ROBUST TECHNIQUE LFC OF TWO-AREA POWER SYSTEM WITH DYNAMIC PERFORMANCE OF COMBINED SMES AND SSSC CONTROL

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ABSTRACT

Superconducting Magnetic Energy Storage (SMES) unit with a self-commutated converter is capable of controlling both active and reactive power simultaneously and quickly, increasing attention has been focused recently on power system stabilization by SMES control. This paper addresses a new technique robust control design for load-frequency control (LFC) in two-area power systems with Static Synchronous Series Compensator (SSSC). The LFC problem is considered as a multi-objective problem and formulated via a SMES new control technique. The proposed selftuning control scheme is used to implement the Automatic Generation Control (AGC) for LFC application adding to SMES control configuration. A two-area power system studied with a wide range of load changes is given to illustrate the proposed approach. The results are compared with the configuration of modified technique SMES units combined with SSSC technique. It is shown that the designed controllers maintain the robust performance, minimize the effect of disturbances and specified uncertainties, very effectively.

KEYWORDS: *Multi-area electric power system, load frequency control, superconducting magnetic energy storage, Static Synchronous Series Compensator.*

I. INTRODUCTION

For large-scale power systems, which consist of inter-connected control areas, load frequency control (LFC) is important to keep the frequency and inter area tie power near to the absolute standard values. The input mechanical power is used to control the frequency of the generators and the change in the frequency and tie line power, which is a measure of the change in rotor angle. A well-designed power system should be able to provide the acceptable levels of power quality by keeping the frequency and voltage magnitude within acceptable limits [2-5].

The modern power systems with industrial and commercial loads need to operate at constant frequency with reliable power [2,4]. The LFC of an interconnected power system is being improved over the last few years. The goals of the LFC are to maintain zero steady state errors in a multi area interconnected power system [2], [5]. The Studies on two area interconnected power system networks were presented based on the new technique. Recently, many researchers have applied superconducting magnetic energy storage (SMES) controllers to improve the dynamic performance of the system [8-16]. Subsequently robust load frequency control for uncertain non linear power systems using SMES approach to quench the transients in frequency deviations and tie line power deviations is presented [10]. In all these works, the basic dynamic model representation of a two–area power system given in the reference [17-21] is considered and the responses of two area power systems are evaluated. These studies using another control methods show that the frequency deviations are oscillatory and the total time to reach final steady state is more [19-22]. The work reported in this paper deals with the representation of a two–area power system with new technique of SMES.

As an AC interconnected power system is subjected to a large load with rapid change, system frequency may be severely disturbed and becomes oscillatory. To stabilize the frequency oscillations, application of one of the sophisticated FACTS devices, i .e. SSSC to stabilize the Frequency of oscillations in an interconnected power system. The SSSC located in series with the tie-line between any interconnected areas, is applicable to stabilize the area frequency of oscillations by high-speed control of tie-line power through the interconnections. Application of SSSC to provide an active control facility for stabilization of frequency oscillations in an interconnected power system is proposed. An SSSC located in series with the tie-line between any interconnected areas, can be applied to stabilize the area frequency oscillations by high-speed control of tie-line power through the interconnections .In addition, the study results in this chapter show that the high-speed control of SSSC can be coordinated with the slow-speed control of governor systems for enhancing the stabilization of area frequency oscillations effectively.

II. TWO-AREA STUDIED SYSTEM WITH NEW TECHNIQUE SMES

The two area interconnected power system with two SMES new technique is shown in Fig. 1 where dF1 and dF2 are the frequency deviations in Hz for area 1 and area 2 respectively. The system investigated for LFC in this study is a two area interconnected power system with reheat turbine type thermal unit in each area. In an interconnected power system, a sudden load perturbation in any of the interconnected areas causes the deviation of frequencies of all the areas and of the tie line powers. Since the time constant of the excitation control system is small compared to the time constant of the load frequency control system, thus the transients in excitation voltage control vanish much faster and do not affect the dynamics of the load frequency control. That is the reason why excitation control and load frequency control are non-interactive for small changes in load, and therefore, can be modeled and analyzed independently. This important fact simplifies the development of the two-area power system model for load frequency control.

III. TWO-AREA STUDIED SYSTEM WITH NEW TECHNIQUE SMES UNITS COMBINED WITH SSSC

The two area interconnected power system with SMES units combined with SSSC new technique is shown in Fig. 1 where dF1 and dF2 are the frequency deviations in Hz for area 1 and area 2 respectively. The system investigated for LFC in this study is a two area interconnected power system with reheat turbine type thermal unit in each area. In an interconnected power system, a sudden load perturbation in any of the interconnected areas causes the deviation of frequencies of all the areas and of the tie line powers. Since the time constant of the excitation control system is small compared to the time constant of the load frequency control system, thus the transients in excitation voltage control vanish much faster and do not affect the dynamics of the load frequency control. That is the reason why excitation control and load frequency control are non-interactive for small changes in load, and therefore, can be modeled and analyzed independently. This important fact simplifies the development of the two-area power system model for load frequency control.

The generalized model [10] of the two-area interconnected power system including the SMES units combined with SSSC is as shown in Fig. 1 where symbols have their usual meanings. Load-frequency control is achieved by two different control actions in two-area power systems: The primary control that makes the initial coarse readjustment of the frequency by making the various generators in the control area track a load variation and share that in proportion to their ratings. The supplementary or secondary control, which operates only after allowing the primary control to act, is a precise control strategy for fine adjustment of the frequency that helps bring back the frequency to nominal or very close to nominal value. The main objective of the supplementary control is to restore balance between each control area load and generation after a load disturbance, so that the system frequency and the tie line power flows are maintained at their scheduled values. This is achieved conventionally with the help of integral control action.

The fact remains that SMES units combined with SSSC systems have received considerable attention in recent years for their use in power systems for different purposes. In the automatic generation control (AGC) problem, the instantaneous mismatch between generation and consumption of real power can be reduced by the addition of fast acting SMES units combined with SSSC unit. Therefore, this study investigates the effects of SMES units combined with SSSC on load frequency control of two-area interconnected thermal power system with SMES units combined with SSSC unit present in the areas. The results obtained show the positive effect of SMES units combined with SSSC units on damping of the oscillations of frequency and tie-line power against small load disturbances. However, the sudden release or absorption of power by SMES units combined with SSSC in accordance with the deviations of load causes the supplementary control to feel the effect of load variations slightly reduced. This may introduce slight sluggishness in the operation of supplementary control. This situation can be improved by providing the power deviations in SMES units combined with SSSC units as an additional signal for the supplementary control [16].

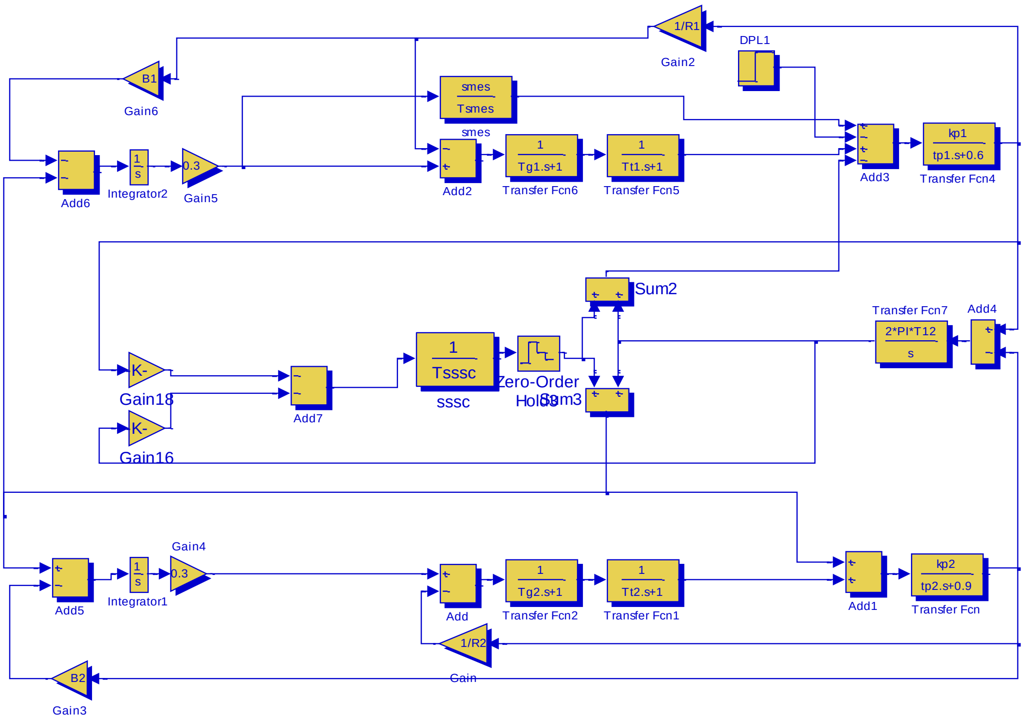

Fig 1. Two area studied system with two SMES new technique

IV. RESULTS AND DISCUSSIONS

In this study simulations were performed using MATLAB Simulink on a two-equal area interconnected power system having steam turbine type thermal units in both areas. The parameters of the power system investigated are as given in appendix. The same system parameters were used in all the cases for comparison purpose. Simulations were performed with SMES units combined with SSSC and with SMES in both areas. The step load perturbation of 20%, 40%, 60%, 80% and 100% disturbance loads was applied in area-1 for all the cases considered and the frequency oscillations and tie-line power flow deviations were investigated. System performances are shown in figures in terms of the deviations of frequencies of each area and the deviations of tie-line power flows i.e. dF1 , dF2, and dPtie. As shown in Figures 2 through 15 where the deviations for the case when the SMES units combined with SSSC controller is used with new SMES.

A new technique of putting SMES units combined with SSSC in the two area system is shown in figure1, and figures 2, 5, 8, 11 and 14 shows the signal of difference frequency dF1 for area 1 with and with SMES for new technique, the difference frequency dF2 for area 2 is shown in Figures 3, 6, 9, 12 and 15 and difference power tie-line power is shown in Fig.4, 7, 10 ,13 and 16. All Figures are shown the deviations of the same variables for the same operation case when the controller is used with new technique of SMES units combined with SSSC.

Comparative analysis of the results is shown in figures 2, 5, 8, 11 and 14. The results indicate that the new technique of SMES controller improves effectively the damping of the oscillations and reduces the settling time and overshoot. The integration of SMES units in both the areas have positive effect on improvement of the dynamic performance of the power system as is visible from the damping of oscillations and reduction in settling time and the new technique of SMES is more effects as showing overshoot and undershoot to a great extent. To feel this effect, simulations were carried out for the same controller settings and the same operation case with SMES combined with SSSC in both the areas as is clearly visible there is definite improvement in the dynamic response of the power system with the modified SMES technique. The results show that this new proposition of technique of SMES combined with SSSC is effective in reducing the overshoot and the settling time it is the same time to return to steady state in all cases by reasonable proportions under step load perturbations.

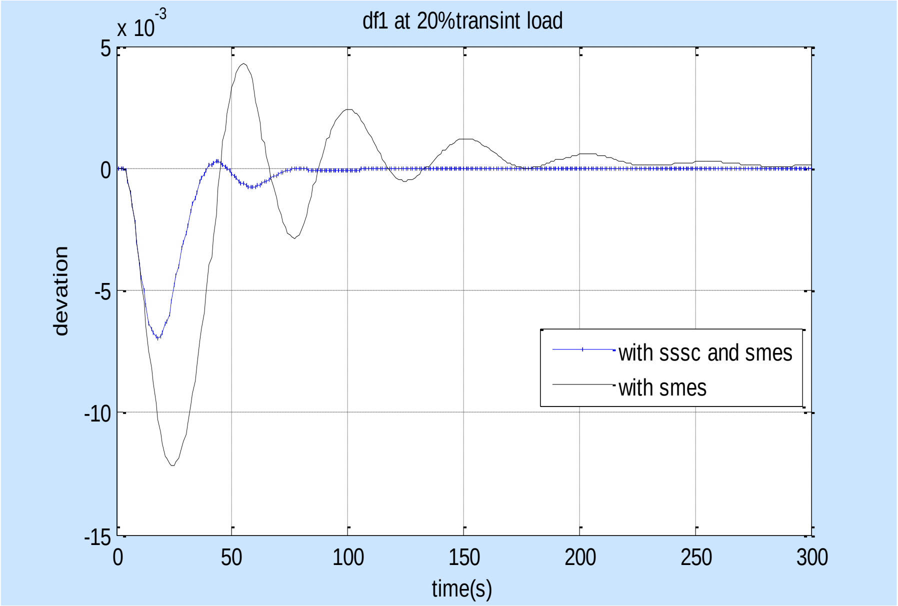

Fig. 2 Difference frequency df_1 with SMES and combined SMES & SSSC for two area studied system at 20 % transient load

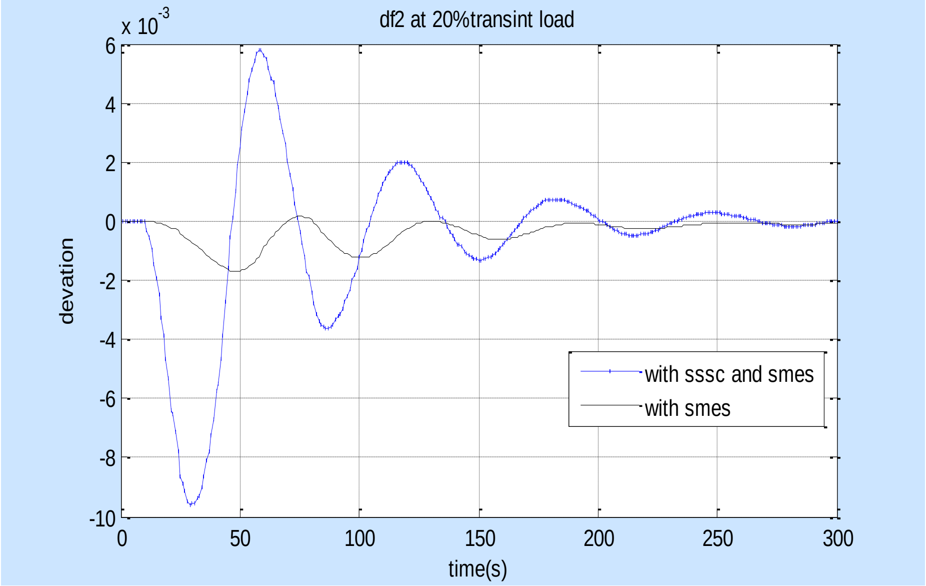

Fig. 3 Difference frequency df_2 with SMES and combined SMES and SSSC for two area studied system at 20 % transient load

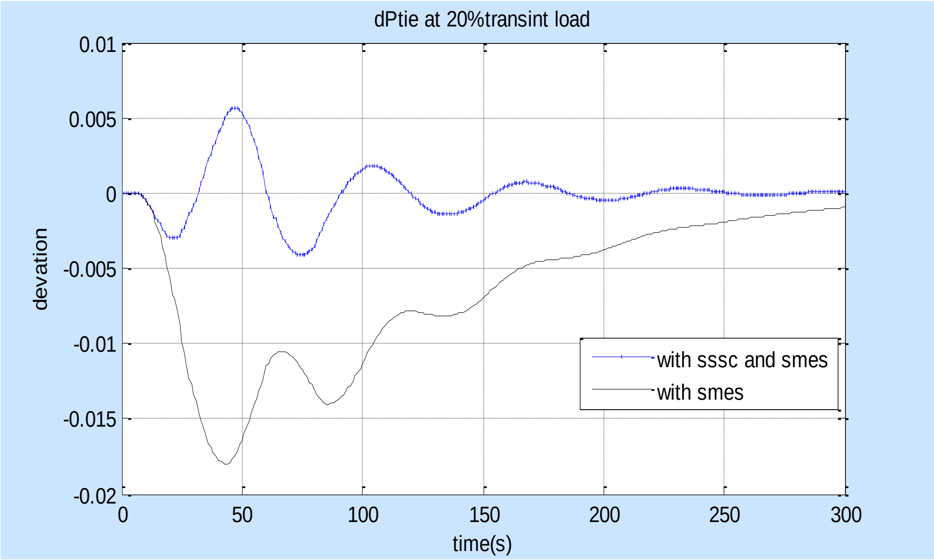

Fig.4 Difference tie line power dP_{tie} with SMES and combined SMES and SSSC for two area studied system at 20 % transient load

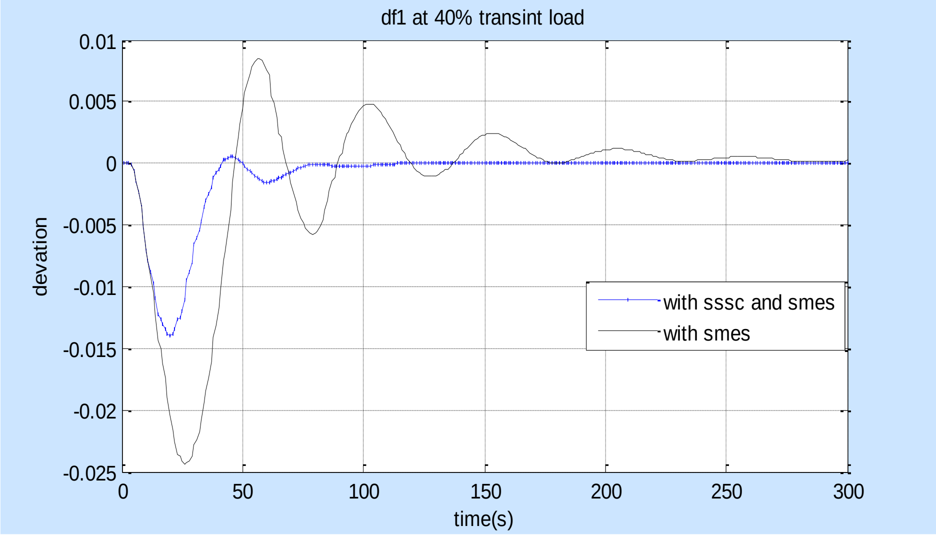

Fig.5 Difference frequency df_1 with SMES and combined SMES and SSSC for two area studied system at 40 % transient load

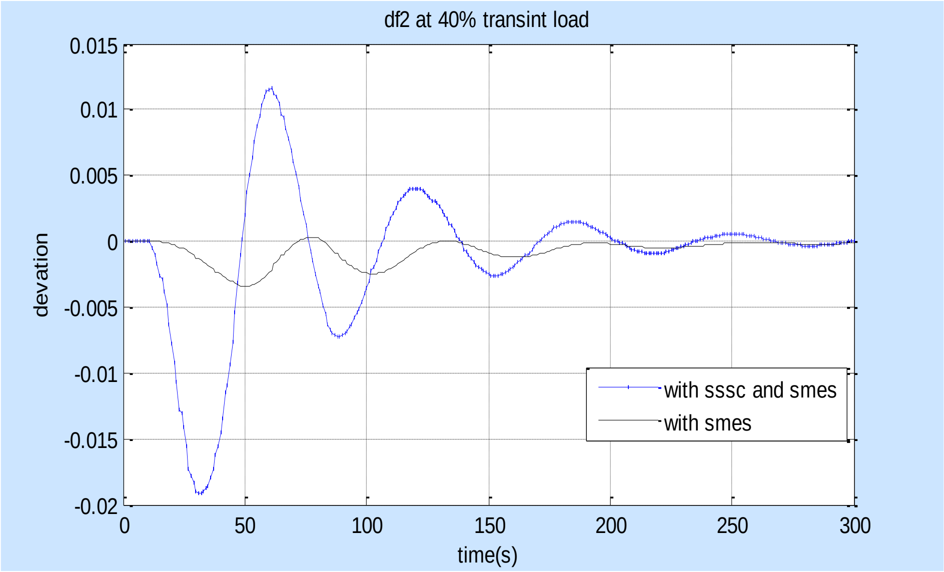

Fig.6 Difference frequency df2 with SMES and combined SMES and SSSC for two area studied system at 40 % transient load

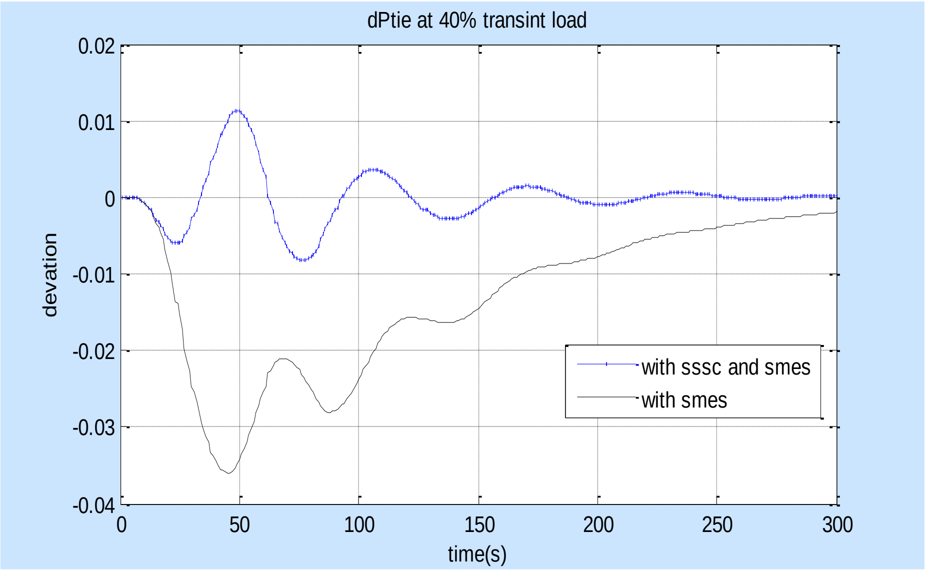

Fig.7 Difference tie line power dPtie with SMES and combined SMES and SSSC for two area studied system at 40 % transient load

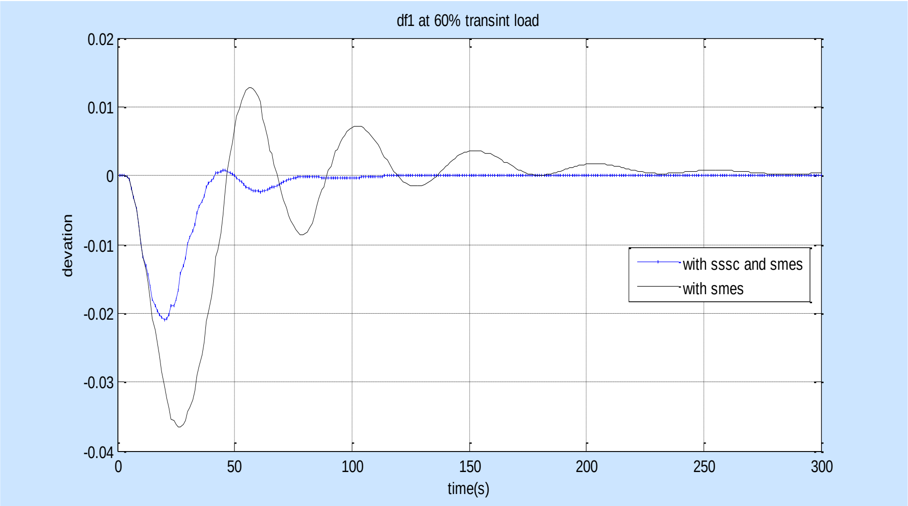

Fig.8 Difference frequency df_1 with SMES and combined SMES and SSSC for two area studied system at 60 % transient load

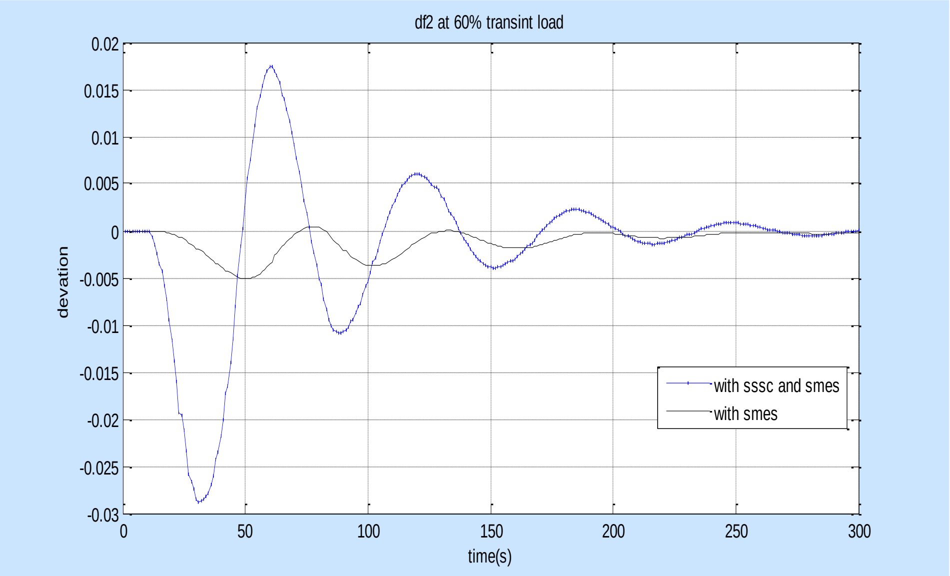

Fig.9 Difference frequency df2 with SMES and combined SMES and SSSC for two area studied system at 60 % transient load

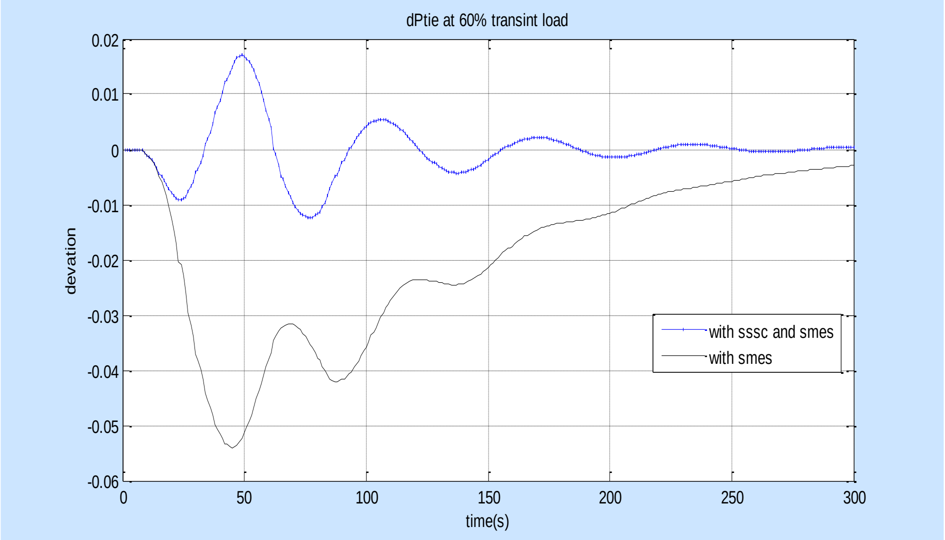

Fig.10 Difference tie line power dP_{tie} with SMES and combined SMES and SSSC for two area studied system at 60 % transient load

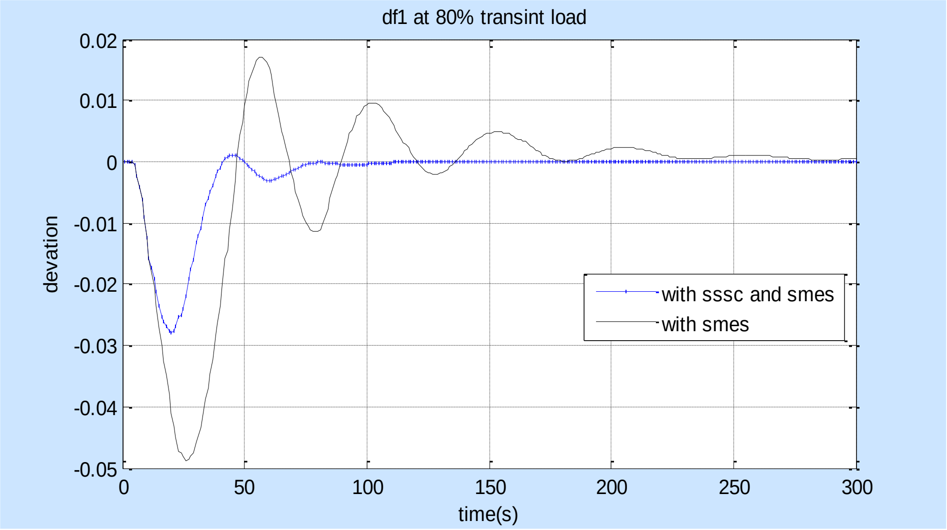

Fig.11 Difference frequency df1 with SMES and combined SMES and SSSC for two area studied system at 80 % transient load

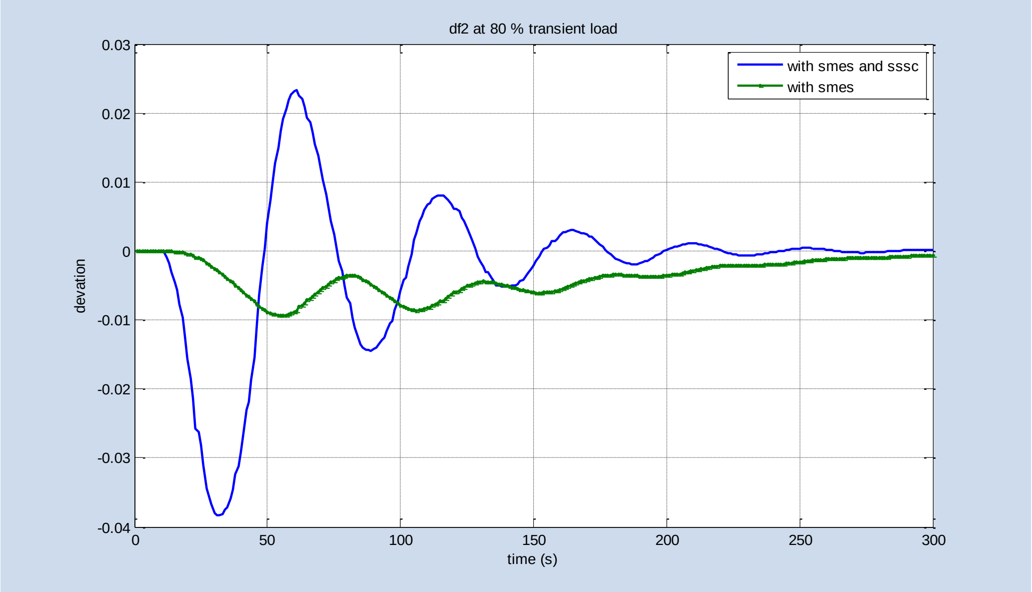

Fig.12 Difference frequency df$_2$ with SMES and combined SMES and SSSC for two area studied system at 80 % transient load

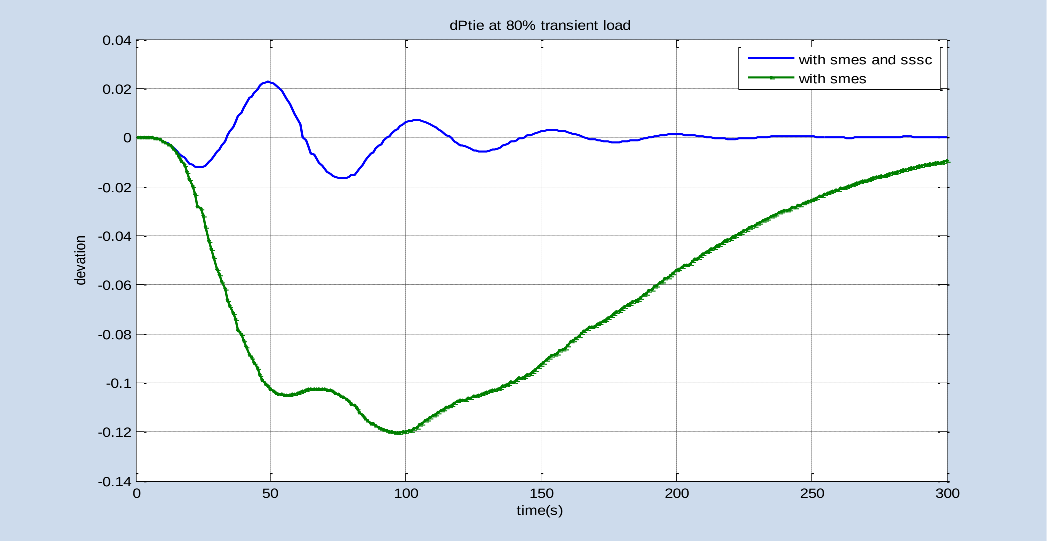

Fig.13 Difference tie line power dPtie with SMES and combined SMES and SSSC for two area studied system at 80 % transient load

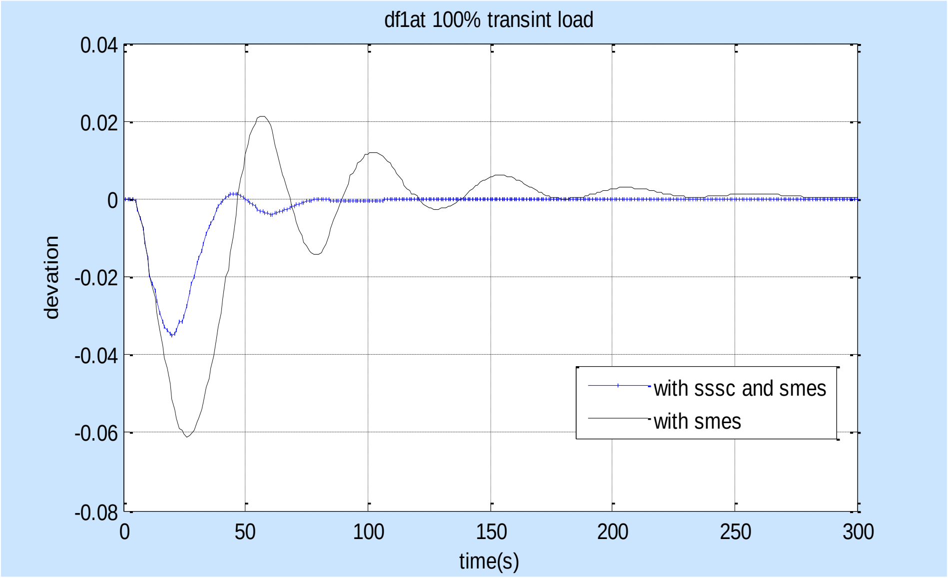

Fig.14 Difference frequency df$_1$ with SMES and combined SMES and SSSC for two area studied system at 100 % transient load

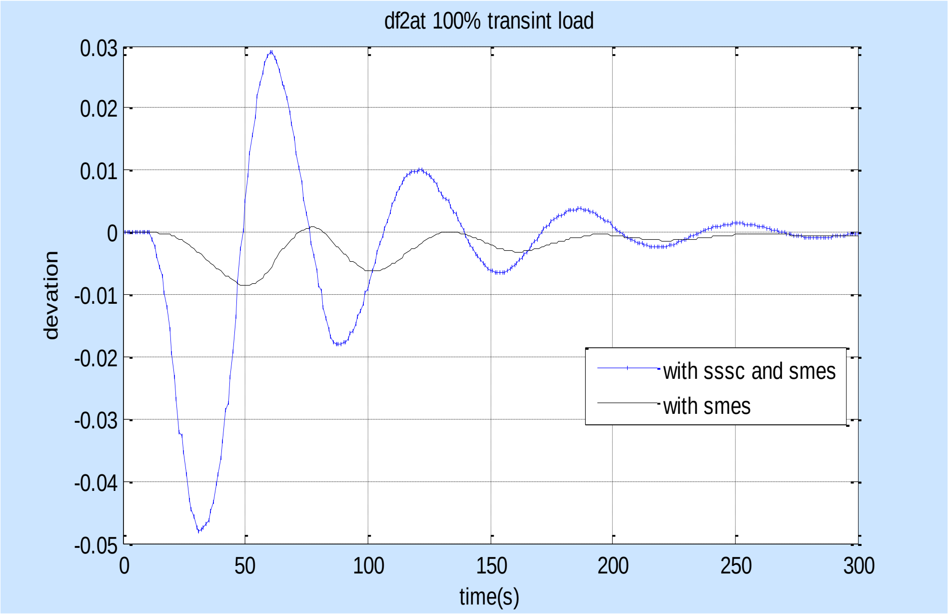

Fig.15 Difference frequency df2 with SMES and combined SMES and SSSC for two area studied system at 100 % transient load

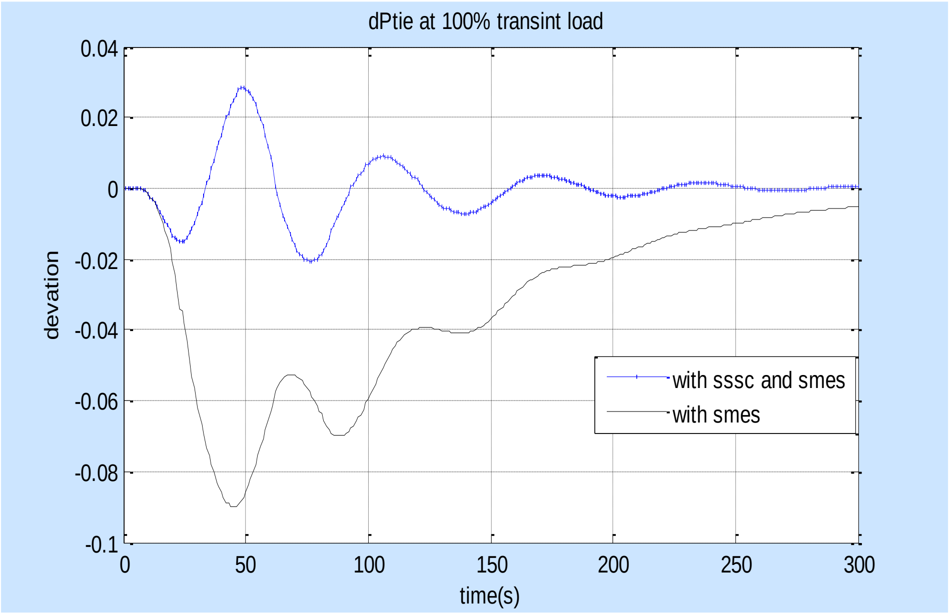

Fig.16 Difference tie line power dP_{tie} with SMES and combined SMES and SSSC for two area studied system at 100 % transient load

Table 1. Two-area power system parameters

T_{g1}= 0.2 s	T_{g2}=0.3 s	B_1 = 20.6	B_2 = 16.9
T_{p1}=100/6s	T_{p2}=80/9 s	$1/R_1$=20	$1/R_2$=16
T_{t1}= 0.5 s	T_{t2}= 0.6 s	K_{11}= 0.3	K_{12} =0.3
T_{SMES}=0.03 s	T_{SSSC}=0.03 s	K_{p1}=10/6	K_{p2}=10/9

V. CONCLUSION

In this study, a new SMES technique is implemented as supplementary controller in each area of a two- area interconnected power system with reheat type steam turbines for the cases that combined SMES with SSSC controller and with SMES units in both areas. 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. The results indicate that combined SMES with SSSC controller improves effectively the damping of the oscillations and reduces the settling time and overshoot as compared to SMES controller. Simulations were carried out for the same controller settings and the same operation case with SMES and SSSC in both the areas as is clearly visible there is definite improvement in the dynamic response of the power system with combined SMES with SSSC technique. The results show that this new proposition of technique of combined SMES with SSSC is effective in reducing the overshoot and the settling time by reasonable proportions under step load perturbations. Simulation results obtained establish the usefulness of the proposed combined SMES with SSSC technique.

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