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Automatic Generation Control Using SMES

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ABSTRACT:

Large scale system frequency should be maintained. SMES is very effective in damping the frequency and tie line oscillations due to load perturbations. In one of the areas to further improve the performance of the controller area control error is also adopted.

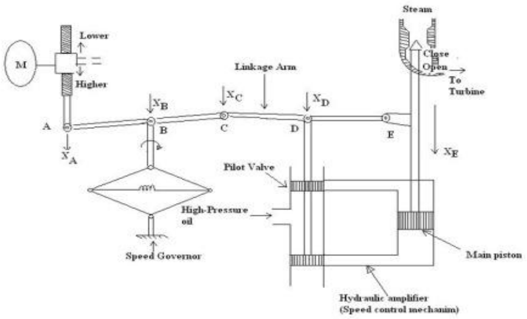
Application for power system stability improvement. Reduction of system oscillations & boosting voltage stability & improving voltage sag. Applications for power quality improvement Offering spinning reserve, Enhancing FACTS performance, balancing fluctuating load, Load leveling, Defending critical loads by backup power supply, Voltage control & frequency control are the area of interest. So the proposed PID controller is compared against conventional PI controller using settling times, overshoots and undershoots of the power and frequency deviations to find out the performance of the controller.

Keyword: Smes, Voltage Stabilty, Pid Controller, Pi Controller.

INTRODUCTION

Generation and distribution of electric energy with good reliability and quality is very important in power system operation and control. This is achieved by Automatic Generation Control (AGC). In an interconnected power system, as the load demand varies randomly, the area frequency and tie-line power interchange also vary. The objective of Load Frequency Control (LFC) is to minimize the transient deviations in these variables and to ensure for their steady state values to be zero.

The LFC performed by only a governor control imposes a limit on the degree to which the deviations in frequency and tie-line power exchange can be minimized. However, as the LFC is fundamentally for the problem of an instantaneous mismatch between the generation and demand of active power, the incorporation of a fast-acting energy storage device in the power system can improve the performance under such conditions. But fixed gain controllers based on classical control theories are presently used for AGC.



Load frequency control for AGC for single area network

The main operational parts of AGC is turbine system and speed governing system of the AGC which are shown in the respectively.

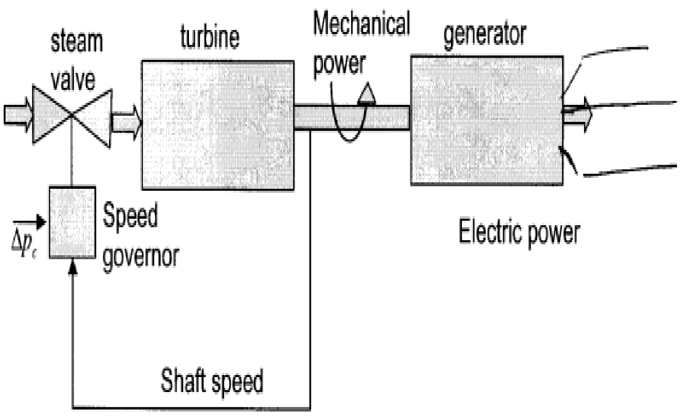
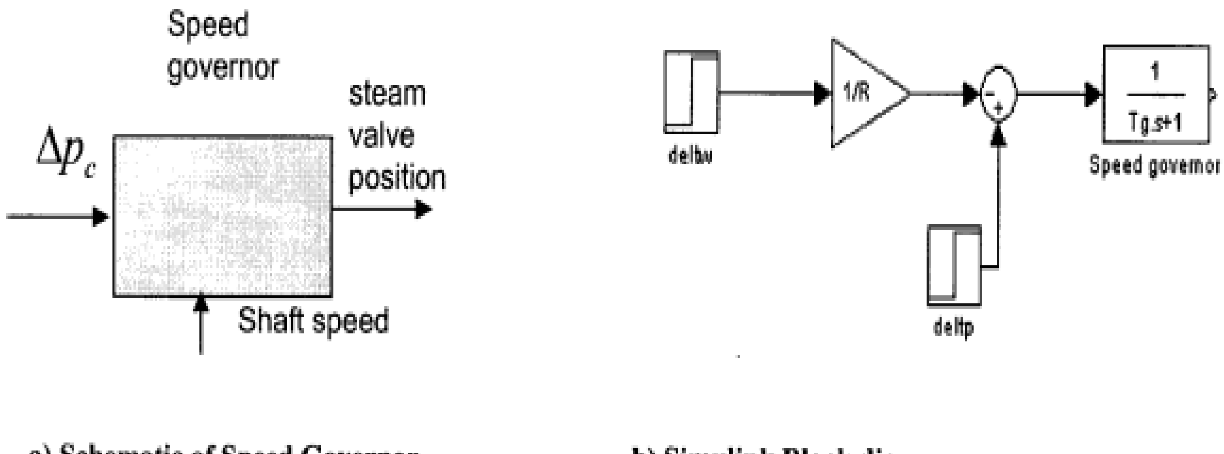


Figure 2. Schematic of Governor-Turbine-Generator System

For designing controllers based on these techniques, the perfect model is required which has to track the state variables and satisfy system constraints. Therefore it is difficult to apply these adaptive control techniques to AGC in practical implementations.

In multi-area power system, if a load variation occurs at any one of the areas in the system, the frequency related with this area is affected first and then that of other areas are also affected from this perturbation through tie lines. When a small load disturbance occurs, power system frequency oscillations continue for a long duration, even in the case with optimized gain of integral controllers. So, to damp out the oscillations in the shortest possible time, automatic generation control including SMES unit is proposed.



a) Schematic of Speed Governor **b) Simulink Block diagram**

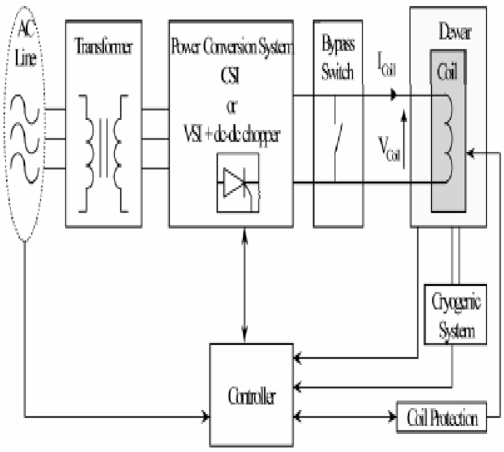
Figure3. Speed governor model

Therefore, in the proposed control system, with an addition of the simple SMES controller, a supplementary controller with KIi is designed in order to retain the frequency to the set value after load changes.

These controllers must eliminate the frequency transients as soon as possible. Using fuzzy logic, the integrator gain (KIi) of the supplementary controller is so scheduled that it compromise between fast transient recovery and low overshoot in dynamic response of the system.
It is seen that with the addition of gain scheduled supplementary controller, a simple controller scheme for SMES is sufficient for load frequency control of multi-area power system.

SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SMES) SYSTEM

A superconducting magnetic energy storage system is a DC current device for storing and instantaneously discharging large quantities of power. The DC current flowing through a superconducting wire in a large magnet creates the magnetic field. The large superconducting coil is contained in a cryostat or dewar consisting of a vacuum vessel and a liquid vessel that cools the coil. A cryogenic system and the power conversion/conditioning system with control and protection functions are also used to keep the temperature well below the critical temperature of the superconductor. During SMES operation, the magnet coils have to remain in the superconducting status. Components of SMES are shown in [Fig.4].



Components of a typical SMES system

A refrigerator in the cryogenic system maintains the required temperature for proper superconducting operation. 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. A basic schematic 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 superconducting state. The superconducting coil is obtaining energy while charging from the power system, then releases the energy stored through discharging. The energy stored in SMES coil can be described

$E_{smes} = \frac{1}{2} L I^2_{SMES}$

E = LI where L is the inductance of the SMES coil, ISMES is the current flowing in the SMES coil.

Supposing the SMES coil discharging with constant power P_0 within specific time t_s, the energy in the SMES coil E(t) at $t<t_s$ is

$$E(t) = E_{SMES} - P_0 t$$

SMES COIL TECHNOLOGY

The SMES coil is the main element in a SMES system.

Where, Mst is the mass of the coil; Qc is the compressive quality factor, its value is within 0 - 1 that depends on the SMES coil configuration; ρst is the configuration density; σst is the average design stress; E is the stored energy in the coil. According to above equations, to reduce the coil mass requires a small Qc value.
The superconducting coil can be divided into a toroidal coil and a solenoid coil. The toroidal coil is suitable for medium-sized and small-sized SMES mainly, the ideal structure adopts the multistage structure, and the advantages of this structure are reducing the magnetic field leakage and the floor space. The solenoid coil is suitable for large-sized SMES; its advantage is having a simple structure, but produces leaking magnetic fields.
In a toroidal coil, the electromagnetic force is inward and in a solenoid coil it works outward.

(a) Toroidal coil
(b) Solenoid coil

A Force-Balanced-Coil (FBC) has been proposed, and the conceptual structure of a FBC. The dark hatch indicates one complete helical winding, and a FBC coil using 340m of Ag sheathed Bi-2223 HTS tapes has been designed, the coil operates current 12A and is cooled by liquid nitrogen.
The test result shows, the tensile stresses and the bending stresses cause the critical current decrease of the coil. To reduce the stress problem, a kind of new coil structure - Tilted-Toroidal-Coils (TTC) have been proposed by changing two tilted angles on the basis of Toroidal field coil (TFC) structure

a). Force-Balanced-Coil (FBC)
b). Toroidal field coil (TFC)

The structure of solenoid coil is simpler than toroidal coil; design of solenoid coil focuses on the optimum the geometry parameters, so that the solenoid coil can store greater energy with less superconducting material and less volume. The ordinary cross sectional shape of solenoid coil is rectangular. However, a new cross sectional shape of step shape has been proposed.
By using the proposed shape, the winding volume and the loss of the SMES coils can be reduced effectively. It is possible to design the larger SMES for power system stabilization with higher energy storage by using the proposed shape.

ADVANTAGE OF SMES

There are several reasons for using superconducting magnetic energy storage instead of other energy storage methods. The most important advantages of SMES are that the time delay during charge and discharge is quite short.
Power is available almost instantaneously and very high power output can be provided for a brief period of time. Other energy storage methods, such as pumped hydro or compressed air have a substantial time delay associated with the conversion of stored mechanical energy back into electricity. Thus if a customer's demand is immediate, SMES is a viable option. Another advantage is that the loss of power is less than other storage methods because the current encounters almost zero resistance.
Additionally the main parts in a SMES are motionless, which results in high reliability. Also, SMES systems are environmentally friendly because superconductivity does not produce a chemical reaction. In addition, there are no toxins produced in the process.
The SMES is highly efficient at storing electricity (greater than 97% efficiency), and provide both real and reactive power. These systems have been in use for several years to improve industrial power quality and to provide a premium-quality service for individual customers vulnerable to voltage and power fluctuations.
The SMES recharges within minutes and can repeat the charge/discharge sequence thousands of times without any degradation of the magnet. Thus it can help to minimize the frequency deviations due to load variations. However, the SMES is still an expensive device.

CONTROL STRATEGIES

A SMES device performance is also determined by its controller, which is a main technique to be considered in a SMES system design. Fig. 9 gives the block diagram of a SMES device control, where power system variables are the deviations of voltage, frequency, and current; Pd and Qd are the demanded active and reactive power; α1 and α2 are the firing angles of power converters; and Ps and Qs are the SMES active and reactive power outputs.

The demanded active and reactive power, needed to support power system performance as measured by voltage, stabilizing power oscillation and improving power transfer, is determined by the external control based on deviations in voltage, frequency, and current.

These input variables are in turn dependent on the system state. The internal control determines the firing angles of the PCS, which are the input signals to the SMES device. The internal control controls the firing angles according to the signals of demanded reactive and active powers. The detailed control strategiesm outlines the proposed simple control scheme for SMES, which is incorporated in each control area to reduce the instantaneous mismatch between the demand and generation, where Ism, Vsm and Psm are SMES current, SMES voltage and SMES power respectively. For operating point change due to load changes, gain (KIi) scheduled supplementary controller is proposed.

Firstly KIi is determined using the fuzzy controller to obtain frequency deviation, Δf, and tie-line power deviation, ΔPtie. Finally ACEi which is the combination of ΔPtie and Δf is used as the input to the SMES controller. It is desirable to restore the inductor current to its rated value as quickly as possible after a system disturbance, so that the SMES unit can respond properly to any subsequent disturbance. So inductor current deviation is sensed and used as negative feedback signal in the SMES control loop to achieve quick restoration of current and SMES energy levels.

POWER CONDITIONING SYSTEM

Power conditioning system (PCS) is the interface between SMES coil and power system, generally there are two types: current source converter (CSC) PCS and voltage source converter (VSC) PCS. The configurations of CSC-PCS and VSC-PCS. VSC-PCS usually uses in a large sized SMES system. VSC-PCS is a voltage source converter in series with a DC/DC chopper, the charge and discharge of a SMES coil is controlled through invert circuit and the chopper. The four-quadrant voltage source converter is utilized to accomplish the power transformation between the three-phase AC power system and the DC bus.

The configuration of CSC-PCS is simple compared to VSC-PCS, and also its control is easier. The most important feature is that the response of power exchange with a CSC-PCS is much faster than with a VSC-PCS, because a SMES stores energy in the form of dc current. CSC-PCS technique is suitable for medium- and minimized SMES, several modules of CSC-PCS with parallel connection are able to be used in the case of high or ultra high power.

The control strategies of PCS are very important in a SMES system, the strategies should be chosen according to the capacity of the SMES, stability of power system, AC harmonic wave and etc.

PHASE-SHIFTING SPWM TECHNOLOGY

With the development of Gate Turn-off (GTO) Thyristor, Sinusoidal Pulse Width Modulation (SPWM) Technology has more and more extensive applications in the electric and electronic devices. However, because Maximum of switch frequency is very low, it produces a large number of harmonic waves, and the bandwidth of PCS is narrow, and high switch frequency can produce heavy switch loss, this makes a contradiction of higher Switch frequency with less switch losses. In order to solve this problem, a new phase-shifting method and Technology that combines the SPWM technology and multiple modules technology together has been proposed, using dynamic SPWM tri-logic as the operating strategy.

This new method mainly has four advantages:

(1) Increasing the current capacity to the level required by the superconducting magnet.

(2) Reducing conduction losses.

(3) Reducing harmonic waves by harmonic cancellation without the need of expensive filter.
(4) Achieving a high frequency bandwidth.

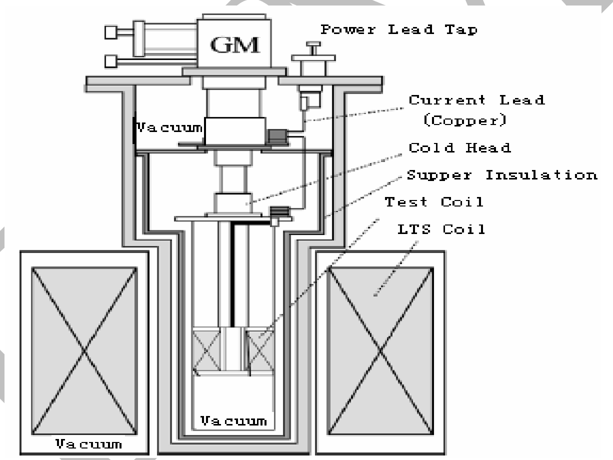
CRYOGENIC SYSTEM

The cryogenic system mainly consists of stainless steel refrigeration device, the distribution system with low temperature liquid, a pair of automatic helium liquefiers, etc. The main compositions of the distribution system are electric connection on the refrigeration device top.

Low-temperature control valve case in which the helium flows; refrigeration between the device, valve case and low temperature liquefier; vacuum device; relief valve when the pressure is too high; helium reserve pot; and the cooling case. There are two kinds of traditional SMES coil cooling methods: one is to let the SMES coil dip in the liquid helium, the other is the forced pressure cooling to flow the ultra critical helium through the conductor. . The first method is good in stability, but not for AC losses and voltage-proof; the second method has good performances in machine intensity, AC losses and over voltage, but improving the stability is needed.

These two methods all consist of the complex system of cryogenic liquid, and the compensation of liquid is needed if the SMES system keep on operating for a long time. In order to solve this problem, it has been proposed not using the liquid helium but using cryocooler to cool the magnet; it is much safer and is no need to make high pressure to liquefaction. It is not only more suitable for operation but also high effective.

Because of the limitation of the HTS material, the cryogenic system of a HTS SMES system mostly uses this method. It is the conduction cooling system with a GM cryocooler without coolant such as liquid helium. This equipment was designed for testing the transient thermal characteristics of cryocooler-cooled HTS coil, where the cryocooler-cooled LTS coils were used to generate a background magnetic field.



The conduction cooling system with GM cry cooler

A two-stage GM cryocooler to cool 1MJ SMES has been adopted, the operation result shows that the power of cryocooler is 60W at 73K and 20W in 20K. However, the cooling method using cryocooler has broken the limitation of the traditional cooling method; even its stability is not high enough. GM cryocooler cannot offer power of 50-100W in 20-40K, therefore the routine GM cryocooler products do not meet the need of SMES magnets using HTS materials. It is very essential to develop the one stage GM cryocooler with high refrigeration capacity for cooling a HTS-SMES.

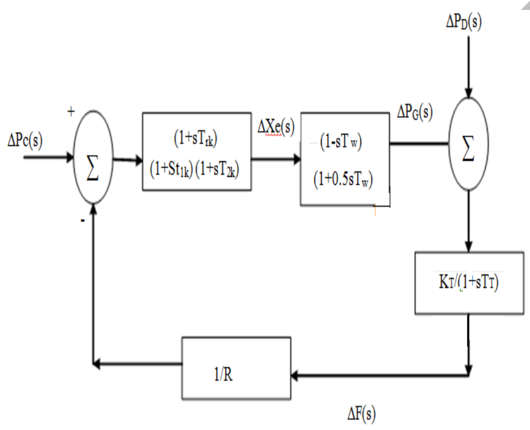
SMES FOR LOAD FREQUENCY CONTROL APPLICATION

A sudden application of a load results in an instantaneous mismatch between the demand and supply of electrical power because the generating plants are unable to change the inputs to the prime movers instantaneously. The immediate energy requirement is met by the kinetic energy of the generator rotor and speed falls. So system frequency changes though it becomes normal after a short period due to Automatic Generation Control. Again, sudden load rejections give rise to similar problems.

The instantaneous surplus generation created by removal of load is absorbed in the kinetic energy of the generator rotors and the frequency changes. The problem of minimizing the deviation of frequency from normal value under such circumstances is known as the load frequency control problem. To be effective in load frequency control application, the energy storage system should be fast acting i.e. the time lag in switching from receiving (charging) mode to delivering (discharging) mode should be very small.

For damping the swing caused by small load perturbations the storage units for LFC application need to have only a small quantity of stored energy, though its power rating has to be high, since the stored energy has to be delivered within a short span of time.

However, due to high cost of superconductor technology, one can consider the use of non-superconducting of lossy magnetic energy storage (MES) inductors for the same purpose. Such systems would be economical maintenance free, long lasting and as reliable as ordinary power transformers.



Isolated Hydro Power System LFC Block Diagram

Thus a MES system seems to be good to meet the above requirements. The power flow into an energy storage unit can be reversed, by reversing the DC voltage applied to the inductor within a few cycles. A 12-pulse bridge converter with an appropriate control of the firing angles can be adopted for the purpose. Thus, these fast acting energy storage devices can be made to sh~~are the su~~dden load requirement with the generator rotors, by continuously controlling the power flow in or out of the inductor depending on the frequency error signals.

ANALYSIS OF THE MAGNETIC ENERGY STORAGE UNIT

The SMES inductor converter unit for improvement in power system LFC application essentially consists of a DC inductor, an ac/dc converter and a step down Y-Y/Δ transformer. The inductor should be wound with low resistance, large cross-section copper conductors. The converter is of the 12-pulse cascaded bridge type connected to the inductor in the DC side and to the three-phase power system bus through the transformer in the ac side.

Control of the firing angles of the converter enables the DC voltage applied (Vsm) to the inductor to be varied through a wide range of positive and negative values. Gate turn off thyristors (GTO) allow us to design such type of converter. When charging the magnet, a positive DC voltage is applied to the inductor.

The current in the inductor rises exponentially or linearly and the magnetic energy is stored. When the current reaches the rated value, the applied voltage is brought down to low value, sufficient to overcome the voltage drop due to inductor resistance. When the extra energy is required in the power system, a negative DC voltage is applied to the inductor by controlling the firing angles of the converter.

The losses in the MES unit would consist of the transformer losses, the converter losses, and the resistive loss in the inductor coil. The inductor loss can be kept at an acceptable level by proper design of the winding.
The converter then works as a rectifier ($-90<\alpha<90$) and the power Psm becomes positive.
If the transformer and converter losses are neglected, according to the circuit analysis of converter, the voltage Vsm of the D.C side of the 12-pulse converter under equal-α (EA, when α1 = α2 = α) mode is expressed by

$$Vsm = Vsm0 (\cos \alpha 1 + \cos \alpha 2) = 2\, Vsm0 \cos \alpha - 2\, Ism\, Rc$$

Where,
α is the firing angle
Vsm is the DC voltage applied to the inductor
Ism is the current through the inductor
Rc is the equivalent commutating resistance and
Vsm0 is the maximum open circuit bridge voltage of each 6-pulse bridge at α=0.

INTEGRATION OF SMES WITH TWO-AREA POWER SYSTEM

The proposed configuration of SMES units in a two-area power system. Two areas are connected by a weak tie-line. When there is sudden rise in power demand in a control area, the stored energy is almost immediately released by the SMES through its power conversion system (PCS). As the governor control mechanism starts working to set the power system to the new equilibrium condition, the SMES coil stores energy back to its nominal level. Similar action happens when there is a sudden decrease in load demand.
Basically, the operation speed of governor-turbine system is slow compared with that of the excitation system. As a result, fluctuations in terminal voltage can be corrected by the excitation system very quickly, but fluctuations in generated power or frequency are corrected slowly. Since load frequency control is primarily concerned with the real power/frequency behavior, the excitation system model will not be required in the approximated analysis.
The basic objective of the supplementary control is to restore balance between each area load and generation for a load disturbance. This is met when the control action maintains the frequency and the tie-line power interchange at the scheduled values. The supplementary controller with integral gain KIi is therefore made to act on area control error (ACE), which is a signal obtained from tie-line power flow deviation added to frequency deviation weighted by a bias factor β.

$$ACE_i = \sum_{j=1}^{n} \Delta P_{tie,\, i\, j} + \beta_i \Delta f_i$$

SMES FOR AUTOMATIC GENERATION CONTROL

The major components of a SMES unit are its superconducting coil, the non-magnetic vacuum vessel, the cryogenic system with liquid helium refrigerator the ac/dc thyristor converter and the local control system. In this we discuss only the low temperature superconducting device. The coil made of NbTi is immersed in a super fluid helium bath supplied from helium refrigeration system and is contained in a helium vessel maintained at a low temperature of 1.8 Kelvin (Critical temperature of the material).
The helium vessel is called a cryostat. The helium vessel is surrounded by and supported from a vacuum vessel in nitrogen shroud surrounding the helium vessel. The vacuum vessel assembly is known as Dewar. The superconducting coil once charged with dc current from ac/dc converter supports a magnetic field of approximately 1.2 Tesla without any losses

APPLICATIONS OF SMES

Modern power systems rely strongly on stabilizing devices to maintain reliable and stable operation. These Devices should provide adequate damping in the system, during the transient period following a system disturbance, such as line switching, load changes and fault clearance.

To prevent collapse of the system due to loss of synchronism or voltage instability, counter measures such as power system stabilizers.

Optimal turbine governor control systems and phase shifters have been used. SMES systems convert the ac current from a utility system into the dc current flowing in the superconducting coil and store the energy in the form of magnetic field. The stored energy can be released to the ac system when necessary. The aforementioned excellent performances of SMES offer very desirable benefits to power system applications.

The application of the SMES to a power system was first proposed in 1969. This idea is to charge the superconducting magnet with the surplus generation of the basic load units during off peak time, and discharge to the ac power system during peak time. The first superconducting power-grid application to achieve full commercial status is SMES in 1981, which is American

Superconductor's SMES system for power quality and grid stability and was located along the 500 kV Pacific Intertie that interconnects California and the Northwest.

This application of SMES demonstrated the feasibility of SMES to improve transmission capacity by damping inter-area modal oscillations. Since that time applications of SMES can be classified into two kinds, which are power system applications and pulse power application. In a survey of the technology of SMES was made. .

One of which is the enhanced system stability and the other is the power quality improvement.

APPLICATIONS OF SMES TO POWER SYSTEMS

1) DAMPING SYSTEM OSCILLATION

Power system stability limitations are often characterized by low frequency oscillations (0.5—1 Hz) following a Major system disturbance. Power transfers are often limited to prevent growing oscillations from occurring, following the loss of a single major transmission line or generator.

When limited by long term stability the transmission capacity can be increased by providing active damping of these oscillations. SMES can actively damp these system oscillations through modulation of both real and reactive power. Because SMES can modulate real power, as well as reactive power, it can be much more effective, and smaller in size, than other technologies. An active and reactive power control in the model power transmission system successfully, and verified the effect of power system stabilizing control by SMES.

Furthermore, the active filter to compensate for the harmonics generated by the PCS of SMES.

A control scheme for the power system stabilization, considering the combination of a SMES and high speed phase shifter to be a unified power system controller. The experiment demonstrated that the proposed apparatus with the proposed control scheme is significantly effective for the stabilization of a long distance bulk power transmission system even through it is located far from the generator The Stat Com- SMES controller can damp the power system oscillations more effectively than a reactive power controller, and therefore stabilize the system faster if the Stat Com-SMES controller is located near a generation area rather than a load area.

2) IMPROVING VOLTAGE STABILITY

Dynamic voltage instability can occur when there is a major loss of generation or heavily loaded transmission Line and there is insufficient dynamic reactive power to support voltages. Voltages will degrade slowly over time in the 5 – 15 minute time frame (sometimes faster) and can result in a voltage collapse.

SMES is effective in mitigating dynamic voltage instability by supplying real and reactive power simultaneously supplanting loss of generation or a major transmission line. Depending on the energy storage capability and the reactive power rating of the converter, SMES can stabilize the system long enough to allow generators or other reactive power sources to come on line and prevent voltage instability.

On the other hand, a transient voltage dip lasting for 10-20 cycles can result when a major disturbance on the power system occurs. SMES is also effective for providing voltage support.

POWER QUALITY IMPROVEMENT

1) SPINNING RESERVE

In case a major generating unit or major transmission line is forced out of service a certain amount of generation must be kept unloaded as "spinning reserve". Most operating guideline requires that this spinning reserve be as much as 7% of the system load or largest single contingency.

Since SMES can store a significant amount of energy it is possible to rely on SMES to provide enough "spinning reserve" to meet the requirement until gas turbine generators can be brought on-line. Providing "spinning reserve" with SMES is much more efficient since it is a virtually lossless form of storage, whereas providing spinning reserve with generation has significant losses and high operating costs.

2) IMPROVING FACTS PERFORMANCE

SMES systems can be configured to provide energy storage for FACTS (Flexible AC Transmission System) devices. FACTS inverters and PCS of SMES systems are configured in very similar ways. FACTS devices, however, operate with the energy available in the electric grid.

SMES can improve FACTS performance by providing greater real power in addition to reactive power control enhancing system reliability and availability. A static synchronous compensator (Stat Com) can only absorb/inject reactive power, and consequently is limited in the degree of freedom and sustained action in which it can help the power grid .The addition of energy from SMES allows the Stat Com to inject and/or absorb active and reactive power simultaneously, and therefore provides additional benefits and improvements in the system.

A SMES coil is incorporated into a voltage source inverter based on Stat Com in damping dynamic oscillations in power systems and simultaneous control of real and reactive power can improve system stability and power quality of a transmission grid. Furthermore, the Stat Com- SMES connected to a bus near the generator shows very effective results in damping electromechanical transient oscillations caused by a three-phase fault.

3) COMPENSATION OF FLUCTUATING LOADS

SMES is a promising device for compensation of fluctuating active and reactive power from various loads such as industrial manufacturing plants, nuclear fusion power plants, and substations of high speed railway system.

A typical power control system located close to the customer end. Two control strategies of the SMES system to suppress voltage fluctuation caused by disturbing loads. One of which, named as the direct strategy, is based on equal and opposite compensation of the active and reactive power components of the fluctuating load.

The other, named as the optimized strategy, maximizes the usage of the limited capacity of the SMES device the simulation and experiment demonstrated that an SMES system installed close to the power consumer end can be used to level load power fluctuations by using the fuzzy control strategy. The active power on the source side is well leveled while the reactive power on the source side is compensated to almost 0 var. In 2001 the performance of SMES systems is investigated as fluctuating load compensator and developed the control algorithm for load fluctuating leveling. Furthermore, these were tested successfully through the simulation and experiment.

Using SMES to compensate for fluctuating power from high intensity synchrotron. It can absorb the fluctuation of Active and reactive power caused by charging and discharging the synchrotron magnet. Without this power compensating system, power fluctuations will exist in the source line. With this system, the fluctuating component of the active power Pe on the source side can be compensated by releasing or absorbing energy from the SMES, and the fluctuating component of the reactive power Qe on the source side can be compensated too.

4) REDUCING AREA CONTROL ERROR

When power is scheduled between utility control areas it is important that the actual net power matches closely with the scheduled power. Unfortunately when generators are ramped up in one control area and down in the receiving control area to send power, the system load can change causing an error in the actual power delivered. This area control error (ACE) can result in inefficient use of generation. SMES can be designed with appropriate controls to inject power to virtually eliminate this error and insure that generation is efficiently used and power schedules are met.

5) LOAD LEVELING

The highest cost energy is produced at peak load conditions. Load leveling is performed by storing energy during off-peak periods and returning energy and capacity on peak. This benefit is realized when SMES gains credit for both converting low-cost energy into higher value energy and its ability to defer the acquisition of high-cost generating resources. SMES can have a large net present worth when it can replace the need to acquire combustion turbine units of similar capacity.

6) PROTECTION OF LOAD

SMES can provide ride through capability and smooth out disturbances on power systems that would otherwise interrupt sensitive customer loads. When momentary disturbances such as transmission line flashovers or lightning strikes occur, power can be lost if the transmission line trips, or voltages can dip low. SMES has very fast response can inject real power in less than one power cycle preventing important customers from losing power.

Hence, SMES systems can provide area protections developed a successful commercial application of Micro-SMES technology to improve power quality for critical loads. The most important characteristic of the developed Micro-SMES system is its ability to completely supply any load connected to it during a short system disturbance such as a voltage sag caused by a remote fault, a momentary interruption caused by lighting or a tree climb, or any supply discontinuity during a load transfer between two available power sources.

In an occurrence of such a disturbance, the Micro-SMES will operate by isolating the load from the power system supplying the load from the energy stored in SMES system to protect critical industrial and military loads against voltage sags and interruptions, as well as to provide continuous power conditioning. SMES systems are investigated for 15 kV substation applications.

7) BACKUP POWER SUPPLY

The energy storage capacity of SMES can be used as a backup power supply for large industrial customers in case of loss of the utility main power supply. SMES systems can be sized with the appropriate energy storage and capacity to provide back up through most disturbances and be cost effective systems as a UPS. They developed the control algorithm for the UPS application.

8) IMPROVING POWER SYSTEM SYMMETRY

In the operation of power systems, voltage asymmetry is very common because asymmetrical fault, single-phase load, unequal capacitor between line and ground, asymmetrical loads, and incomplete transposition of transmission line are unavoidable. Asymmetrical voltages will increase the loss of transformer and transmission line, decrease the output power of transformer, reduce the efficiency of motors, affect the operation of critical load, and even endanger the safety of equipments.

The harmonic voltage and unbalanced voltage, which is negative sequence voltage contained in source voltage, are compensated by VS from the SMES unit and investigated the compensation of harmonics and negative sequence components in line current and voltage by the SMES system. The SMES system provides sinusoidal and balanced voltage and eliminates current harmonics and unbalanced in three phase lines of the distribution system.

CONCLUSIONS

As in this paper the Automatic Generation Control (AGC) is coupled with the Superconducting Magnetic Energy Storage (SMES) System for the stable and continuous power availability and generation but because of the use of SMES, the system become very expensive and not cost effective.

Hence further the objective is to reduce the cost of the system and for that purpose the SMES system is removes and the PI Controllers and the PID controllers are used for same continuous and stable power generation availability.

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