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Performance Evaluation of Thermal-Hydro Hybrid system with Wind Energy Storage system

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Abstract— ***In the research work, impactness of Renewable Energy source like Wind Energy is reinforced to enhance the dynamic performance of Thermal and Hydro power plant under various operating conditions in which steam act as a major contributor for generation of electricity and rest of the generation through water. This technique is helpful in agricultural as well as islet spaces. The uneven generation of power will cause fluctuation in load followed by large disturbance in frequency of power system. To overcome this nature of fluctuations, wind energy will offer and consume instantly the true and apparent powers. The execution and it's testing are exhausted in a convenient MATLAB/Simulink condition with the application of step load and a continuing load perturbation of 1% within the system and whose results exposed that involvement of wind energy storage unit in the hybrid Thermal Hydro power system enhance transient performance of each thermal & hydro sides.***

Keywords— ***Renewable Energy storage unit, Hybrid system, Load Frequency Control***

I. INTRODUCTION

The energy which is accumulated from the natural attributes like geothermal heat, tides, wind and sunlight etc. is called Renewable Energy.[1] Unlike the traditional fossil fuels, these resources are considered as endless because these are sustainable type of sources due to which the expansion and evolution of hygienic and sustainable energy origins has increased in worldwide market.. They are stable, profitable, biodegradable and economical in providing good amount of power at lesser cost. The power system based on sustainable energy are better choice to provide energy in remote and island type locations otherwise traditional power plants will increase transmission line losses and voltage drops. This type of power system is employed in remote or grid connected mode either in hybrid or unaccompanied system. In hybrid energy system, more than one energy source is applied for distributing electricity to associated load, while remote system serve individually for same exercise without another source.

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Sometimes Thermal and Hydro energy system is unable to generate useful power throughout the year because of dependence on uneven and uncertain generation rate constraints. To handle such situation, a renewable energy based hybrid system is used for generation. Thermal and Hydro plant along with Wind energy is an example of sustainable energy based hybrid power systems.

II. HYBRID POWER SYSTEM CONFIGURATION

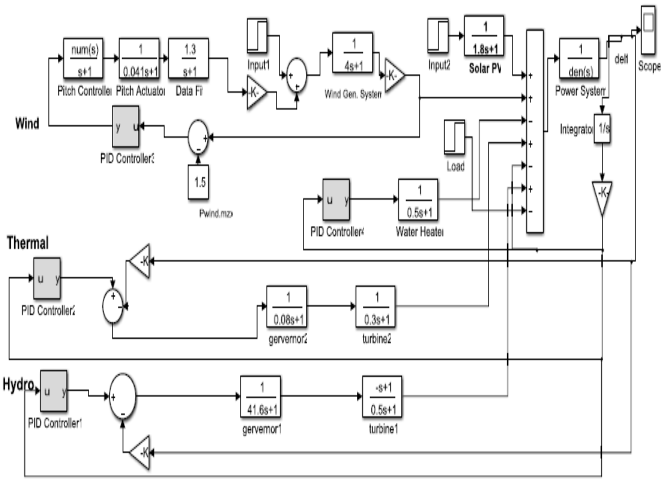


Figure 1: Block Diagram of proposed system

III. 3 WIND TURBINE GENERATOR UNIT

The wind turbine power (*Pw*) can be determined by following relation:

$$P_w = 0.5p\,(\pi R^2)\, C_P\, \pi\, V_{\omega}^{3}$$

where
ρ = Density of wind
R = length of turbine's blade
p C = power constant

This methodology of controlling the pitch is used in every economical methods to manage the WTG output as with variation in wind's direction, the blades of turbine are automatically set at the best angle. A pitch controller (K_{pitch}) are often a straight forward first order PI controller which takes output power of generator as feedback signal [13] By ignoring non-linearities, transfer function of Wind Turbine Generator are often given as [14]:

$$G_{WTG} = \frac{K_W}{1 + sT_W}$$

where Tw = time constant
and K_W = gain constant

The governable warmer is employed to utilised extra generation from Renewable Energy Sources whose transfer function of LFC model is controlled by PID controller. In this system, wherever number of generators and motors are interconnected, the variation in frequency is declined if whole moment of inertia from all rotating machines is high. It may be related by:

$$\frac{1}{2H}(P_g - P_l) = \frac{d\Delta f}{dt}$$

where H is effective moment of inertia [12].

IV. BINARY MOTH FLAME OPTIMIZATION

Moth-Flame Optimizer is recently proposed meta-heuristics search algorithm [30], which is encouraged by direction-finding nature of moth and their converges towards light. Albeit, moths are having a strong ability to maintain a fixed angle w.r.t the moon and possess an adequate structure for wandering in a straight line for lengthy spans. Moreover, they are ensnared in a deadly/idle spiral path over imitation source of lights. In conventional moth flame optimizer, the logarithmic spiral path of the moths are controlled by equation

$$D_i = \left|F_j - M_i\right|$$

In proposed research, to improve performance of optimizer around deadly corkscrew path around imitation source of lights, for discrete optimization problems, two binary variants has been implemented. In the first binary variant of MFO (i.e. BMFO1), the probability of selection of binary numbers are based on flipping of coin. In the second variant (i.e. BMFO2), the modified Sigmoid Transformation is used, whose mathematical formulation is presented in the subsequent section

V. RESULT AND DISCUSSION

This subsection presents the performance of proposed BMFO algorithm for studied deregulated power system. The algorithm code runs 50 times at 300 iterations to get the optimal gain of the PI controllers as displayed in Figure 1. The convergence characteristics of BMFO algorithm show that the objective function converges to final optimum value approximately after 50 numbers of iterations in the proposed system. But, the 300 number of iteration and 50 runs are taken as to obtain fair and reliable results. The statistical data in lieu of best, average, worst, Standard deviation & median values after 300 iterations and 50 trials of proposed power system is represented in Table 1. The optimal gain values of controller's specifications for Hybrid power system is presented in Table 2. These optimal specifications are utilized to review the dynamic performances of expected power system under different contract schemes of deregulated power system.

Table-1: Performance of various algorithmin the proposed system

Parameter	No. of Trials	Best	Average	Worst	Standard Deviation
PSO	50	0.02783	0.03607	0.05076	0.008346
MFO	50	0.02807	0.04637	0.050718	0.006482
BMFO1	50	0.02706	0.0282	0.032195	0.000826
BMFO2	**50**	**0.02755**	**0.02804**	**0.028102**	**0.000103**

Table-2: Optimal gain value of PI controller with various algorithm

Controller type	Controller parameters			
	Area-1		Area-2	
	K_1^{p}	$K_1^{Int.}$	K_2^{p}	$K_2^{Int.}$
PSO	0.430065	-7.02E-06	0.185158	-0.72609
MFO	0.423331	-0.60889	0.214237	-0.99806
BMFO1	0.431264	-0.0002	0.184349	9.71E-06
BMFO2	0.450248	-9.06E-07	0.185454	-1.90E-06

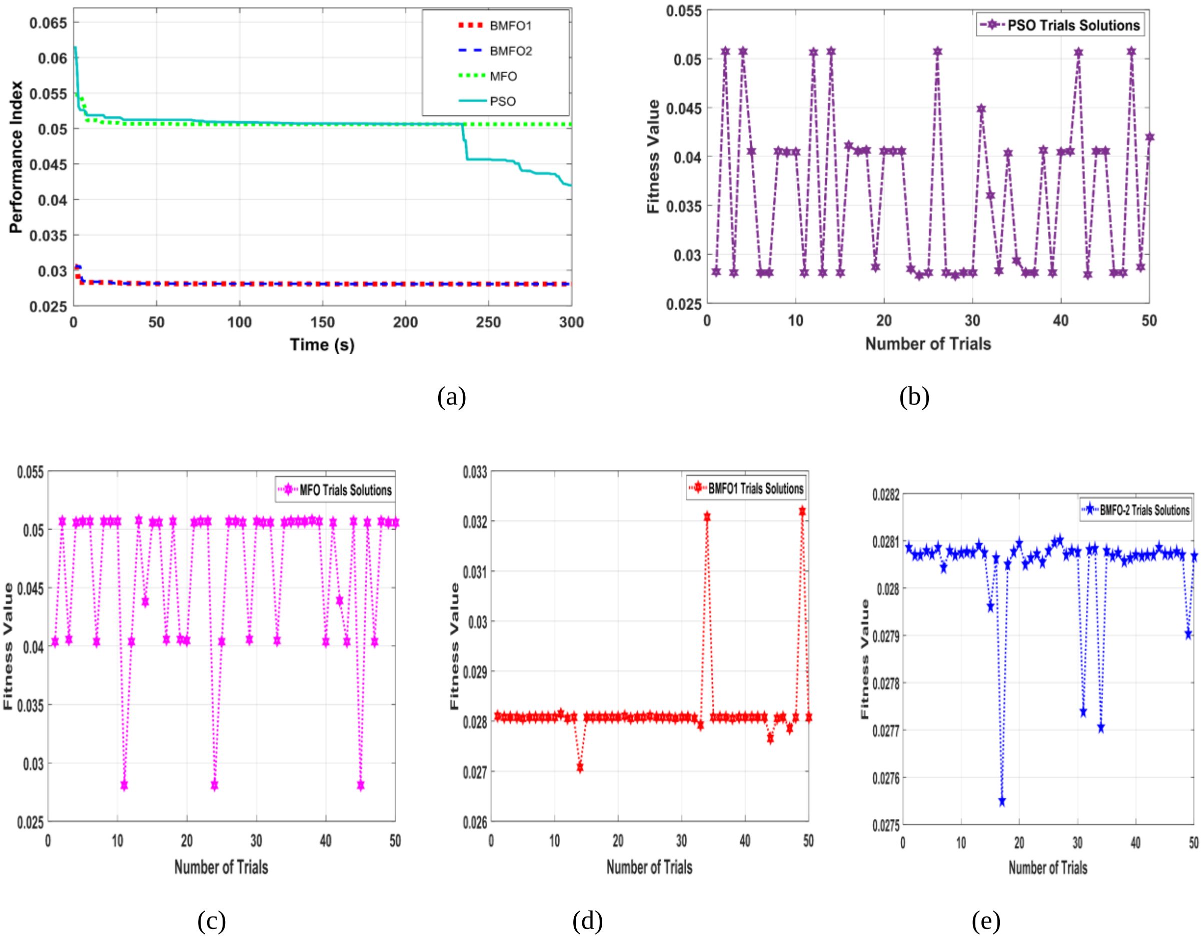


Figure 2: Graphical presentation of performance index wrt number of trials

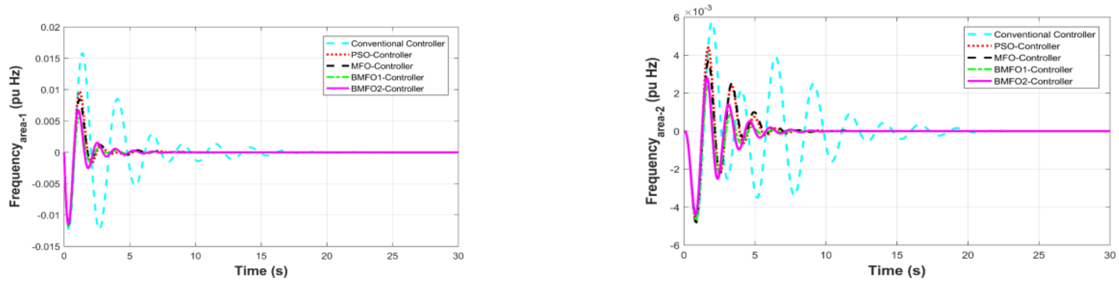
The modeling of the various components and simulations of the proposed power system has been performed with MATLAB R2013a software in Simulink situation. The optimal gain of PI controller are attained with the help of BMFO algorithm. The time domain simulations have been accomplished to investigate performance of structure under possible contract scenarios of competitive electricity market. The relevant data used in studied power system have been given in Ref. [8]. The developed model is simulated for a load fluctuation of 0.01 pu in each area. Various case studies conducted are as follows:

a. *Unilateral transaction*

As per the assumed scenario of deregulated electricity market, every GENCO can involve uniformly in LFC and DISCO can make contract with their own GENCOs area, i.e. the apfs are apf_{11}=0.5 and apf_{12}=0.5 or it will be $apf_{11}+apf_{12}$=1 for area 1. Furthermore, apf_{21} and apf_{22}=0.5 are the apfs in area 2 so that $apf_{21}+apf_{22}$=1.0. The DPM which describe the contract among the GENCOs and DISCOs for unilateral scenario can be described as shown below:

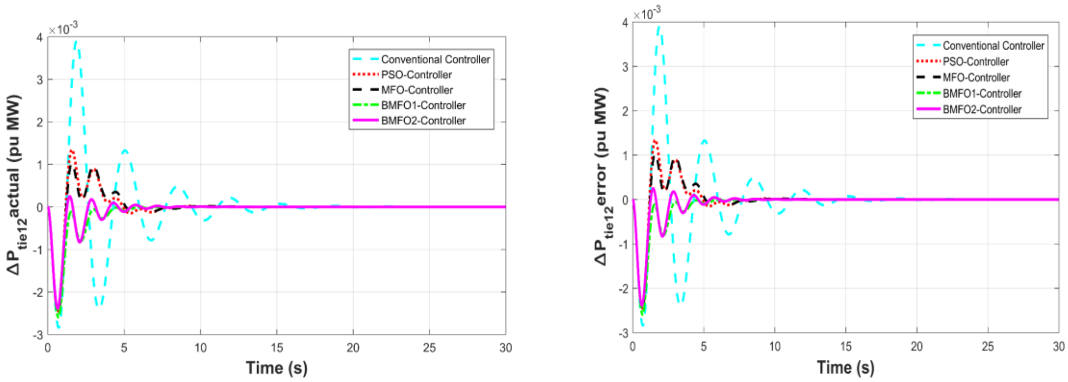
$$DPM = \begin{bmatrix} 0.5 & 0.5 & 0 & 0 \\ 0.5 & 0.5 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

The simulations have been performed to check the expected response of power system in terms of area frequency, power flow among interconnected areas, and the response of generating unit's during a sudden load change condition with respect to the assumed contracts of the deregulated electricity market as displayed in Figure 3-5.



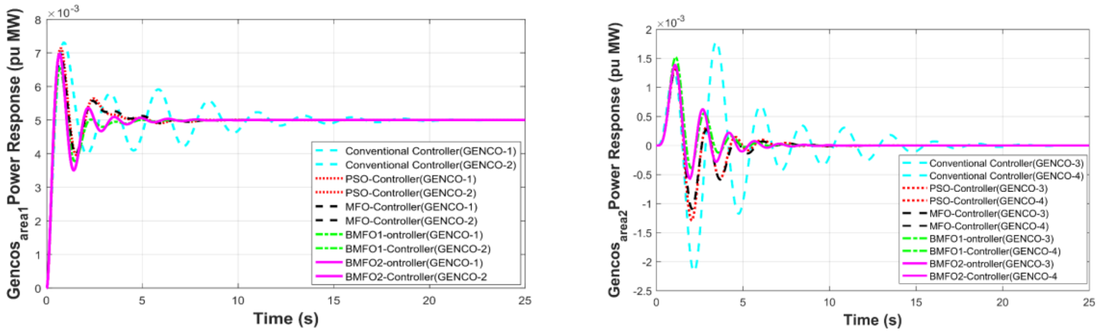
(a) (b)

Figure 3: Dynamic response of area frequency with various controller under poolco based contract



(a) (b)

Figure 4: Deviation in substantial tie-line power flow with various controller under poolco based contract



(a) (b)

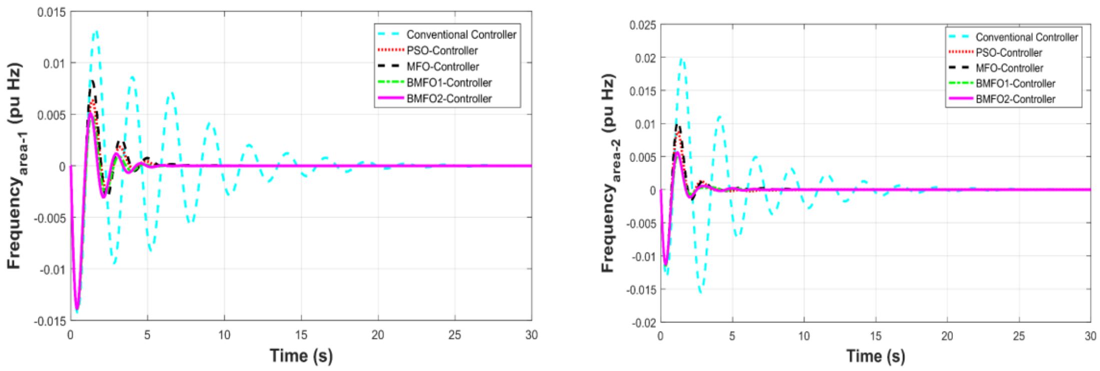
Figure 5: Both areas GENCOs generation response with various controller under poolco based contract case

b. *Bilateral based transaction*

The bilateral transaction scenario represents the two-sided, mutual exchange of contracted power between a DISCO and a GENCO. According to this scenario, GENCOs and DISCOs stand entirely by the terms of the predefined contract and make their power transaction from any area to fulfil the load demand for reliable power system operation[31]. The DPM represents the bilateral contract for every DISCO and GENCO for this case study, which can be displayed as shown below:

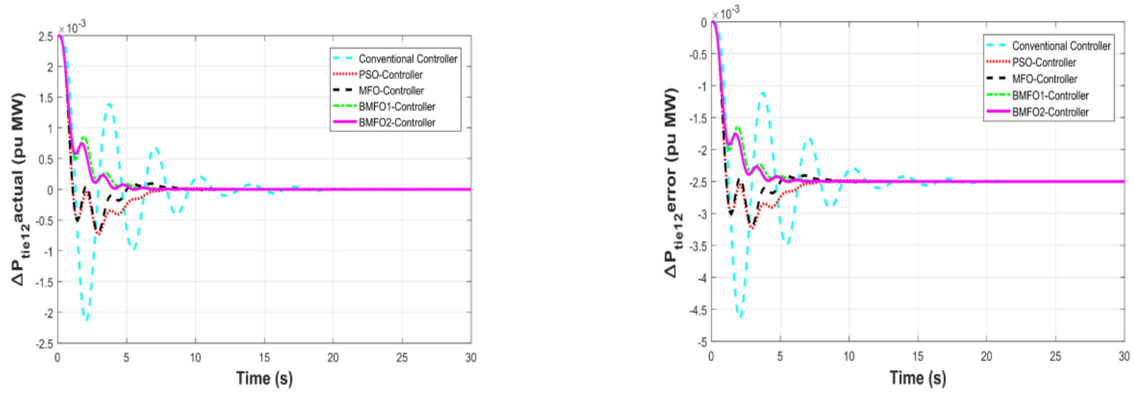
$$DPM = \begin{bmatrix} 0.5 & 0.25 & 0 & 0.3 \\ 0.2 & 0.25 & 0 & 0 \\ 0 & 0.25 & 1 & 0.7 \\ 0.3 & 0.25 & 0 & 0 \end{bmatrix}$$

According to the bilateral transaction, the contracted power requirement of every DISCO is 0.005 pu, which results a load demand of 0.01 pu in both areas respectively. Every GENCO engaged in LFC is described as apfs: apf_{11} =0.750, apf_{12} = 0.250, apf_{21} = 0.50 and apf_{22} = 0.50. The various dynamic response with and without optimal controller is represented in Figures 6-8.



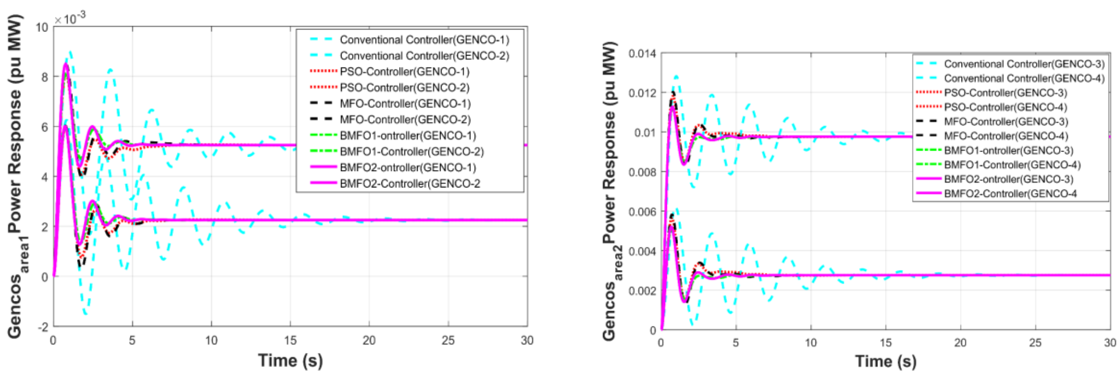
(a) (b)

Figure 6: Dynamic response of area frequency with various controller under bilateral based contract



(a) (b)

Figure 7: Deviation in substantial tie-line power flow with various controller under bilateral based contract



(a) (b)

Figure 8. Both areas Gencos generation response with various controller under bilateral contract case

c. Contract violation case

Consider 2nd case again with an alternations that DISCO requests 0.003 pu MW of extra power according to contract-violation case. The power requirement in the area-2 remains equal, because the additional power is requested by only area-1DISCOs. The entire area 1 load requirement is 0.015pu MegaWatt because of excess demand by DISCOs. The various dynamic responses with and without optimal controller in two areas and the tie line are presented in Figure 9 to Figure 11.

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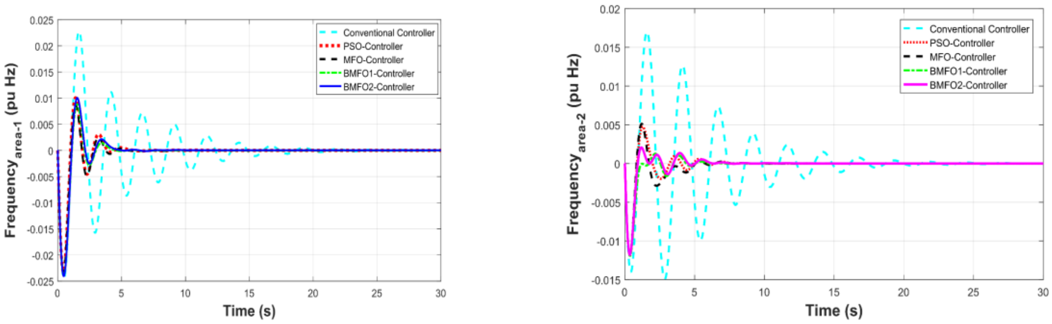
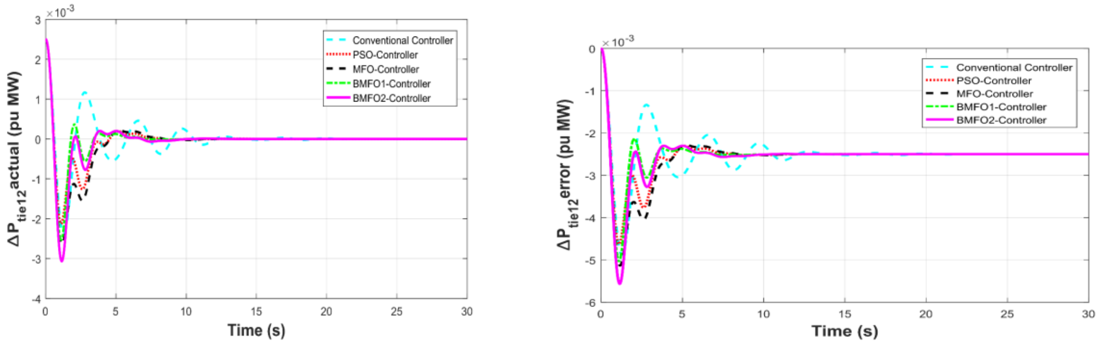


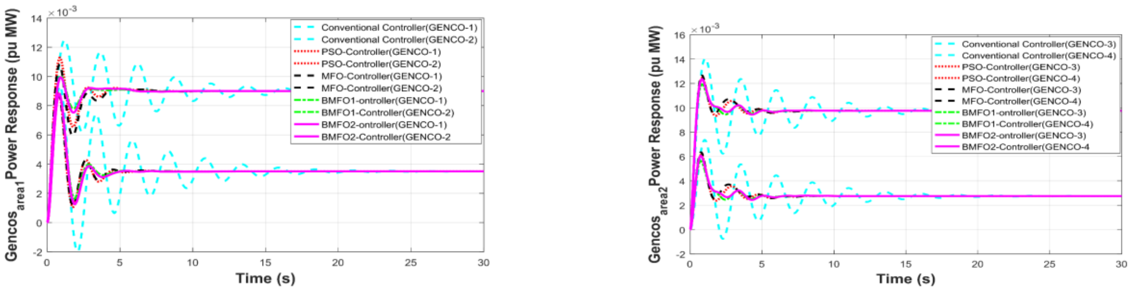
(a) (b)

Figure 9: Dynamic response of area frequency under contract violation



(a) (b)

Figure 10: Deviation in substantial tie power flow with various controller under contact violation



(a) (b)

Figure 11: Both areas Gencos generation response with various controller under contract violation

The obtained results reveal that the system with BMFO based PI controller has a consistent frequency response with minimum oscillations in corelation to the conventional, PSO and MFO-based PI controllers. The optimally tuned BMFO based controller provides better frequency dynamics in the course of smaller oscillations and reduced settling time more quickly and enhances the dynamic performance by swiftly settling the oscillation and overshoot. Hence, it can be determined that the system with BMFO based controller attains better frequency response that leads to faster system frequency recovery in expected system under deregulated electricity scenario.

According to the scenario, every DISCO makes contract only with its own area GENCOs and purchase the required power to fulfill the load demand. Due to this, there is no potential requirement among both areas, which results as zero power flow among the tie-lines. But, in bilateral and contract-violation cases, the DISCOs have ability to make contracts and invest power from any GENCOs of any area. According to these scenarios, the DISCOs demand power from GENCOs to fulfill the excess load demand, which results as the power flow between interconnected areas of planned power system. The tie-line power obtained is -0.0025 pu MW as per contract scenarios and the same has been displayed in the Figure 12 (a) and Figure 15 (a). The values of the actual power flow in-between the interconnected areas obtained after simulation are exactly same as the mathematical calculated values, according to the different contract scenarios. In addition, it will be analyzed from obtained outcomes that BMFO based PI controller is superior than conventional PSO and MFO-based PI controller provides support to damp tie-line variations in interconnected power system.

Figure 10. shows power response of generators during unilateral contract scenario. The generators respond as per the predefined contract agreement in which area-1 generating units (GENCO-1, and 2), produce power to meet the load demand according their contract participation factors. The generators produce the required amount of power at the steady state as given in Figure 4 (a). However, there is no power requirement by DISCOs of area-2. Therefore, variation in generation response by all GENCOs comparable to this area is least as represented in Figure 4(b). Similarly, Figure 6 depicts response of various generating units of planned power system as per the bilateral contract scenario. According to this scenario, every DISCO can make contracts and demand power form any GENCOs. Due to this, the generating units respond according to their predetermined contract and generate required extent of power to satisfy the demand of different DISCOs, as displayed in Figure 6 (a and b).

This power generation response of different GENCOs (conventional generators) during the contract-violation case in the proposed have been presented in Fig.11 (a & b). The DISCO of area-1 demand excess of power of 0.003 pu Mega Watt by violating predefined contract agreement. This demand is fulfilled only by GENCOs of the same area to which DISCO belong. Therefore, the generating units of area-1 respond and increase their power output to fulfill the uncontracted load requirement as shown in Figure 11(a). However, no violation of contract takes place in area-2. Therefore, the generating units (GENCO-3, and 4) of area-2 will not be affected by this as represented in Figure 11(b). The excess power requirement is effectively satisfied by the generators as per the contracts agreement as displayed in the results. In entire contract scenarios of deregulated electricity market, the simulated responses of every GENCO are same as the theoretical calculated responses, as displayed in Figs. 5, 8, and11. Every generator in both areas responds according to its *apfs* and swiftly reaches new limit of generation to meet additional power requirement of DISCOs. The comparative results show that the BMFO based PI controller produces superior outcomes as correlated to system having conventional, PSO and MFO-based PI controllers. Both peak overshoot/undershoot and settling time are reduced or fluctuations are more rapidly damped in system having BMFO tuned PI controller which confirms its capability of the planned algorithm.

VI. CONCLUSION

In the proposed analysis, 2 binary variants of moth flame optimizer has been given to resolve benchmark issues and automatic generation control downside of the electrical power grid. Results of 2 variants have been proved for non-precise, extremely unnatural, non-arched engineering style & optimisation issues, that embody twenty three benchmark issues. The planned algorithm has been accustomed to examine optimum gain of PI controller with suitable error criteria. Moreover, the efficiency of BMFO algorithm tuned with PI controller is additionally correlated with standard MFO and PSO formula tuned PI controller in several contract eventualities of a deregulated power grid. The analyses disclosed that proposed BMFO algorithm offers superior kind of solutions as correlated to alternative described meta-heuristics search algorithms. In future work, the effectualness of the BMFO formula is studied for the optimum answer of the many alternative engineering issues.

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