AUTOMATIC GENERATION CONTROL OF INTERCONNECTED POWER SYSTEM WITH THE DIVERSE SOURCES USING SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SMES)

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***Abstract*— The primary purpose of the AGC is to balance the total system generation against system load and losses so that the desired frequency and power interchange with interconnected systems are maintained. Any mismatch between generation and demand causes the system frequency to change from scheduled value. Thus high frequency deviation may lead to system collapse. Power system operation at a lower frequency affects the quality of power supply and if the frequency is not maintained within the scheduled values then it may first on the way to tripping of the lines then system collapse as well as blackouts.**

***Index Terms*—MATLAB, Automatic Generation Control (AGC) Superconducting Magnetic Energy Storage devices (SMES), Load Frequency control (LFC).**

I. INTRODUCTION

The automatic generation control (AGC) considering generator rate constraints of interconnected power systems with combination of the automatic load frequency control (LFC) and market based deregulated system. The primary purpose of the AGC is to balance the total system generation against system load and losses so that the desired frequency and power interchange with interconnected systems are maintained. Any mismatch between generation and demand causes the system frequency to change from scheduled value. Thus high frequency deviation may lead to system collapse [1]

Power system operation at a lower frequency affects the quality of power supply and if the frequency is not maintained within the scheduled values then it may first on the way to tripping of the lines then system collapse as well as blackouts. Objective of an LFC are to be maintaining area frequencies and tie-line power at their scheduled values in deregulated system [2][3]. With use of super magnetic energy storage (SMES) suppress power oscillations in system and in single attempt to improve the frequency control performance of an interconnected system in deregulated power system environment.

The automatic load frequency control loop is mainly associated with the large size generators. The main aim of the automatic load frequency control (ALFC) can be to maintain the desired unvarying frequency, so as to divide loads among generators in addition to managing the exchange of tie line power in accordance to the scheduled values. Power system operation considered so far was under conditions of steady load. However, both and reactive power demands are never steady and they continually change with the rising or falling trend. Steam input to turbo generators (or water input to hydro-generators) must, therefore, be continuously regulated to match the active power demand, failing which may be highly undesirable (maximum permissible change in power frequency is ± 0.5 Hz)[6]. Also the excitation of generators must be continuously regulated to match the reactive power demand with reactive generation, otherwise the voltages at various system buses may go beyond the prescribed limits. In modern large interconnected system, manual regulation is not feasible and therefore automatic generation and voltage regulation equipment is installed on each generator.[7]

II. SUPERCONDUCTING MAGNETIC ENERGY STORAGE

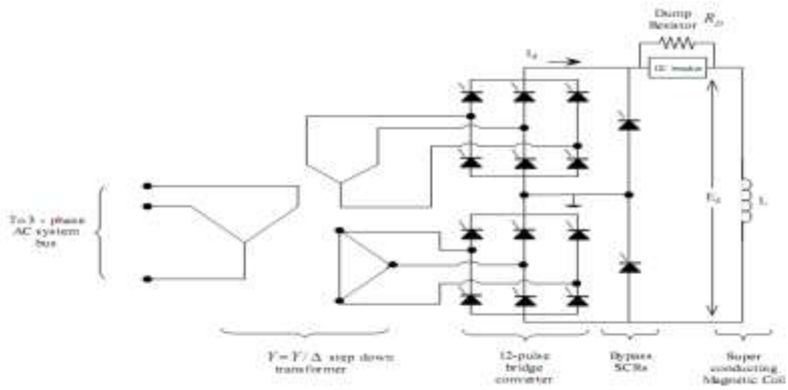


Fig. 1. SMES circuit diagram

Since fast-acting energy storage devices provide storage capacity, they can be considered for effectively suppressing such oscillations in the power system as and when required. A Superconducting Magnetic Energy Storage (SMES) is a device for storing and instantaneously discharging large quantities of power. It stores energy in the magnetic field created by the flow of DC in a coil of superconducting material that has been cryogenically cooled since direct current flows with almost zero losses in superconductors. SMES is very efficient with an energy efficiency of about 97% as there is no conversion of energy from one form to another, the cost per unit of stored energy decreases as storage capacity increases, the number of charge- discharge cycles obtainable can be huge which means longer life, has extremely short charge and discharge times which can be further accelerated to meet specific requirements depending on system capacity, has no moving parts (except in the refrigeration system), has high power density and has smaller size and reduced weight.

The SMES unit contains a DC superconducting coil and a 12-pulse converter, which are connected to grid through a Y-Δ/Y-Y transformer. The superconducting coil can be charged to a set value from the utility grid during steady state operation of the power system. The DC magnetic coil is connected to grid via inverter/rectifier arrangement. The charged superconducting coil conducts current which is immersed in a tank containing helium. The energy exchange between the superconducting coil and the electric power system is controlled by a line commutated converter. When there is a sudden rise in the load demand, the stored energy is almost released through the converter 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 and are similar for sudden release of load

A. Control Of SMES Unit

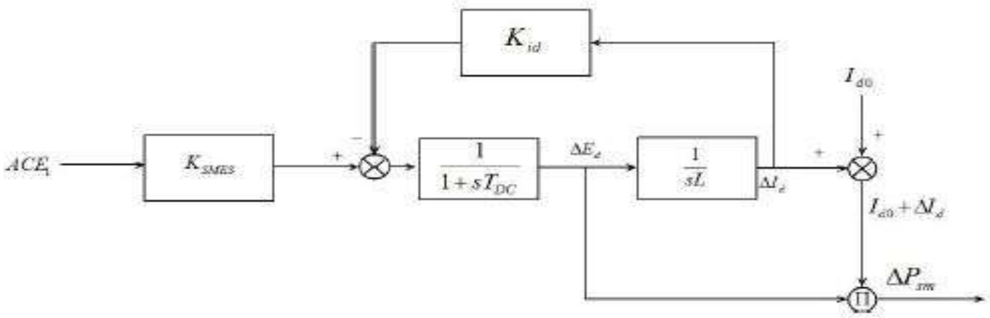


Fig. 2. Schematic diagram of SMES

DC voltage Ed across the superconducting inductor is continuously varied during the LFC operation based area control error. Moreover inductor current deviation is used as a negative feedback signal in the SMES control loop. Hence the inductor current has to bring back to its nominal value at its steady state. If the load demand changes suddenly, the feedback provides the prompt restoration of current. After load disturbance, inductor current has to be restored to its nominal value as fast as possible so that it can respond to the next load disturbance immediately. Fig.1 shows the block diagram of SMES unit. The equations governing the control unit of SMES is given as follows [6]. The deviation in inductor voltage,

$$\Delta E_d = \left[\frac{K_{SMES}}{1+T_{DC}}\right]\Delta Er \quad (1)$$

Where T_{DC} is converter time delay, K_{SMES} gain of control loop the inductor current is given by

$$\Delta I_d = \left(\frac{\Delta E_d}{s}\right) \quad (2)$$

III. AGC SYSTEM INVESTIGATED

The Power system comprising a two are system contain of thermal and hydro power plant for simulation studies. Fig 3 show linearized transfer function model of interconnected power system with two area with multi source power generation with SMES. KI1 and KI2 are the integral gain settings in area 1 and area 2 respectively αf11, αf12 are gain factors of area- 1 same as αf21 and αf22 are gain factors of area- 2 it noted that αf11+ αf12=1 and αf21+ αf22=1. The system parameters are given in appendix 1.the standard for of the system can be expressed as

$$X = AX + BU + \varphi p \tag{3}$$

Where X,U and p are state, control and load disturbance factors input vectors respectively whereas A B and φ are the respective matrices of dimensions

$$\left.\begin{array}{l} X = [\,\Delta f1 \quad \Delta PG1 \quad \Delta PTR1 \quad \Delta PT1 \quad \Delta PG2 \\ \Delta PRH1 \quad \Delta PGH1 \quad \Delta PG3 \quad \Delta PF1 \quad \Delta PYG1 \\ \Delta Pbg1 \quad \Delta f2 \quad \Delta PG4 \quad \Delta PTR2 \quad \Delta PT2 \\ \Delta PG5 \quad \Delta PRH2 \quad \Delta PGH2 \quad \Delta PG6 \quad \Delta PF2 \\ \Delta PYG2 \quad \Delta Pbg2 \quad \Delta Ptie12 \quad \Delta Id \quad \Delta Ed]^T \end{array}\right\} \tag{4}$$

$$U = [u1\ u2]^T \tag{5}$$

$$p = [\,\Delta PD1 \quad \Delta PD2] \tag{6}$$

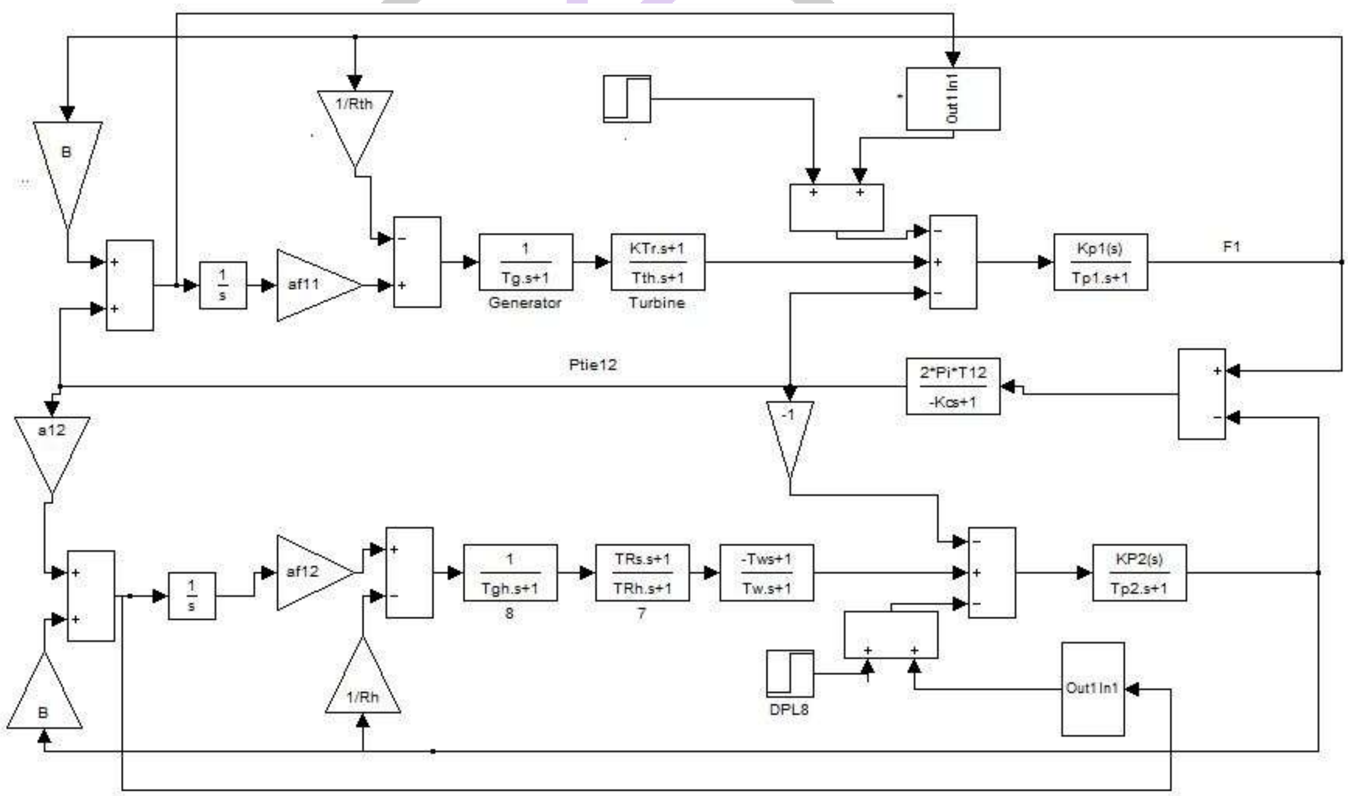
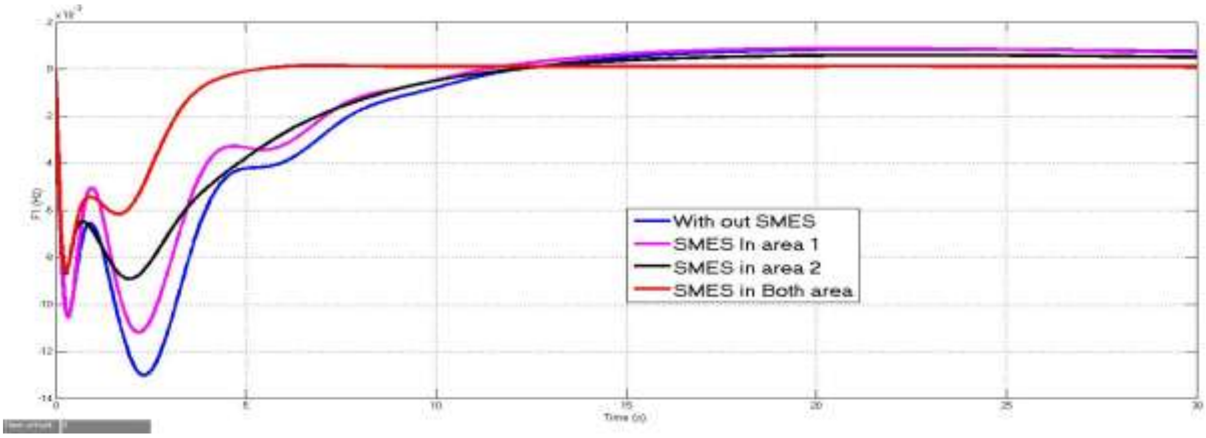


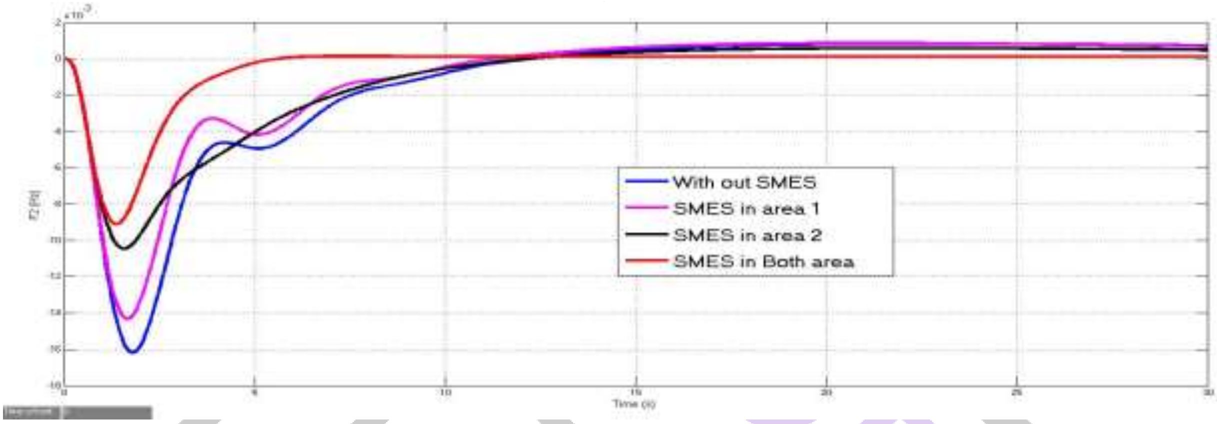
fig 3 interconnected power system model with SMES

IV. SIMULATION RESULTS

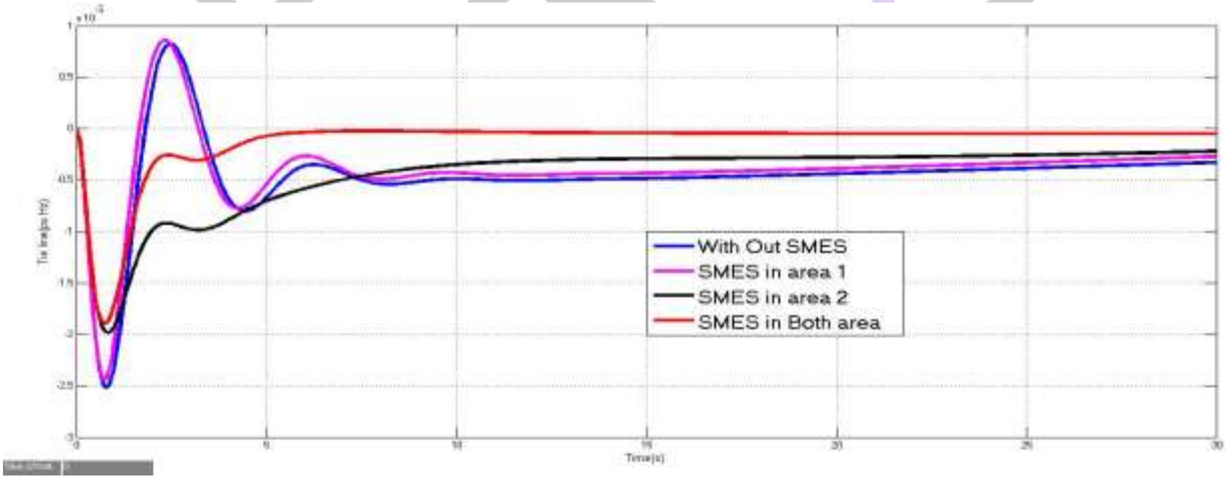
The results are simulated of the two area interconnected with diverse sources. The load disconcertion of 1% consider in either area 1 or area 2. SMES Placed in series with the area 1 near the tie line the integral step size of 0.01 is considered for simulation results. The simulation results are given below



(a) Deviation in frequency of area 1

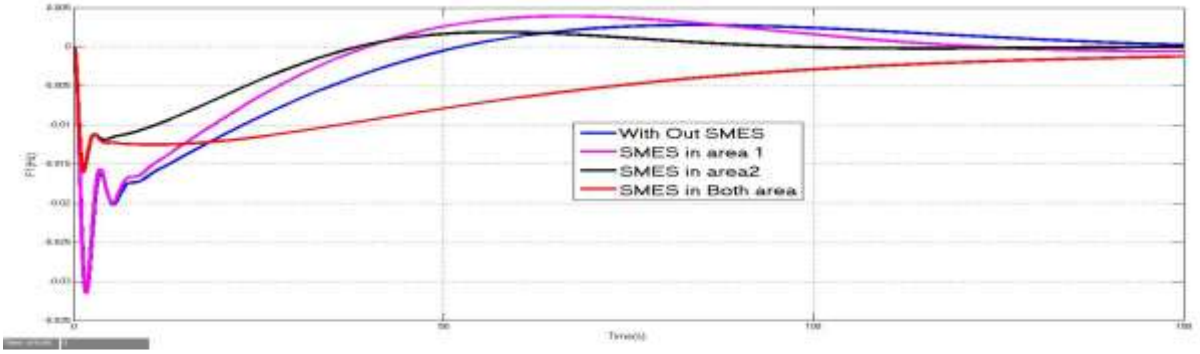


(b) Deviation in frequency of area2

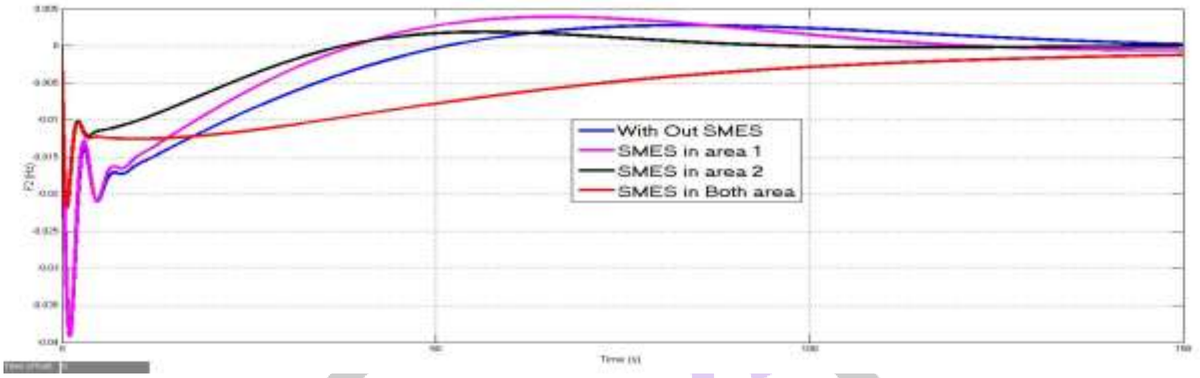


(c) Tie line power deviation

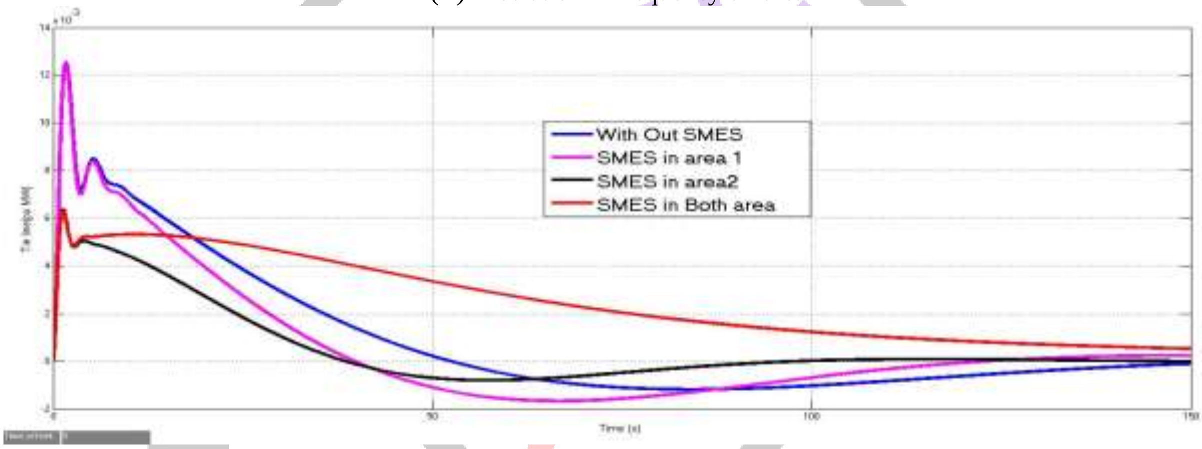
fig 4 variation in area frequency of (f1 and f2) and tie line power (P12) when 1% load change in area 1



(A) Deviation in frequency of area1



(B) Deviation in frequency of area 2



(C) Deviation in tie line power

fig 5 variation in area frequency of (f1 and f2) and tie line power (P12) when 1% load change in area 2

Table 1 integral gain setting with and without SMES for 1% step load in either of the areas

Condition	**K11**	**K11**
WITH OUT SMES	0.198	0.4
SMES in area 1	0.18	0.69
SMES in area 2	0.438	0.77
SMES in Both area	0.26	0.2879

V. CONCLUSION

The simulation is carried out in MATLAB and according to the waveform it is verified that inclusion of SMES in the existing system improves the dynamic performance of AGC. When SMES placed in both areas, there is not much improvement in the system performance in comparison with SMES in either of the areas it clearly visible in fig. Due to economic reasons, it is advisable to consider SMES in any of the areas.

VI. APPENDIX

1) System Data [3]
   Prt = 2000MW
   PL = 1640MW
   f = 50Hz
   H = 5MW − s/MV A
   D =(∂PL/∂f)(1/Prt)puMW/Hz
   KP = 1 /D Hz/puMW
   TP = 2.H / f.D s
   TT = 0.3s
   RTH = RHY = RG = R = 2.4Hz/puMW
   KR = 0.3
   TR = 10s
   TW = 1.0s
   TRH = 28.75s
   TF = 1.0s
   TCR = 0.01s
   TCD = 0.2s
2) SMES Data [4]
   L = 2.65H
   TDC = 0.03s
   KSMES = 100kV/unitMW
   Kid = 0.2kV/kA
   Id0 = 4.5kA

VII. ACKNOWLEDGMENT

I wish to express my deepest gratitude to my project guide Prof. Bharti B. Parmar Department of Electrical Engineering, V.V.P. Engineering College, Rajkot, for his constant guidance, encouragement and support. I warmly acknowledge and express my special thanks for his inspiring discussion and infallible suggestion.

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