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Load Frequency Control in deregulated environment of an interconnected power system with multi source generation using Superconducting Magnetic Energy Storage device

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Abstract—*In this paper, analysis of two area interconnected power system in deregulated environment considering local loads is done with thermal ,hydro and gas turbine systems using SMES in area 2. The effect of SMES in improving the system damping is studied. Dynamic response of frequency deviation and tie line power deviations is obtained with different load disturbances in each area and comparison is done with and without considering SMES. It has been observed that the oscillations in frequency and tie line power have been damped out effectively and settling time is also reduced.*

Keywords*— Load Frequency control(LFC), Superconducting Magnetic Energy Storage(SMES), Integral Squared Error(ISE), Integral Absolute Error(IAE), Integral Time Absolute Error((ITAE)*

I. INTRODUCTION

An electric energy system must be maintained at the desired operating level characterized by system frequency, voltage profile. The generation changes must match the load variations. In interconnected power system it is necessary to maintain the tie line power irrespective of load changes in an area. To control the frequency deviation and tie line power many control strategies have been proposed just to match the generation with load variations. Many control strategies are available in the market to control the frequency and tie line power. In this paper the use of SMES and its effect is simulated and analyzed.

Literature survey reveals that most of researchers have made an attempt to design LFC controllers using optimal control theory and applied either thermal or hydro power generations. Here the effect of SMES unit in suppressing the power system oscillations incurred by sudden fluctuations of real power load demand is studied. To reduce the oscillations and to improve the stability margin the energy storage system has following characteristics a)They should be continuously controllable. b)They should be able to absorb or release sudden excess or scarcity of power due to load fluctuations. c) The rise time and settling time of the resultant response should be small.

Here study is done for LFC in deregulated environment of two area system considering local loads in each area. The interconnected two area system has the combination of thermal, hydro and gas turbine system with SMES connected in area 2.

II. SUPER CONDUCTING MAGNETIC ENERGY STORAGE

A SMES is a dc current device that stores energy in the magnetic field. From a circuit point of view, the essential elements of SMES unit are (a) an inductor coil made up of superconducting wire(b) a cryogenic system with its liquid helium refrigerator to maintain the super conducting material at cryogenic temperature (c) power conversion system(PCS) which includes 12 pulse converter as shown in Fig. 1. The superconducting coil can be charged to a set value (which is less than full charge)from utility grid during normal operation.

The DC magnet coil is connected to the AC grid through a power conversion system, which includes an inverter/rectifier. The coil is maintained at an extremely low temperature by immersion in a bath of liquid Helium.

When there is sudden increase in the demand , the stored energy is almost immediately released through the power conversion system to the grid .
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.

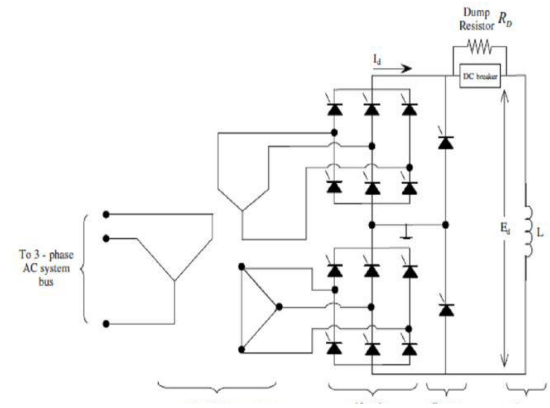
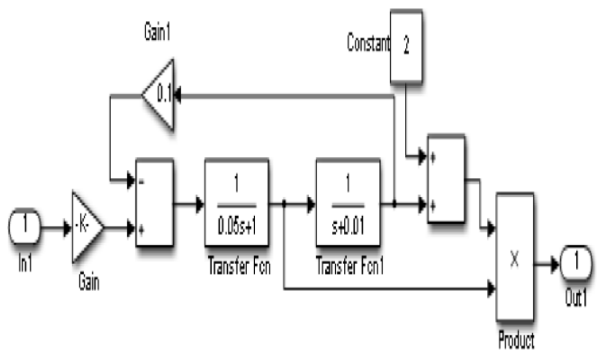


Fig. 1:SMES Circuit point of view

The matlab simulink representation of SMES is shown in Fig. 2.



III POWER SYSTEM MODEL

The detailed transfer function block diagram of two area interconnected system with diverse sources of electric power generation namely thermal, hydro and gas is show in Fig 3. The uncontrolled two area power system has generation sources of hydro in area 1 and combination of thermal and gas sources in area 2. The SMES unit is incorporated in area 2. The small disturbances of 5% is given in area 2 and IAE, ISE, ITAE has been calculated for different perturbations of load disturbances.

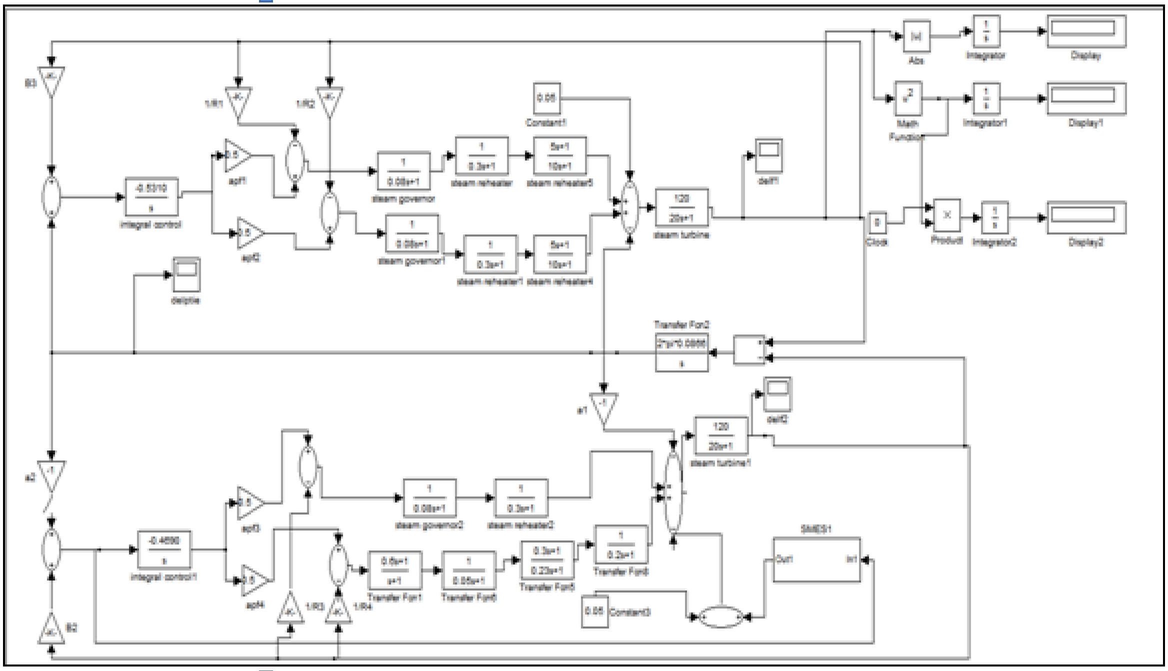


Fig 3:Simulink model of multi source two area power system with SMES

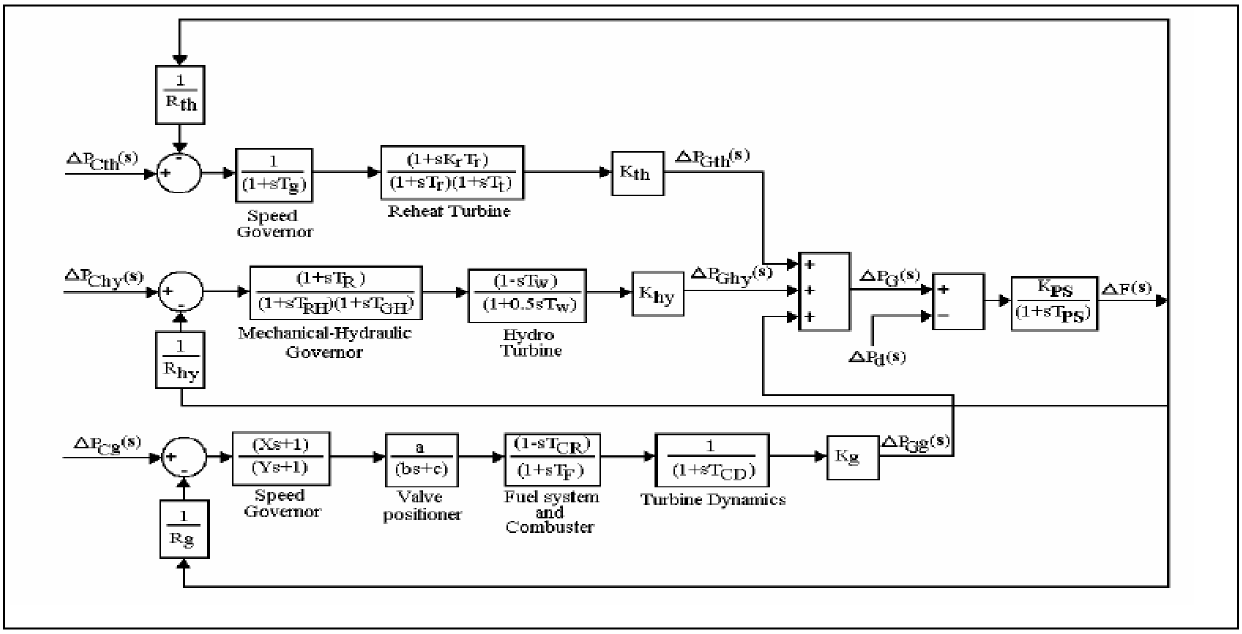


Fig 4:Transfer function block diagram of power generations of thermal, hydro and Gas sources

IV SIMULATION RESULT

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The two area power system is considered for the simulation and quantitative comparison is done for different load disturbances by calculating ISE, IAE, ITAE.

Case 1:

For step load disturbance of 5% in area 2

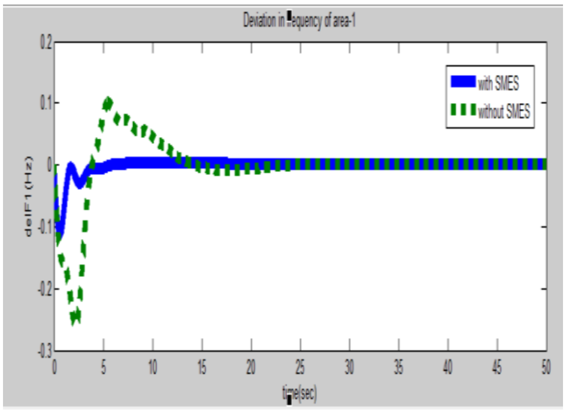

Fig 5: Response of change in frequency in area 1

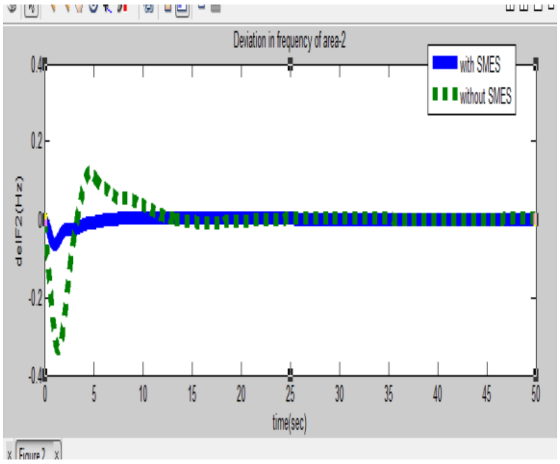

Fig 6:Response of change in frequency in area 2

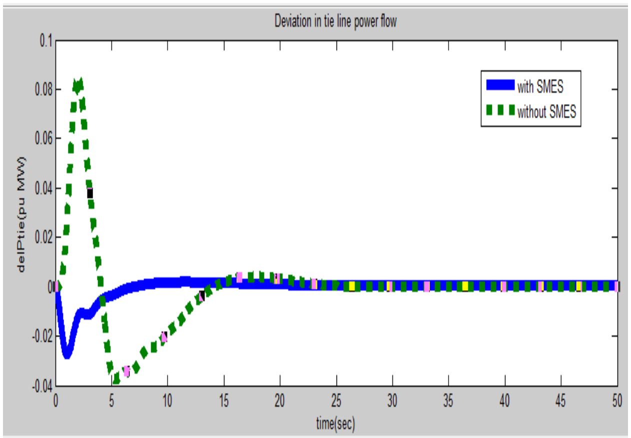

Fig 7: Response of change in tie line power exchange between area1 and area2

Table 1: Comparison of settling time and error values

	With SMES				Without SMES			
	Setting Time (Sec)	**IAE**	**ISE**	**ITAE**	**Setting Time (Sec)**	**IAE**	**ISE**	**ITAE**
$\Delta F1$	10	0.1957	0.00979	0.009554	24	0.2479	0.01267	0.01557
$\Delta F2$	10	0.1941	0.005659	0.0103	24	0.2454	0.0113	0.0157
ΔP_{tie}	10	0.08702	0.001017	0.001952	24	0.2552	6.716 e-005	0.002145

Case 2:For step load disturbance of 10% in area 2

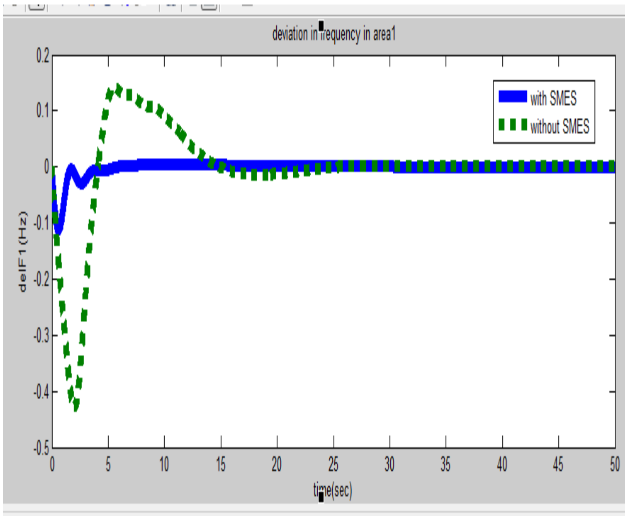

Fig 8: Response of change in frequency in area 1

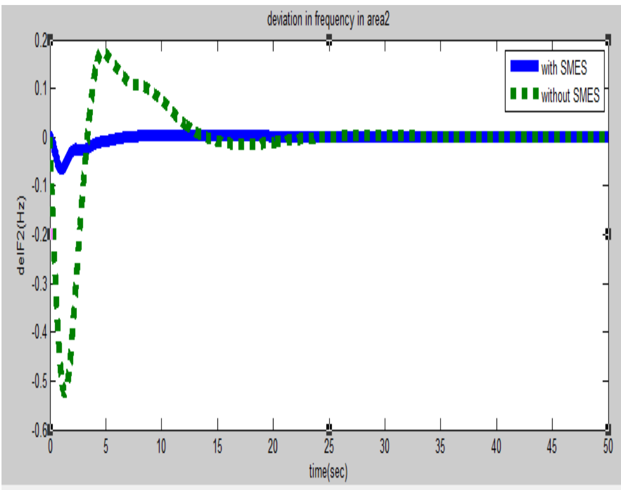

Fig 9 : Response of change in frequency in area 2

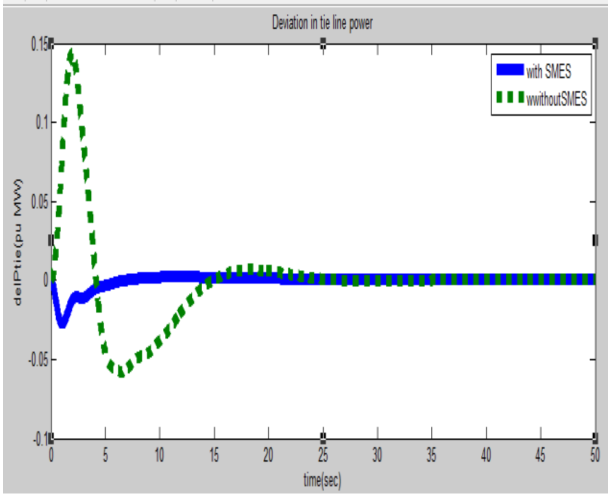

Fig 10 : Response of change in tieline power exchange between area 1 and area 2

Table 2: Comparison of settling time and error values

	With SMES				Without SMES			
	Setting Time (Sec)	**IAE**	**ISE**	**ITAE**	**Setting Time (Sec)**	**IAE**	**ISE**	**ITAE**
Δ F1	11	0.2048	0.009828	0.0109	25	0.3651	0.0245	0.03718
Δ F2	11	0.2033	0.005790	0.0109	25	0.3658	0.0284	0.03353
ΔP_{tie}	11	0.09417	10.001017	0.002145	25	0.05952	0.0004671	0.001098

<u>Case 3</u>:for Step load disturbance of 2% in area 1

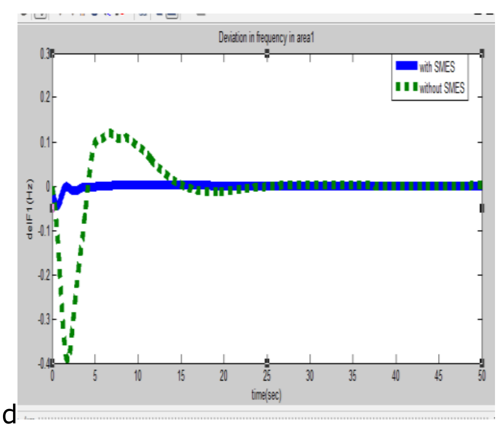

Fig 11 : Response of change in frequency in area 1

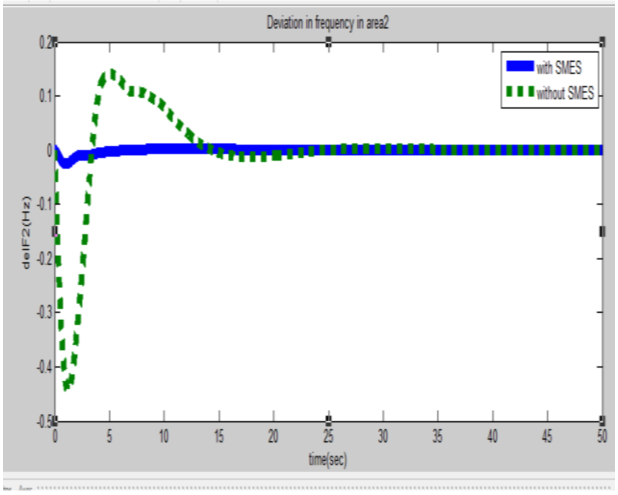

Fig 12 : Response of change in frequency in area 2

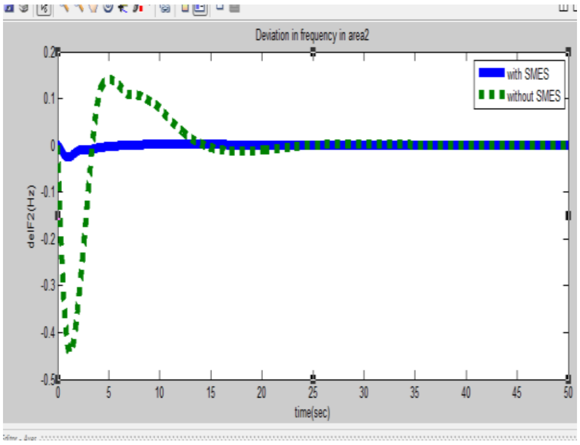

Fig 13 : Response of change in tieline power exchange between area1 and area 2

Table 3: Comparison of settling time and error values

	With SMES				Without SMES			
	Setting Time (Sec)	**IAE**	**ISE**	**ITAE**	**Setting Time (Sec)**	**IAE**	**ISE**	**ITAE**
$\Delta F1$	11	0.09539	0.001605	0.00236	25	0.5083	0.008 67	0.00613
$\Delta F2$	11	0.09504	0.000959	0.00252	25	0.5235	0.004 58	0.00911
ΔP_{tie}	11	0.04612	0.000167	0.00053	25	0.2809	0.001 47	0.002469

Here various case studies were done considering SMES in area 2 and without SMES with load disturbances of 5% and 10% in area 2 and 2% in area 1.It is clear that the addition of SMES in the system improves the dynamic performance of LFC and the errors(IAE,ISE,ITAE).It has been observed that the settling time and responses are considerably reduced.

V CONCLUSION

In this paper, the LFC control using SMES has been proposed for an interconnected two area, multi source power system. Settling time and gain settings of integral controllers with and without SMES are optimized . From the simulation studies it is clear that SMES can effectively damp out the oscillations and reduce the settling time.

APPENDIX

1) System Data

$T_{g1}= T_{g2}=0.08s$; $T_{t1}=T_{t2}=0.3s$
$T_P=20s$; $K_p=120$; $Tr=5s$;
$Tw=0.2s$; $R_1=R_2=R_3=2.4Hz$ pu/MW
$X=0.6s$; $Y=1.0s$
a=1; b=0.05; c=1
$T_f=0.23s$; $Tcr=0.3s$; $Tcd=0.2s$;

2) SMES Data

$L=2.56H$
$T_{dc}=0.03s$
$K_{SMES}=100kV$/unit MW
$K_{id}=0.2kV/kA$
$I_{do}=4.5kA$

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