Volume 8, Issue 5
October 2019

ITEE Journal
Information Technology & Electrical Engineering

ISSN: - 2306-708X

©2012-19 International Journal of Information Technology and Electrical Engineering

Ancillary Service Management to Improve the Transient Stability in Deregulation Environment

[1]Dr. Y. Butchi Raju, [2]SK. Chanbasha and [3]V. Mohan Achuth Varma
Department of Electrical and Electronics Engineering,
Sir. C.R.R Engineering College, Eluru -534007, Andhra Pradesh, India
E-mail: [1]butchiraju.y@gmail.com, [2]chan7862007@gmail.com, [3]achuthvarma@gmail.com

ABSTRACT

In a deregulated power system, the consumption of transmitted power with the unpredictable variable load tends the frequency and transferring power between the lines to fluctuate. Ancillary services regulate Load frequency, which synchronizes with the automatic generation control (AGC) to provide energy balance. In this paper, Thyristor Controlled Phase Shifter (TCPS) damp out the tie-line power oscillations, along with the coordination of Energy storage devices like Ultra Capacitor (UC), superconductor magnetic energy storage system (SMES), Capacitive Energy Storage (CES) and Redox Flow Batteries (RFB) to damp oscillations in frequencies of both areas. For effective coordination, the control scheme is tested on a two-area power system in the deregulated environment under the PoolCo transaction and bilateral transaction contract scenarios.

Keywords: *Automatic Generation Control (AGC), Bilateral transactions, PoolCo transactions, Energy Storage Devices (ESD), Deregulation Environment, Load Frequency Control (LFC).*

1. INTRODUCTION

Under deregulation, the generation, transmission, and distribution operate independently, unlike the vertically integrated utility [1]. Energy storage plays a prominent role in the deregulated scenario as the frequency stability and network stability are essential in power system operation. The generation of electricity is provided by the small unit in a large number [2].In the restructured scenario, maintaining the Grid Integrity, Frequency and Voltage mean as Ancillary Services, These ancillary services are entrusted to the Independent System Operator (ISO), who has to secure these services from various Generating and Transmitting Activities under the monitoring control and guidance of Regulatory Consultants [3].

Load frequency control is one of the key problems in the power system, which synchronizes with automatic generation control. Inspecting the diverse factors that cause unbalance in the power system is necessary, and one of the essential factors random load [4, 5].In an interconnected power system, the frequency of the system and the terminal voltages are to be maintained within the specified limits to guarantee the quality and reliability of the power generation [1-3].

The new opportunities are available due to the recent advancements in power electronics. FACTS devices are utilized to enhance power system operation & stability [6]. A Thyristor Controlled Phase Shifter (TCPS) is expected to be an efficient means for the management of the tie-line power of an interconnected power system. By modifying the phase angle [7-12], it injects a variable series voltage to affect the power flow. It modulates active power flow in the power system, and its high speed makes it suitable to be used for improving power system operation and control.

Absorption of the power fluctuations may be effectively achieved by incorporating the Energy storage devices in the power system. Super Capacitor Energy Storage (SCES) unit. Super Capacitor / Ultra Capacitor (UC) store electrical energy during surplus generation and delivers power during peak load demand period within a short duration of time [17]. The power demand is always changing from time to time, which made it unpredictable, and fluctuating may lead to defective power supply [12]. Hence, to diminish this, energy storage devices (ESD) Capacitive Energy Storage (CES) [10], superconducting magnetic energy storage (SMES) [19], ultra-capacitors (UCs), [13, 14] and redox flow batteries (RFBs) [20, 21] can be incorporated so that uninterrupted power is supplied to the load, and concurrently, minimum system cost can be accomplished. SMES is studied for two area thermal systems [19].

If the renewable sources give surplus power over the load demand, it is stored by the energy storage for a short time, and later they discharge them to the grid. They also decrease fluctuations in the grid frequency, thereby improving the power quality. The above works of literature [13-21] have applied various ES devices in diverse fields. In this paper, the FACTS device, the TCPS is used in between the two control areas in series with the tie-line improves the power transfer between the control areas. TCPS in coordination with the various EDS, which diminishes the frequency fluctuations in the power system according to their storage and discharge capacities.

2. MODELING OF DEREGULATED POWER SYSTEM

In the vertically integrated structure of the traditional power system, the Generating Companies (GENCOs), Transmission companies (TRANSCOs), and Distribution companies (DISCOMs) are integrated [5]. In this deregulated power system, these three entities are operated independently with the independent system operator, which has their operating data open access to all the entities in the market their goal is to

©2012-19 International Journal of Information Technology and Electrical Engineering

keep the frequency constant. In Fig .1, it is shown that the bilateral contracts between two areas, GENCOs have the option to participate in the load frequency control (LFC). Discoms have the liberty to choose the GENCOs for power contracts.

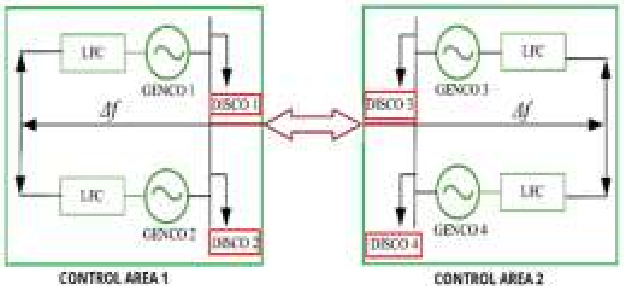


Fig 1: Block Diagram of Control areas in deregulation scenario

2.1 Distribution Participation Matrix

The proposed power system model is under the deregulation environment, there will be participation factors regarding the demands of DISCOM to each individual generation companies is represented by the distribution Participation matrix (DPM).

$$\text{DPM} = \begin{bmatrix} cpf11 & cpf12 & cpf13 & cpf14 \\ cpf21 & cpf22 & cpf23 & cpf24 \\ cpf31 & cpf32 & cpf33 & cpf34 \\ cpf41 & cpf42 & cpf43 & cpf44 \end{bmatrix}$$

The DPM contains rows and columns whose rows are equal to the number of GENCOs and columns equals the number of DISCOMs in the power system. So in the DPM we have a contract participation factor of each GENCO to deliver the generation demanded by each DISCOM. The total of each individual DISCOM demand equal to one. The simulation diagram of DPM is shown in the below figure 2.

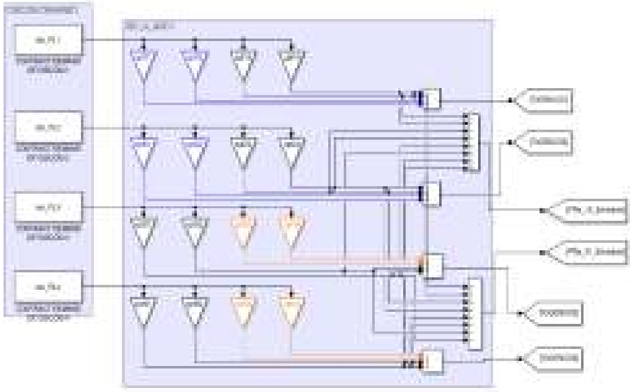


Fig 2: Simulation diagram of Distribution Participation Matrix

2.2 Power System Model

This paper proposes two area deregulated power system, area-1 incorporates two GENCOs, Thermal with two DISCOMs 1, 2; Area-2 includes two GENCOs Thermal with two DICOMs 3, 4. The simulation diagram of a proposed two-area deregulated power system shown in figure 3.

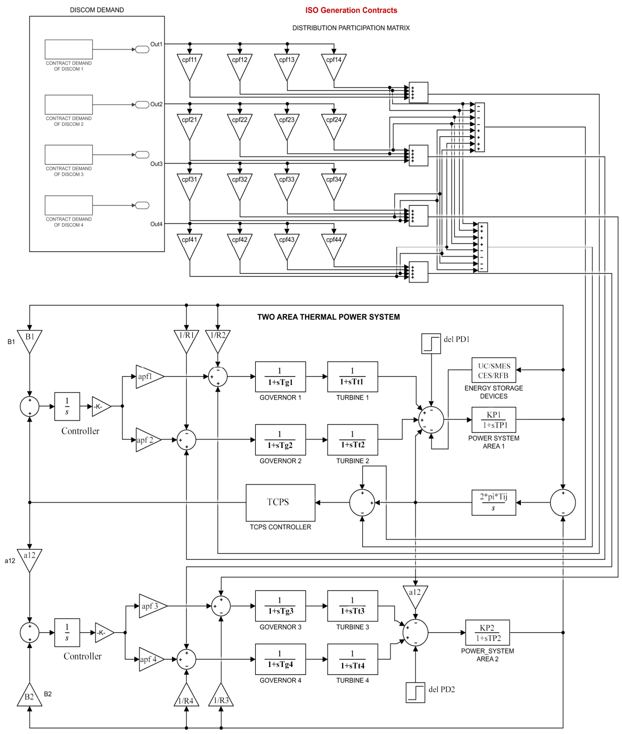


Fig 3 : Block diagram of the proposed deregulated two area power system

In figure 3, R1, R2, R3, and R4 are the primary regulation parameters of the units in area 1, and 2 respectively in p.u. Hz. B1, B2 are the frequency bias constants of area 1 and 2, respectively in p.u. MW/Hz.

3. TCPS CONTROLLER

A Thyristor-controlled phase shifter (TCPS) is a device that modifies both the magnitude and phase angle of the System by injecting a variable series voltage to affect the power flow. TCPS modulates active power transmission in the power system [10]. TCPS is connected in between two control areas in series with the tie-line, as shown in figure 4 below. Near to the area-1 the TCPS controller is placed and the Tie line resistance is neglected [12].

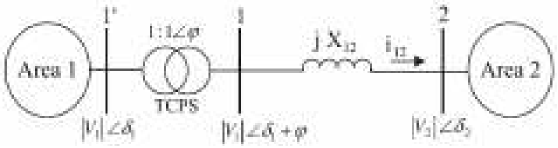


Fig 4: A schematic of TCPS in series with tie-line

©2012-19 International Journal of Information Technology and Electrical Engineering

The phase angle is changed by the TCPS in between the system voltages [9-11].

$$\Delta\emptyset(s) = \frac{K_{TCPS}}{1 + sT_{TCPS}} \, .\Delta f_1(s) \qquad \text{………(1)}$$

Where K_{TCPS} is the gain and T_{TCPS} is the time constant of TCPS controller. The interconnected tie-line power flow from area 1 to area 2 without TCPS expressed as:

$$\Delta Ptie_{12}(s) = \frac{2\pi T_{12}}{s}\left[\Delta f_1(s) - \Delta f_2(s)\right] + T_{12}\frac{K_{TCPS}}{1 + sT_{TCPS}}\Delta f_1(s) \qquad \text{……(2)}$$

The TCPS controller provides efficient damping of low-frequency oscillations and improves the voltage profile of the System significantly under severe disturbances.

4. ENERGY STORAGE DEVICES

4.1. Ultra-capacitor (UC)

Super-capacitor or ultra-capacitor is an energy storage device. Unlike Batteries, this is a passive electronic component that physically separates the charges and stores energy. Super-capacitor or ultra-capacitor provides significant storage capacity and high power density [13, 14]. The energy stored near the carbon electrode surface and stores in the double layer as shown in figure 5.

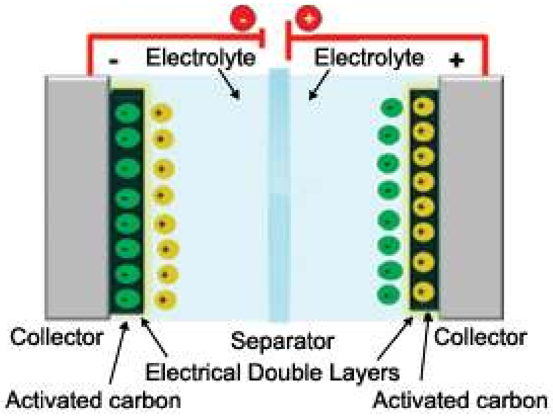


Fig 5: Electric Double Layer Capacitor

So these are also in the category of double-layer capacitors. Neglecting all the non-linearities, its transfer function is given in below equation 3

$$G_{UC} = \frac{K_{UC}}{1+sT_{UC}} \qquad \text{………..………. (3)}$$

4.2. Capacitive energy storage (CES)

The capacitive energy storage system is preferable when compared to the energy systems like Flywheel Energy System (FES) because of its characteristic behavior which respond quickly to the changes in power. CES has a power conversion system (PCS) and storage capacitors. The rectifier or the inverter unit is included in the power conversion system which helps the capacitors in connecting with the alternating current grid.

In regular operation of the power system the capacitor charged form the grid to a voltage of set value. This value is below the complete charge level. During charging and discharging, gate turn-off Thyristor helps in reversing the switch arrangement and helps in changing the direction of current through a capacitor. During the disturbances in the power system to sudden power demand the capacitive energy storage system acts as a spinning reserve, So that the system regains its stability [10]. Its transfer function is given in equation 4.

$$G_{CES} = \frac{K_{CES}}{1+sT_{CES}} \qquad \text{……………………. (4)}$$

4.3. Superconducting magnetic energy storage (SMES)

Superconducting magnetic energy storage systems first proposed as energy storage technology for power systems. Their response is fast, and operating efficiency is high.

When compared to other ES technologies, superconducting magnetic energy storage systems are expensive. Integrating with the FACTS devices decreases the largest share in cost by eliminating the inverter unit.

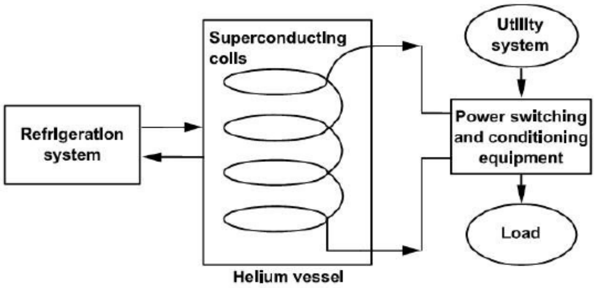


Fig 6: Block Diagram of SMES

SMES consists of an inductor-converter unit, a dc superconducting inductor, an AC/DC converter, and a step-down transformer. As all parts of SMES are static, its stability is much more superior to other energy storage devices. The charged superconducting coil conducts current and is immersed in liquid helium to maintain a shallow temperature. When there is a quick rise in load demand, the stored energy is rapidly released to the grid as ac power via a PCS. The coil charges back to its primary value of current as control mechanisms start working on setting the power system to the new equilibrium condition [19]. The transfer function is given in below equation 5.

$$G_{SMES} = \frac{K_{SMES}}{1+sT_{SMES}} \qquad \text{……..…….…… (5)}$$

©2012-19 International Journal of Information Technology and Electrical Engineering

4.4. Redox flow battery (RFB)

The Redox Flow Batteries are different from conventional power storage batteries as they are suitable for high capacity systems. In the electrolyte the reaction occurs only in the valence of vanadium ion so the service of the battery lasts longer than the other batteries because of using a solid active substance like electro depositions. The RFB units suppress the load frequency control problem and the power quality problems. These RFB units are well established to absorb power fluctuations which affect the generation control and improves the power quality [20, 21]. The transfer function is represented in below equation 6.

$$G_{RFB} = \frac{K_{RFB}}{1+sT_{RFB}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

5. SIMULATION RESULTS AND ANALYSIS

The simulations are carried out on an Intel, Core i-3 CPU of 2.5 GHz, 4 GB, 64-bit processor computer in the MATLAB (R2018b) environment. The model of the system under study shown in Fig.3 is developed in MATLAB/SIMULINK environment. The data used for the system is shown in tables 1 and 2 below.

Table 1: GENCOs data from area 1 and area 2 of the proposed system

GENCOs Data	Area 1		Area 2	
	GENCO 1	GENCO 2	GENCO 1	GENCO 2
Tt(s)	0.3	0.3	0.3	0.3
Tg(s)	0.08	0.08	0.08	0.08
R (Hz/pu)	2.4	2.4	2.4	2.4

Table 2 : Control Parameters of area 1 and area 2 of the proposed system

Control area parameters	Area 1	Area 2
Kp (Hz/pu)	120	120
Tp(s)	20	20
B (Hz/pu)	0.425	0.425
T12 (Hz/pu)	0.545	0.545

In this paper the two-area deregulated thermal power system is considered and the FACTS device, the TCPS is used in between the two control areas in series with the tie-line improves the power transfer between the control areas. TCPS in coordination with the various EDS which diminishes the frequency fluctuations in the power system according to their storage and discharge capacities. The best combination of the EDS with the TCPS is evaluated with the help of simulating the two-area power system in which the energy storage devices are placed in control area 1 and the case study is observed in the PoolCo transaction and Bilateral transaction of deregulation contract scenarios.

The comparison results are observed in both the scenarios with UC, CES, SMES and RFB energy storage devices when coordinated with the TCPS controller.

Case I: PoolCo Scenario

In this deregulation scenario, DISCOM has no contracts with GENCOs form other areas. So it is assumed that the load disturbance occurs only in the area1. The GENCOs will have equal participation in AGC. The Area Control Error (ACE) participation factors mentioned below.

apf1=0.5, apf2=1-apf1= 0.5,
apf3= 0.5, apf4=1-apf3=0.5.

Here DISCO1 and DISCO2 are the only DISCOMs that demand power. Let the load demand is 0.1 p.u MW for each of them. The corresponding Distribution Participation Matrix is as shown in below table 3.

Table 3: DPM during PoolCo scenario

Distribution Participation Matrix - PoolCo Scenario				
	DISCOM 1	DISCOM 2	DISCOM 3	DISCOM 4
GENCO 1	0.5	0.5	0	0
GENCO 2	0.5	0.5	0	0
GENCO 3	0	0	0	0
GENCO 4	0	0	0	0

So there is no demand of power from DISCOM3 and DISCOM4 from any GENCOs, and the area participation factors (3 and 4 columns) becomes zero. The total demand of DISCOs as:

$\Delta PM1 = 0.5(0.1) + 0.5(0.1) = 0.1$ pu MW
$\Delta PM2 = 0.5(0.1) + 0.5(0.1) = 0.1$ pu MW
$\Delta PM3 = 0(0.1) + 0(0.1) + 0(0.1) + 0(0.1) = 0$ pu MW
$\Delta PM4 = 0(0.1) + 0(0.1) + 0(0.1) + 0(0.1) = 0$ pu MW

Here generation of GENCO4 and GENCO3 are not in contract by any DISCOM for power transaction.

5.1 Comparison of results during the PoolCo Scenario

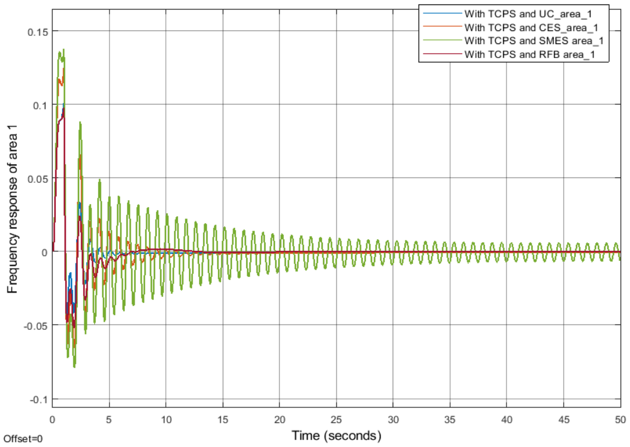


Fig 7: Comparison of frequency changes with TCPS and UC, CES, SMES, RFB in area1 in PoolCo Scenario

©2012-19 International Journal of Information Technology and Electrical Engineering

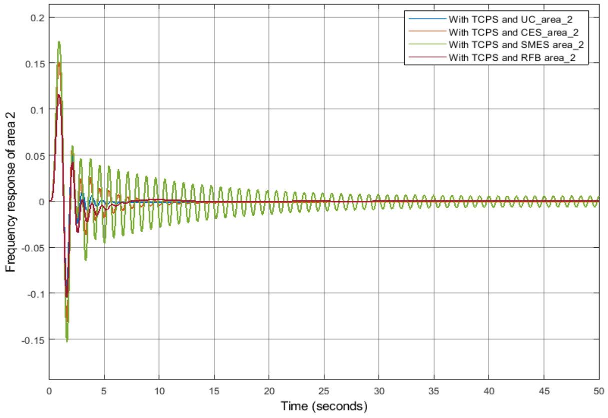


Fig 8: Comparison of frequency changes with TCPS and UC, CES, SMES, RFB in area2 in PoolCo Scenario

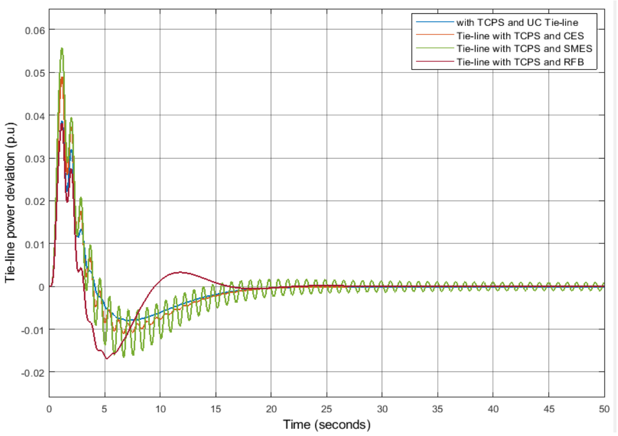


Fig 9: Comparison of Tie line power with TCPS and UC, CES, SMES, RFB in PoolCo Scenario

Case II: Bilateral Scenario

In this deregulation scenario, DISCOMs have the liberty to contract with any GENCOs within or with other areas. DISCOM participation matrix of bilateral contracts between the Area1 & Area2 mentioned below table 4.

Table 4: DPM during Bilateral Scenario

Distribution Participation Matrix Bilateral Scenario				
	DISCOM 1	DISCOM 2	DISCOM 3	DISCOM 4
GENCO 1	0.5	0.25	0	0.3
GENCO 2	0.2	0.25	0	0
GENCO 3	0	0.25	1	0.7
GENCO 4	0.3	0.25	0	0

DISCOMs in each area demand 0.1 pu MW power from GENCOs in their own area and other areas too. Contract participation factors in DPM and the participation of each GENCO in automatic generation control given by area participation factors below

apf1 = 0.75, apf2 = 1-apf1 = 0.25,
apf3 = 0.50, apf4 = 1-apf3 = 0.50,

$$\Delta P_{tie1-2,scheduled} = \sum_{i=1}^{2}\sum_{j=3}^{4} cpf_{ij}\Delta P_{L_j} - \sum_{i=3}^{4}\sum_{j=1}^{2} cpf_{ij}\Delta P_{L_j}$$
$$= -0.05\text{pu MW}$$
$$\Delta P_{tie2-1,scheduled} = 0.05 \text{ pu MW} \qquad \text{........ (7)}$$

In the steady state condition the GENCO's must generate
ΔPM1 = (0.1)0.5 + (0.1)0.25 + 0.3 (0.1) = 0.105 pu MW
ΔPM2 = 0.2(0.1) + 0.25(0.1) + 0 + 0 = 0.045 pu MW
ΔPM3 = 0 + 0.25(0.1) + 1(0.1) + 0.7(0.1) = 0.195 pu MW
ΔPM4 = 0.3(0.1) + 0.25(0.1) + 0 + 0 = 0.055 pu MW

5.2 Comparison of results in Bilateral Scenario

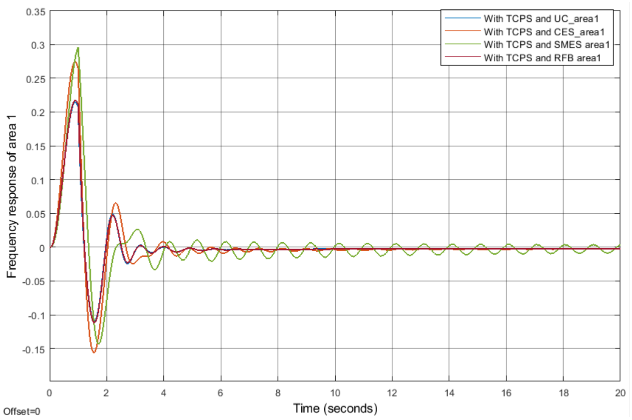


Fig 10: Comparison of frequency changes with TCPS and UC, CES, SMES, RFB in area1 in Bilateral Scenario

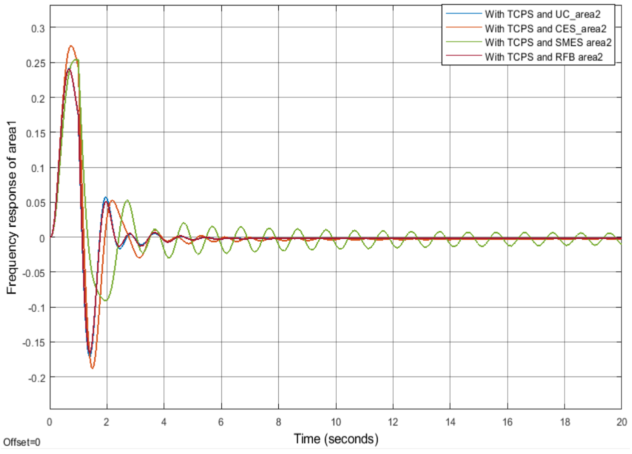


Fig 11: Comparison of frequency changes with TCPS and UC, CES, SMES, RFB in area2 in Bilateral Scenario

©2012-19 International Journal of Information Technology and Electrical Engineering

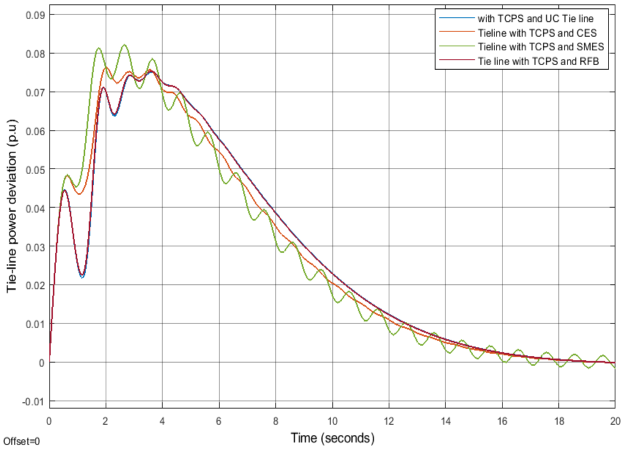


Fig 12: Comparison of Tie line power with TCPS and UC, CES, SMES, RFB in Bilateral Scenario

The responses of the two-area interconnected deregulated power system have studied in detail. Fig 7,8 9 shows the tie-line power deviations and dynamic responses for frequency in the PoolCo scenario and Fig 10,11,12 shows the tie-line power deviations and dynamic responses for frequency in the Bilateral scenario.

The power system is tested with the TCPS in coordination with the ES devices. From the observation in Table 5, the frequency deviation of area1 has peak overshoots 0.099 with UC, 0.122s with CES, 0.135s with SMES and 0.1s with RFB. Similarly when the comparisons made for the undershoot, the UC and RFB gave the less undershoots.

During the Bilateral scenario as all the GENCOs share the contracts the load demand of each DISCOM is taken as 0.01 p.u in both the control areas. The frequency deviations are having a minimum peak overshoot of 0.215 seconds and minimum undershoot of 0.1 seconds and the settling time of both the areas is at less than 7seconds for both UC and RFB.

Table 5: Comparison of results observed from TCPS in coordination with UC, CES, SMES, and RFB.

Over shoot	Bilateral Scenario			PoolCo Scenario		
	ΔF1	ΔF2	ΔPTie	ΔF1	ΔF2	ΔPTie
UC	0.215	0.241	0.075	0.099	0.115	0.03
CES	0.274	0.274	0.076	0.122	0.15	0.049
SMES	0.313	0.261	0.176	0.135	0.173	0.056
RFB	0.217	0.241	0.075	0.1	0.116	0.03
Undershoot	ΔF1	ΔF2	ΔPTie	ΔF1	ΔF2	ΔPTie
UC	-0.43	-0.188	0	-0.041	-0.095	-0.08
CES	-0.156	-0.17	0	-0.065	-0.131	-0.11
SMES	-0.191	-0.299	0	-0.079	-0.152	-0.017
RFB	-0.111	-0.166	0	-0.042	-0.096	-0.08
Settling time	ΔF1	ΔF2	ΔPTie	ΔF1	ΔF2	ΔPTie
UC	6.8	7.2	20	8.01	7.15	20.19
CES	14	10	20.8	15.15	13.3	20.89
SMES	10.5	11.9	25.6	24.26	21.9	21.93
RFB	7.1	7.7	20.26	9.16	8.1	20.28

The overall performance of the power system with TCPS in series with the tie line coordinated with the various ES devices is efficient with the UC and with the better results next to UC is RFB in both the scenarios with best settling times less than 8 seconds for frequency and it is less than 25 seconds for the tie-line power deviation in between the two control areas of the deregulated two area power system.

6. CONCLUSIONS

This paper analyses the two-area deregulated thermal power system behavior in frequency regulation using the FACTS device coordinated with various energy storage in PoolCo and Bilateral transaction deregulated environment scenarios. The settling time and peak deviations of tie-line power and frequency are better with TCPS in coordination with UC when compared with other energy storage devices. However, RFB is also giving better results after UC in improving transient stability. Hence, along with the basic frequency regulation, the application of TCPS with coordinated UC expected to be implemented as the Ancillary service for stabilizing the transients in the power system in a deregulated environment.

7. APPENDIX

a) Tcps Controller

Ttcps = 0.1s, Ktcps = 1.5 rad/Hz.

b) Energy Storage Devices

Ku = 0.7 Hz/pu, Tu = 0.01s;	Ultra Capacitor
Kr = 0.6787 Hz/pu, Tr = 1s;	Redox Flow Battery
Ks = 0.12 Hz/pu, Ts = 0.03s;	SMES
Kc = 0.3Hz/pu, Tc = 0.0352s;	CES

c) Power Plant

F = 50Hz, R = 2.4, B = 0.425, T12 = 0.545, Tg = 0.08s, Tt = 0.3s, a_{12} = -1s, P_{tie} = 200MW

d) Power System

KP = 120 Hz/pu, TP = 20s.

©2012-19 International Journal of Information Technology and Electrical Engineering

REFERENCES

[1] A.R.Abhaynkar , Prof. S.A.Kahparde, 'Introduction to Deregulation in Power Industry'-Lecture01

[2] Author LOI LAI LEI , Power-System-Restructuring-and-Deregulation-Trading-Performance - and-Information-Technology, Text Book

[3] Indu Maheshwari, Dr Leena G, Professor , Dr. N. S. Saxena, Ancillary Services in Indian Power System - A Review Paper

[4] Seyed Hossein Rouhania,∗, Abdolreza Sheikholeslamib, Roya Ahmadia and Hossein Hosseinic, 'Using optimal fuzzy logic controller to improve transient fluctuations in deregulated power system with random variable load', Journal of Intelligent & Fuzzy Systems 27 (2014) 3145–3157

[5] S, S., K.R, S., & Y, B. R. (2016). Fuzzy Load Frequency Controller in Deregulated Power Environment by Principal Component Analysis. International Journal of Fuzzy Logic Systems, 6(1), 13–30. https://doi.org/10.5121/ijfls.2016.6102

[6] Ibraheem, P. Kumar and D. P. Kothari, "Recent philosophies of automatic generation control strategies in power systems," in IEEE Transactions on Power Systems, Vol. 20, no. 1, pp. 346-357, Feb. 2005.

[7] H. Shayeghi, H.A. Shayanfar and A. Jalili, "Load Frequency Control Strategies: A State of-the-art Survey for the Researcher," Energy Conversion and Management, Vol. 50, pp. 344-353, 2009.

[8] C. E. Fosha and O. I. Elgerd, "The Megawatt Frequency Control Problem: A New Approach via Optimal Control Theory," IEEE transactions on Power Apparatus and Systems, Vol. PAS-89, No. 4, pp. 563-571, April 1970.

[9] Xing, Kai, and George Kusic. "Application of thyristor-controlled phase shifters to minimize real power losses and augment stability of power systems." IEEE Trans. Power Electronics, Vol. 3, no. 4, 1988.

[10] S.P. Ghoshal and R. Roy, Evolutionary Computation Based Comparative Study of TCPS and CES Control Applied to Automatic Generation Control International Conference on Power System Technology and IEEE Power India Conference (2008), pp. 1–6.

[11] Abido MA. Thyristor controlled phase shifter based stabilizer design using simulated annealing algorithm. In: Proceedings of the IEEE conference on power tech, Budapest; 1999. p. 307.

[12] X. del Toro García, P. Roncero-Sánchez, A. Parreño and V. Feliu, "Ultracapacitor-based storage: Modelling, power conversion and energy considerations," 2010 IEEE International Symposium on Industrial Electronics, Bari, pp. 2493-2498, 2010.

[13] A. Kuperman, M. Mellincovsky, C. Lerman, I. Aharon, N. Reichbach, G. Geula, and R. Nakash, "Supercapacitor sizing based on desired power and energy performance," IEEE Trans. Power Electron., Vol. 29, no. 10,pp. 5399–5405, Oct. 2014.

[14] A. Dutta and S. Prakash, "Effect of FACTS on load frequency control in deregulated environment," India Int. Conf. Power Electron. IICPE, vol. 2016-November, pp. 3–8, 2017.

[15] I. Pan and S. Das, "Fractional order fuzzy control of hybrid power system with renewable generation using chaotic PSO," ISA Trans. 62, 19–29 (2016).

[16] D. C. Das, A. K. Roy, and N. Sinha, "GA based frequency controller for solar thermal–diesel–wind hybrid energy generation/ energy storage system," Int. J. Electr. Power Energy Syst. 43(1), 262–279 (2012).

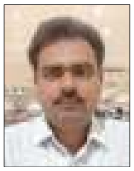
[17] N. Mendis, K. M. Muttaqi, and S. Perera, "Management of battery super capacitor hybrid energy storage and synchronous condenser for isolated operation of PMSG based variable-speed wind turbine generating systems," IEEE Trans. Smart Grid, Vol. 5, no. 2, pp. 944–953, Mar. 2014.

[18] D. Saha and L. C. Saikia, "Performance of FACTS and energy storage devices in a multi area wind-hydro-thermal system employed with SFS optimized I-PDF controller," J. Renewable Sustainable Energy 9(2), 024103 (2017).

[19] S. Padhan, R. K. Sahu, and S. Panda, "Automatic generation control with thyristor controlled series compensator including superconducting magnetic energy storage units," Ain Shams Eng. J. 5(3), 759–774 (2014).

[20] I.A. Chidambaram, B. Paramasivam, Optimized load-frequency simulation in restructured power system with redox flow batteries and interline power flow controller, Int. J. Electr. Power Energy Syst. 50 (2013) 9–24.

AUTHOR PROFILES



1. **Dr. Y. Butchi Raju** Received Ph.d In Electrical Engineering from Andhra University, Visakhapatnam Andhra Pradesh. Research area of Interest is Power System Stability, Artificial Intelligence Techniques. He is working as Professor in EEE Department, Sir C R Reddy College of Engineering, Eluru, Andhra Pradesh.

2. **Mr. Sk. Chanbasha** received the M.Tech degree in power system and automation from Sir C. R. Reddy College of Engineering, in 2015. Research area of interest is distributed generation and power system smart management. He is working as an Assistant Professor in EEE Department, Sir C R Reddy College of Engineering, Eluru, Andhra Pradesh.

3. **V. M. Achuth Varma** pursuing M.Tech in Electrical and Electronics Engineering (Power Systems Automation) from Sir C. R. Reddy College of Engineering, JNTU Kakinada, Andhra Pradesh. Research area of interest is Power System Deregulation, Internet Technologies.