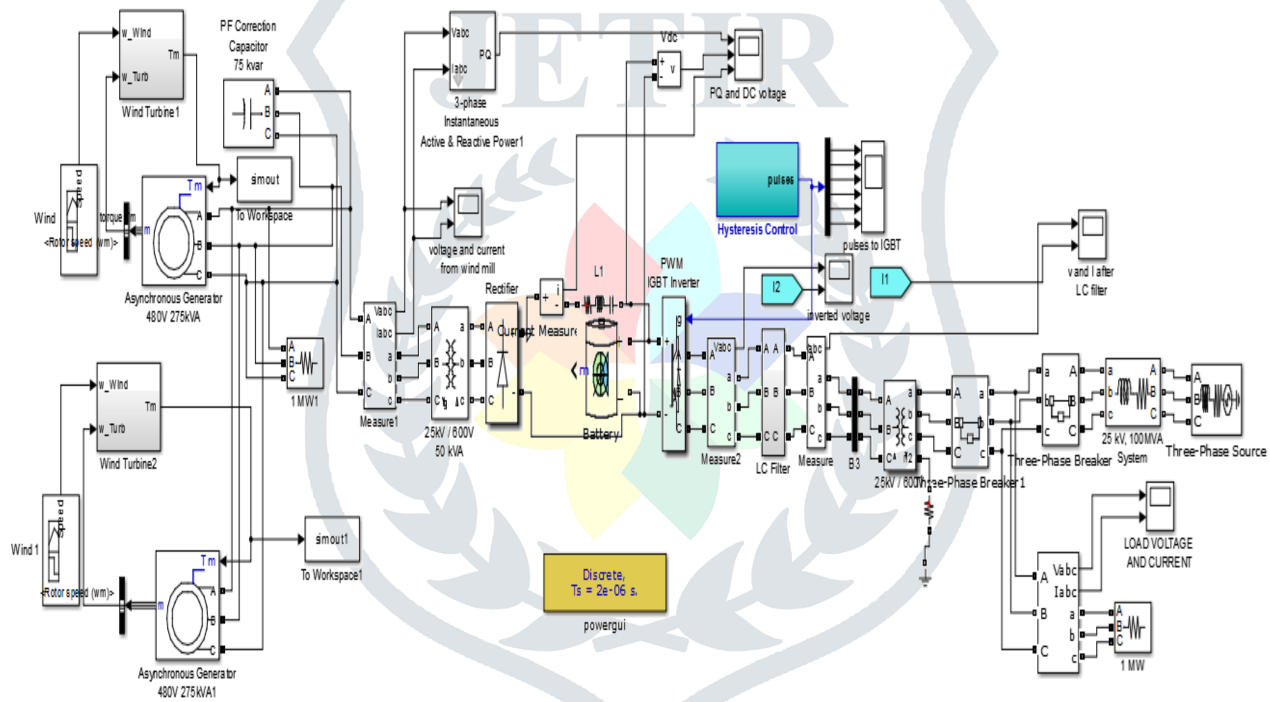
3.3.5 PID CONTROLLER

A proportional-integral-derivative controller (PID controller) is a control loop feedback mechanism (controller) widely used in industrial control systems. A PID controller calculates an error value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process through use of a manipulated variable.

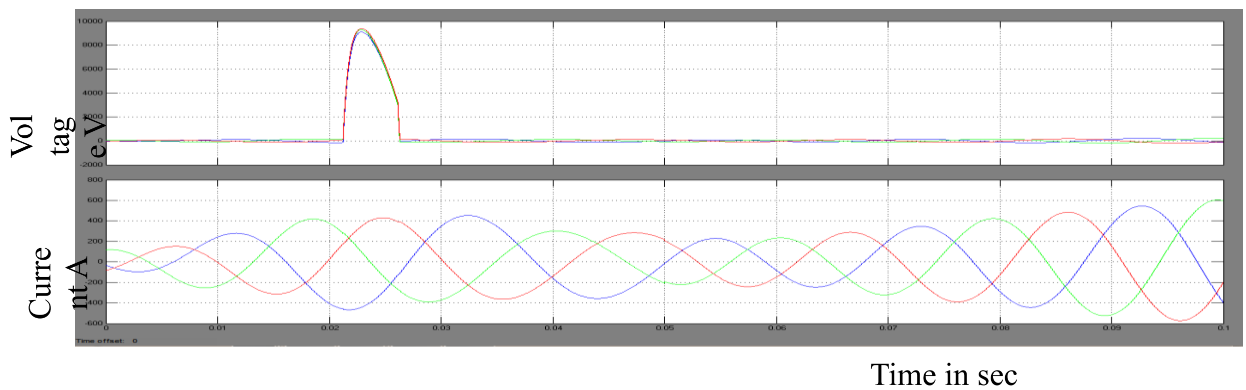
3.3.6REMOTE SIGNAL

This is the signal received from any other system operator regarding the power flow status. This is received through any one of the communication standards with good data secutiry. A zigbee , Bluetooth or wimax can be a better choice.

3.8 SIMULINK MODEL



3.9.6 LOAD VOLTAGE AND CURRENT



3.10.1 MERITS

- Since SA is used, optimization time is very less in the order of milli seconds done at online.

- relaxation of stability constraints
- suppression of low-frequency oscillations increasing power transfer capability between interacting areas.
- enhanced secure power flows reducing unplanned system separation or blackouts.

3.10.2 APPLICATIONS

- Applicable for hybrid control system where a better controllability Is needed.
- This can be incorporated in FACTS based power systems.

CONCLUSION

Active power and reactive power graphs obtained at 3 phase fault. POD controller is designed using an observer based state-feedback approach with transmission time-delay compensation . System implemented with hysteresis control. Its extend to multi machine system and also implemented with GA algorithm.

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