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Review

Automatic Genaration and Energy Storage using Super Conducting Magnetisim

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Modern power system network consists of a number of utilities interconnected together and power is exchanged between utilities over tie-lines by which they are connected. Automatic generation control (AGC) plays a very important role in power system as its main role is to maintain the system frequency and tie line flow at their scheduled values during normal period and also when the system is subjected to small step load perturbations. Many investigations in the field of automatic generation control of interconnected power system have been reported over the past few decades. Literature survey shows that most of the earlier work in the area of automatic generation control pertains to interconnected thermal system and relatively lesser attention has been devoted to automatic generation control (AGC) of interconnected hydro-thermal systems involving thermal and hydro subsystems of widely different characteristics [(Concordia and Kirchmayer, 2008 : Kirchmayer, 2002 : Kothari, 2007 : Kothari et al., 2003).This thesis work has been tempted because it could be a nice concept to meet the need of the power requirement whenever the load and power demand increases. This uneven load changes and power demand can be compensated by the Automatic Generation Control using various proposed controllers method. In a large integrated power system, the generation usually comprises a suitable mix of thermal, hydro and nuclear units. Nuclear units, because of their high efficiency, are usually kept at base load (rated load) close to their maximum output with no participation in automatic generation control (AGC). Thus the natural choice for AGC falls on either thermal or hydro generating units. Megawatt frequency control or Automatic Generation Control (AGC) problems are that of sudden small load disturbances which continuously disturb the normal operation of an electric energy system. The purpose of AGC is to maintain system frequency very close to a specified nominal value and to maintain generation of individual units at the most economical value and to maintain the scheduled tie- line power interchange between different control areas corresponding to the change in load demands. An interconnected power system is made up of several areas. In each area, an Automatic Generation Controller (AGC) monitors the system frequency and tie line power flows, computes the net change in the generation required (generally referred to as Area Control Error ACE) and changes the set positions of the generators within the area to the trend of the randomly changing load of the area, so as to keep the system frequency and the tie line power flow close to scheduled value.

Keywords: Energy Storage, Magnetisim, Automatic Genaration

INTRODUCTION

SMES devices are potentially an efficient way of storing electrical power to maintain a load during voltage sag. A superconducting magnetic energy storage system is a DC current device for storing and instantaneously

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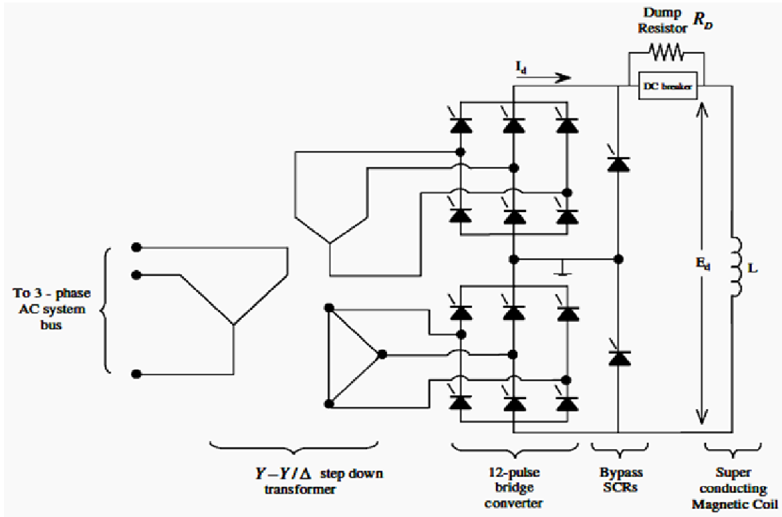


Figure 1. SMES unit configuration

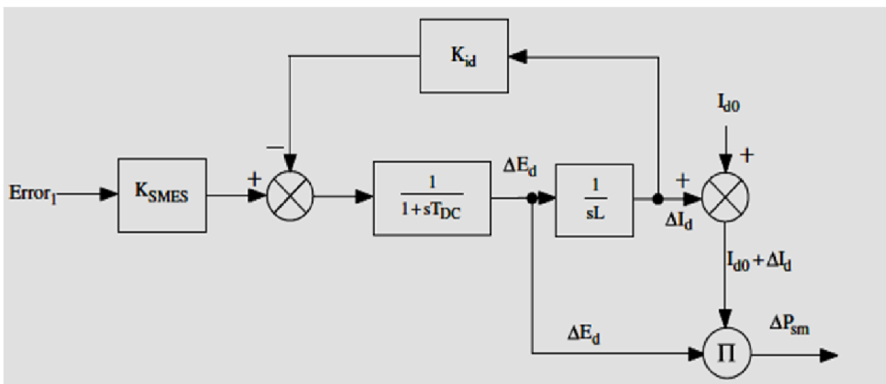


Figure 2. SMES block diagram with negative inductor current deviation feedback

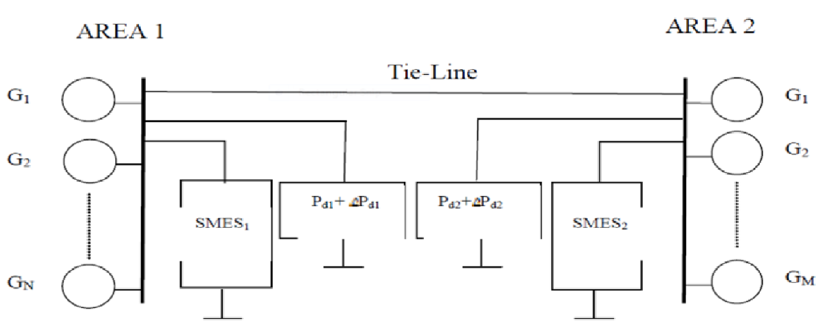


Figure 3. Two area interconnected power system

discharging large quantities of power. Thus, these fast acting energy storage devices can be made to share the sudden load requirement with the generator rotors, by continuously controlling the power flow in or out of the inductor depending on the frequency error signals. Figure 3.1 shows a basic schematic diagram of an SMES system. Utility system feeds the power to the power conditioning and switching devices that provides energy to charge the coil, thus storing energy. When a voltage sag or momentary power outage occurs, the coil discharges through switching and conditioning devices, feeding conditioned power to the load. The cryogenic (refrigeration) system and helium vessel keep the conductor cold in order to maintain the coil in the

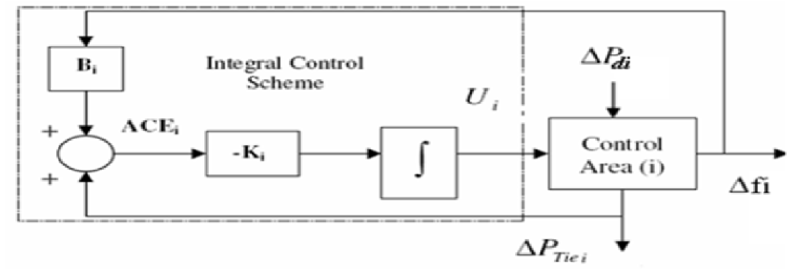


Figure 4. Conventional PI controller installed on ith area

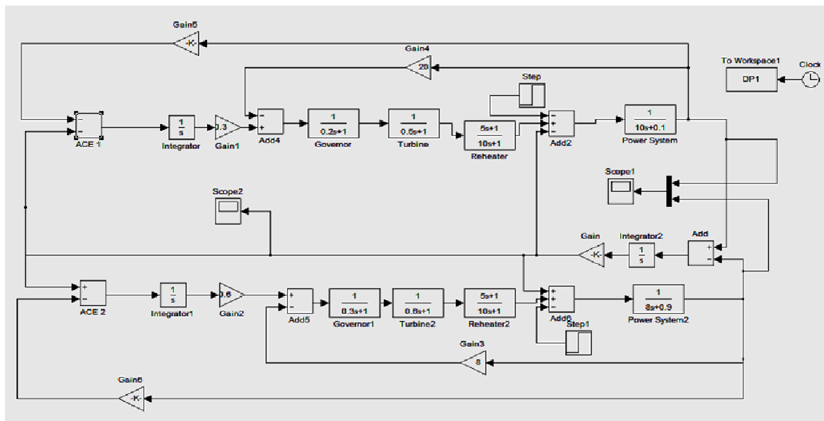


Figure 5. Transfer function model of two area reheat thermal system

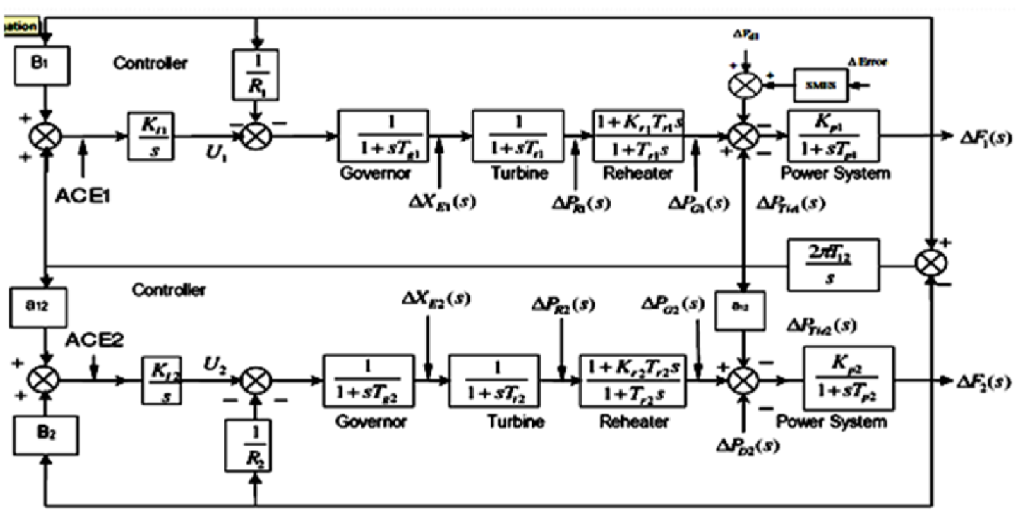


Figure 6. T. F model of two areas reheat thermal system with PI controller and SMES

superconducting state. It has been gradually seen that superconducting magnetic energy storage (SMES) systems, because of their fast dynamics, high power, and high efficiency, have received considerable attention for their application as load-frequency stabilizers (Banerjee et al., 2000 : Sathans and Akhilesh, 2011 : Tripathy et al., 1992).

In the AGC problem, the instantaneous mismatch between generation and consumption of real power can be reduced by the addition of fast acting SMES unit, and this in turn results in significant improvement in the transients of frequency and tie-line power deviations against small load disturbances. Therefore, in this study, the simulations are carried out with and without SMES units in both areas of the two-area power system. It is observed that the FGSPI controller along with an SMES unit in each area with a simple control scheme is sufficient for load frequency control of two-area thermal

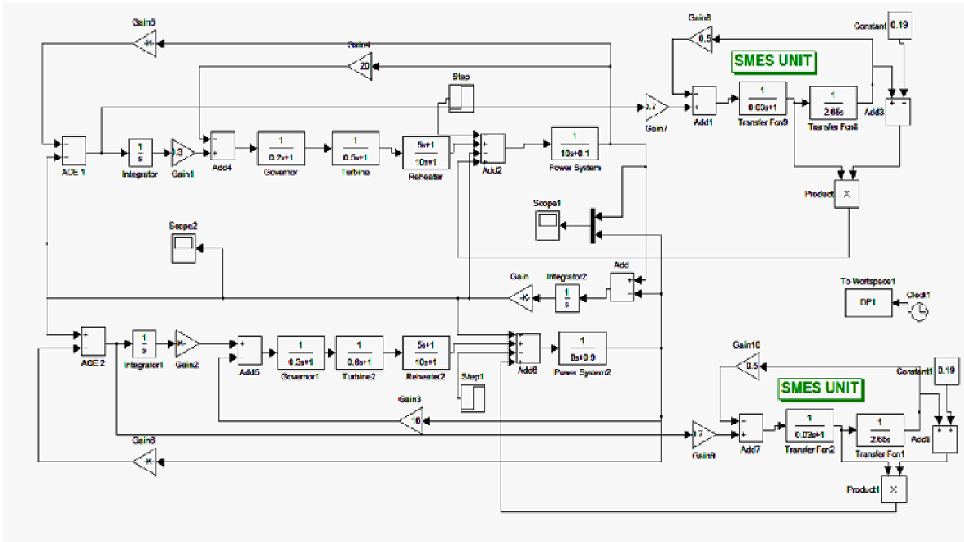
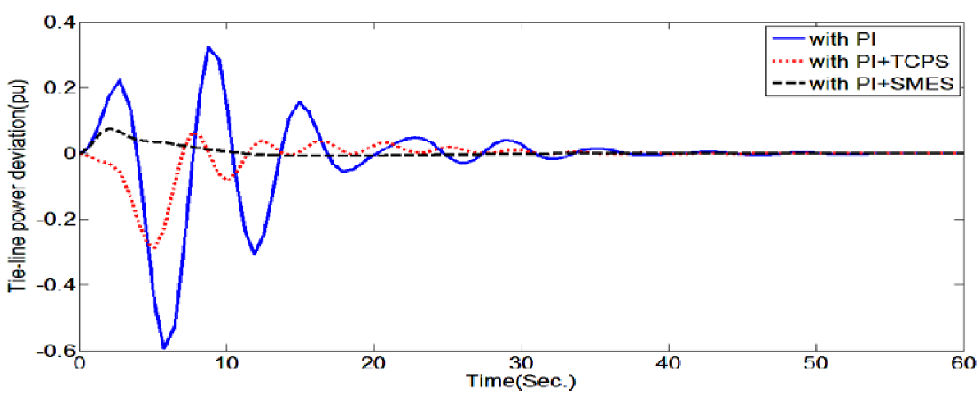
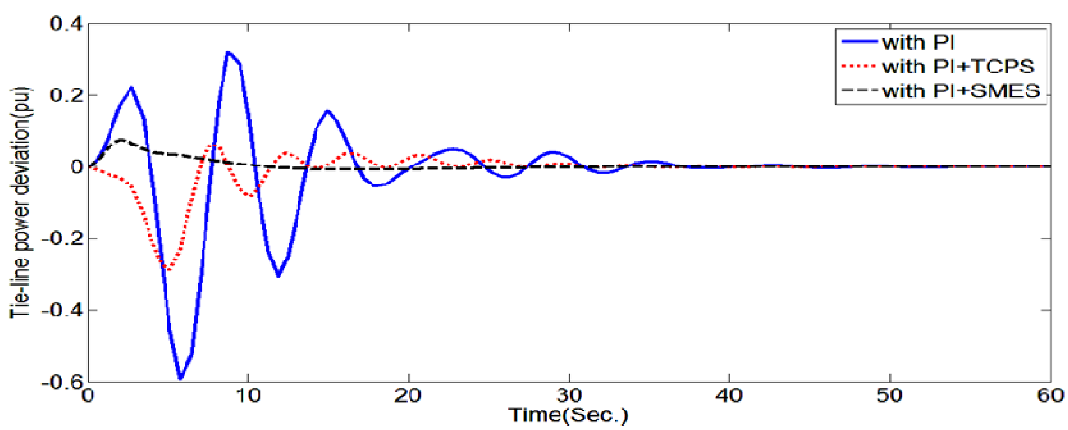


Figure 7. Simulink model of two areas reheat thermal system with PI controller with SMES





power system. The results obtained indicate the positive effect of SMES units on the improvement of the frequency and tie-line power oscillations due to step load perturbation. Superconducting Magnetic Energy Storage (SMES) systems store energy in the magnetic field created by the flow of direct current in a superconducting coil which has been cryogenically cooled to a temperature below its superconducting critical temperature (Cheung et al., 2003 : Sheahen, 1994). Storage process compared to other methods of storing energy. SMES systems are highly efficient; the round-trip efficiency is greater than 95%.

Due to the energy requirements of refrigeration and the high cost of superconducting wire, SMES is currently used for short duration energy storage. Therefore, SMES is most commonly devoted to improving power quality. If SMES were to be used for utilities it would be a diurnal storage device, charged from base load power at night and meeting peak loads during the day .

Principle

The principle behind SMES is the combination of following three principles of physics.

- Some materials (superconductors) carry current with no resistive losses
- Electric currents induce magnetic fields
- Magnetic fields are a form of energy that can be stored

The DC current flowing through a superconducting wire (made up of certain materials like Niobium or Titanium in a large magnet creates the magnetic field. If the ends of the wire are connected the current remains constant due to the absence of resistance in the superconductor. When the short is opened, the stored energy is transferred in part or totally to a load by lowering the current of the coil via negative voltage (positive voltage charges the magnet).

Configuration and working

In the SMES unit, a dc magnetic coil is connected to the ac grid through a Power Conversion System (PCS) which includes an inverter/rectifier. The current in the superconducting coil will be tens of thousands or hundreds of thousands of amperes. Transformers are mounted on each side of the converter unit to convert the high voltage and low current of the ac system to the low voltage and high current required by the coil. The energy exchange between the super conducting coil and the electric power system is controlled by a line commutated converter. The superconducting coil can be charged to a set value from the grid during normal operation of the power system. Once the superconducting coil gets charged, it conducts current with virtually no losses as the coil is maintained at extremely low temperatures. When there is a sudden rise in the load demand, the stored energy is almost released through the PCS (Power Conversion System) to the power system as alternating current. As the governor and other control mechanisms start working to set the power system to the new equilibrium condition, the coil current changes back to its initial value. Similar action occurs during sudden release of loads.

The control of the converter firing angle provides the dc voltage appearing across the inductor to be continuously varying within a certain range of positive and negative values. The inductor is initially charged to its rated current $\mathbf{I_{d0}}$ by applying a small positive voltage.

A typical SMES system includes three parts: superconducting coil, power conditioning system and cryogenically cooled refrigerator. Once the superconducting coil is charged, the current will not decay and the magnetic energy can be stored indefinitely. The stored energy can be released back to the network by discharging the coil. The power conditioning system uses an inverter/rectifier to transform alternating current (AC) power to direct current or convert DC back to AC power. The inverter/rectifier accounts for about 2–3% energy loss in each direction. SMES loses the least amount of electricity in the energy once the current reaches its rated value; it is maintained constant by reducing the voltage across the inductor to zero since the coil is superconducting. Charging and discharging of the SMES unit is controlled through the change of commutation angle α. If α is less than 90 degrees, converter acts in the converter mode (charging mode) and if α is greater than 90 degrees, the converter acts in the inverter mode (discharging mode).A bypass switch is used to reduce energy losses when the coil is on standby. And it also serves other purposes such as bypassing DC coil current if utility tie is lost, removing converter from service, or protecting the coil if cooling is lost. To reduce the harmonics produced on the ac bus and in the output voltage to the coil, a 12-pulse converter is preferred. Helium is used as the working fluid.

Control Strategy

Figure 2. Outlines the proposed simple control scheme for SMES which is incorporated in each control. When power is to be pumped back into the grid in the case of a fall in frequency, the control voltage $\mathbf{E_d}$ (DC value applied to the inductor) is to be negative since the current through the inductor and the thyristors cannot change its direction. Thus finally the inductor current must be restored to its nominal value quickly after a system disturbance so that it can respond to the next load perturbation immediately. Hence, the inductor current deviation can be sensed and used as a negative feedback signal in the SMES control loop as shown below to achieve quick restoration of current and SMES energy levels.

Where, ΔE_d is the incremental change in converter voltage,

T_{DC} is the converter time delay,

K_{SMES} is the gain of the control loop,

$Error_1$ is the input signal to the SMES control logic,

ΔI_d the inductor current deviation,

ΔP_{sm} is the SMES power,

Fig.3. shows the configuration of SMES units in the two-area interconnected power system. The two areas are interconnected via a weak link called the tie-line that allows power exchange between areas. The superconducting coil of the SMES system can be

charged to a set point (which is less than the full charge) from the utility grid during normal operation of the grid. The dc magnetic coil is connected to the ac grid through a power conversion system (PCS) which includes an inverter/rectifier. Once charged, the superconducting coil conducts current, which supports an electromagnetic field, with virtually no losses. The coil is maintained at extremely low temperature (below the critical temperature) by immersion in a bath of liquid helium. When there is a sudden rise in the demand of load, the stored energy is almost immediately released through the PCS to the grid as line quality ac. As the governor and other control mechanisms start working to set the power system to the new equilibrium condition, the coil charges back to its initial value of current. Similar is the action during sudden release of loads. The coil immediately gets charged towards its full value, thus absorbing some portion of the excess energy in the system, and as the system returns to its steady state, the excess energy absorbed is released and the coil current attains its set point (Tripathy et al., 1992).

Detailed Study Of Dynamic Response Of Two Area Reheat Thermal System

Pi Controller

A number of control strategies have been employed in the design of load frequency controllers in order to achieve better dynamic performance. Among the various types of load frequency controllers, the most widely employed is the conventional proportional integral (PI) controller. Conventional controller is simple for implementation but takes more time to settle and gives large frequency deviation. Here a step load perturbation of 1% of nominal loading has been considered in area-1 and 2. The tie-line power deviations can be assumed as an additional power disturbance to any area for the load frequency control, the proportional integral controller is implemented.

Conventional PI Controller

Transfer Function Modl Using Pi Controller Only

Transfer Function Model Using Pi Controller With Smes

Simulink Model Using Pi Controller With Smes

CONCLUSIONS

In this study, a PI controller is implemented as controller in each area of a interconnected power system with reheat type steam turbines for the cases with and without SMES units. The positive effects of SMES units on the dynamic response of AGC of two-area power system have been demonstrated. Simulation studies have been carried out using MATLAB platform to study the transient behaviors of the frequency of each area and tie-line power deviations due to load perturbations in one of the areas.

Further, the performance of conventional integral controller (PI) and fuzzy logic controller (FLC) in a reheat thermal system as well as in a hydro-thermal system has been investigated. These controllers are designed to improve the transient performance of the interconnected systems following a disturbance in the areas. Effectiveness of the proposed controller in increasing the damping of local and inter area modes of oscillation is demonstrated in a two area interconnected power system. The dynamic system responses have been examined considering a 1% step load perturbation in either area. Also the simulation results are compared with a conventional PI controller. It is observed that incorporation of SMES and TCPS units with PI controller in reheat thermal system reduces settling time greatly. As compared to TCPS unit, use of SMES unit reduces overshoot further with almost the same settling time. Instead of PI controller when FLC is used overshoot and undershoot decrease further. Settling time also improves to some extent when TCPS and SMES units are added to the FLC. And in hydrothermal system settling time falls to a much lower value with the fuzzy logic controller (FLC) with a slight decrease in under shoot. The result shows that the proposed intelligent controller is having improved dynamic response and at the same time is faster than conventional PI controller.

Future Work

Following are the areas of future study which can be considered for further research work.

- The proposed controllers are applied by using PI and Fuzzy logic controller (FLC) with TCPS and SMES in reheat thermal plant only. Effectiveness of the proposed controller like PI and FLC can be used in hydrothermal plant.
- A lot of scope is there to proceed with Hybrid fuzzy-neurocontroller and PI with LQR/FGSPI controller for future research purposes Moreover, on-line adaptation of supplementary controller gain makes the proposed intelligent controller more effective and it is expected that the controller will perform effectively under different operating conditions.
- The primary objectives of Automatic Generation Control are to regulate frequency to the specified nominal value and to maintain the interchange power between control areas at the scheduled values. In this work AGC for a two area system is carried out, the future scope of

this work is that AGC can be carried out for more than two areas. As in this work Fuzzy Logic is used to reduce area control error is reduced to some extent but it can be reduced more by applying some other artificial intelligence technique also.

- Particle Swarm Optimization (PSO) based Model Predictive Control (MPC) scheme can be applied to Automatic Generation Control (AGC) systems. This can be proposed to formulate the MPC as an optimization problem and PSO can be used to find its solution.

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