TRANSIENT ANALYSIS OF AN INTERCONNECTED POWER SYSTEM INCORPORATING SMES ALONG WITH ELECTRIC VEHICLE UTILIZING OPTIMIZED CONTROLLER TUNING.

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ABSTRACT:

In present power scenario, the generation of electrical power has been increasing day by day, in order to meet out the power demand of the end users. The main objective of the power sector is to provide reliable power with reduced losses and external load disturbances. Load frequency controller gains importance in mitigating the frequency deviation and tie power flow variations within stipulated time. The Proposed paper deals with development of FOPID controller to improve the System Performance of Interconnected Power System Network. An attempt is made in paper wherein the performance of FOPID controller is validated using the flower pollination Algorithm along with Differential Evolution and particle Swarm optimization technique applied to a large scale power system network .To escalate the performance of proposed controller, the system is being analyzed with implementation of super conducting magnetic energy storage device (SMES) and Electrical vehicle to study the impact of ancillary controllers in load frequency control. The objective function relies on reduction ITAE applied to three area power system network.

Keywords:

Load frequency control (LFC), Fraction order proportional integral derivative controller (FOPID), Super conducting Magnetic Storage device (SMES), Flower Pollination Algorithm (FPA), Differential Evolution (DE) & Particle Swarm optimization (PSO).

Introduction:

Nowadays large scale power system comprises of generation transmission, and Distribution network enabling supply of uninterrupted power to meet out consumer needs. In practice it is necessity for power sector to provide continuous power supply even on the occurrence of any fault. If any fault encountered there is possibility for the system to undergo frequency as well Tie line power flow deviation. Various researches are emerging out to chalk out solution to maintain these deviations within specified limit. One of such theme concentrates on load frequency control for stable and secure operation of the power system network. Automatic generation control provide a balance between generation and load demand from time to time.LFC also helps to overcome the disturbances caused due to varying load demands. Proper design of controller and tuning of parameters aids reliable operation of the system. Selection of controller plays a significant role to mitigate these deviations and restore the system in stable operating point. Over the past decades, a number of controller have been proposed namely PI, PID, cascade PI-PD controller, the proposed FOPID controller provide robust performance in load frequency control compared to classical conventional controller both in equal and unequal area systems. FOPID gain importance due to fact that is able to tune two extra parameters capable of providing greater flexibility in controlling purpose and it suits research interest in various control application. The proposed FOPID controller explores its performance compared with conventional controller. The proposed paper elaborates a two area thermal system along with re-heater, interfaced with SMES and Electrical Vehicle and the objective function is concentrated in course of reduction of tie line power flow and frequency deviations.

Many researchers have developed various computational algorithms to obtain optimal solution for the problems related to LFC. The tuning of parameter for PID controllers using PSO, genetic Algorithm and Fuzzy logic controller were proposed in various literatures applicable to single area and multi area power system network. Some of the intelligent Meta heuristic Algorithm involving LFC was also applied to test system performance of the interconnected power system. In contrary to conventional controller the fractional order controller employed along with the soft computing techniques has proven remarkable results in reducing frequency deviations and tie line power flow variations. Fractional order PI controller for perturbed load frequency control for single area using kharitonov's theorem always justifies the context application of FOPID controller yield optimal solution for load frequency control. A powerful Meta heuristic population based algorithm commonly termed as flower pollination algorithm which involves the principle of survival of fittest ongoing through process of local search, random walks and global exploration provides better convergence characteristics. The application of above said algorithm involving PI-PD controllers in Multi-Area system were also reported to provide dynamic response of the controller. This is also Meta heuristic search global optimal solution.

Literature Survey:

Researchers have developed various computational algorithms to obtain optimal solution for the problems related to LFCS. The tuning parameters for PID using PSO and Genetic Algorithm and Fuzzy logic controller were proposed in various literature applications to single area and multi area power system network.

Luliu et al [1] have presented variable order fuzzy fractional PID controller and five parameter (k_p, k_i, k_d, λ and μ) are varied and the performance is compared with FOPID and OPID using mamdani interfacing involving 7 linguistic variable and 49 rules are carried and found the optimum result . However, the performance analysis for these controllers is obtained only with tuning and variations of five parameters. No external load disturbance is taken into account.

Indranil pan et al [2], have presented PID, slow FOPID and fast FOPID using chaotic NSGA-11 algorithm taking into consideration hyper volume indicator, diversity metric, parcto spread of the NSGA-11. However, controller performance analysis may be done with the help of energy storage device and the system under consideration may be extended to large scale power system.

Tyagi et al [3] In a three area system, Genco and Disco contract in proposed with Disco participation matrix. Fuzzy logic controller is used to tune PID Fuzzy with SMES and without SMES. It is evident from the results the LFC PID fuzzy with SMES has low magnitude of variation in frequency and tie line power flow.

Hesam parvaneh, shahriar moradinejed Dizah [4] have presented SOA tuning for PID controller, considering two areas. The results are compared with the GA and PSO in the reduction of ITAE. However, performance of the system incorporating energy storage devices not been evaluated.

Javard morsali et al [5] proposed FOPID along with TCSC damping controller has been considered for two area system to reduce ITSE and found best performance. However, another energy storage device along with TCSC may be implemented and analysis for system performance may be carried out.

Hassan yousef [6] proposed Hybrid power system where in the system performance for various controllers has been tested. FOPID controller tuned with chaotic maps shows better performance than PID and FUZZY PI. However performance variation for tuning of controllers alone analyzed.

Yanmei Tang et al [7] have made LADRC is taken into account and the parameter tuning obtained with hybrid PSO technique based on reduction of ITAE and performance compared with PI and Fuzzy PI controller found better optimal solution. To obtain the fast response low frequency deviation FOPID may be implemented and energy storage device may be incorporated to obtain the better performance.

Mohammed Hassan et al [8] have presented PID, FPID, BFPI and SAMBA for four area system among the proposed controllers SAMBA gives best performance. To improve the performance of Power System Network, TCSC or any other energy storage device may be concentrated for secure reliable operation.

The algorithm is being tuned with PID, Fuzzy PID and Fuzzy FOPID using Henon map argumentation by indrani pan et al [9] The analysis of system with variation of parameters in multi area power system may be considered.

Debdeep saha et al [10] highlights the Dynamic response and Boiler Dynamics in the FACTS devices and energy storage device. The effects of FACTS with different secondary controllers are taken in to account. To improve the performance, FOPID controller may be implemented for better convergence characteristics.

Swati sondhi et al [11] proposed, LFC has been introduced in system controller and optimization using integral error criterion 50% uncertainty introduced and their performance has been validated. The paper may be extended to multi area system network along with energy storage may be implemented.

The performance of cascading PI-PD controller yields better convergence considering step load perturbation. The performance analysis of index ISE forms the optimum performance by Puja Dash [12] this may extended to large area network; load disturbance and boiler dynamics may be accounted involving energy storage devices.

Puja Dash, Lalit Chandra Saikia, Nidul Sinha [13] discussion on the FOPID controller for single area has been studied and it reveals better performance with load disturbance rejections. It may be extended to multi area system along with ancillary controllers.

Swati Sondhi, Yogesh V.Hote [14] states that fractional order integral action controller found to be advantageous, while in contrary with fractional order deviation action and also reveals the FOPID controllers provides optimal solution suitable for tuning of parameters. The application of set point followed by load disturbance rejection is addresses but it is not applied for multi area consideration.

Fabrizio Padula, Antonio Visioli [15] proposes that tuning of controllers for load frequency control FOPID find better optimal solution in comparison with conventional PID controllers.

Sathish kumar Injeti [16] Two area system of PV and diesel generator considered to reduce ITAE Bat algorithm provides better convergence among the comparative study of controllers. But the changes of irradiation of PV system alone considered, the disturbance occurrence due to diesel generator system (or) prime mover mechanism are not considered. The same study may be extended to multi area network along with ancillary control.

Adaptive control strategy involving combination of general type 2 FUZZY, MHSA PI systems in considered. Battery Energy storage device instead of small batteries is employed. Load disturbance, wind power fluctuation has been considered. The performance analysis based on controller ancillary control may be used and performance comparison may be done.

In view of above discussion, the main objectives of the present work are as follows

a) Development of an unequal interconnected two area system considering Thermal with reheater unit, along with SMES, Electrical vehicle and appropriate GRC.
b) Application of DE, PSO and FPA algorithm for optimization of controller parameters of FOPID controller performance is validated against PID when considered one at a time in the system and compare the dynamic performance of the system and to determine the best among them.
c) Evaluate the performance of the energy storage devices with SMES and without SMES and electrical vehicle in the two area algorithm and determine the best among them.system with different optimization

Super Conducting Magnetic Energy Storage Principle:

Super conducting magnetic energy storage device are capable of providing compensation for surplus or deficit of real power in LFC multi area power system due to the presence of large inductor. Super conducting inductor is fed with the supply obtained from 3Ø AC system via thro ү-ү- transformer which in turn pass through 12 pulse bridge converter circuit. The inductor is capable of operating in rectifier and inversion mode accordance with variation of firing angles of the semiconductor switches present in 12 pulses bridge converter.

The output voltage of the converter is obtained as

$$V_d = 2V_{dc} \cos\alpha \quad \ldots\ldots\ldots\ldots\ldots \quad 1$$

Where,

V_d = converter output voltage

V_{dc}= open circuit voltage of converter

α = Triggering angle

The output voltage of the converter is held constant and converter output current I_d is unidirectional and constant power flow in the inductor is achieved by variation of the firing angle. The current through the inductor is obtained as

$$I_d = \frac{1}{L}\int vd.dt \quad \text{…………… 2}$$

When the current through the inductor increases, energy is stored in the inductor and this is given by

$$P_L = 1/2\ Li_d^2 \quad \text{…………… 3}$$

When P_L is the energy stored in the inductor. The SMES unit is being interfaced in the power system network enabling for LFC operation. The voltage across the converter is obtained in accordance with variation in frequency deviation f. The Interfacing of SMES unit in the proposed paper validates the fact, that the frequency deviation settles to zero and the tie line power flow is maintained within the permissible limits for stable operation of the power system network.

Electric Vehicle:

The proposed system considers an equivalent Electrical Vehicle model. The model used in this system tries to exhibit the behavior of one EV battery and used for the calculation of total power charging (or) discharging in a controllable state.

The parameters of EV area denoted as time constant (Te), LFC signal sent to the EV as μe. Moreover inverter capacity constraint ± μe and power ramp rate constraint ± δ_e.

E denotes the energy of the EV battery, maximum controllable energy of the battery as E_{max} and minimum controllable energy of the battery as E_{min}. The charging and discharging power of the battery as ΔP_E.

When $P_E = 0$, the EV is in idle condition, $\Delta P_E > 0$ means EV is in discharging condition & $\Delta P_E < 0$ denotes EV is in charging condition ± μe denotes EV's charging & discharging bounds.

Whenever, the EV energy storage exceeds its upper limit E_{max}, then it should it should be discharged in the range of (0 - μe). Similarly, if the EV energy storage is lesser than the lower limit E_{min}, then it should be charged within the range of (- μ_e ~ 0).

Proposed system:-

The prime motto of the proposed system concentrates on reduction of integral area control error and tie lie power flow deviation is to restore the system in stable operation. The proposed system consists of two thermal systems along with reheater unit. In order to elevate the performance electric vehicle along with SMES is being embedded in the system. In case of automatic generation control, load frequency control using energy storage device is gaining importance due to its advantages in damping out oscillation and mitigation undesired oscillations. Our proposed system concentrates on the performance analysis of FOPID controller with characteristic comparison of three optimization algorithm, Furthermore the system performance is validated in comparison by embedding SMES unit. The following cases are considered and the performance evaluations are carried out.

i) 2 Area thermal systems with reheater without SMES.
ii) 2 Area thermal systems, with reheater along with SMES.
iii) 2 Area thermal systems, along with electric vehicle and without SMES.
iv) 2 Area thermal systems, interfacing electric vehicle and embedding SMES.

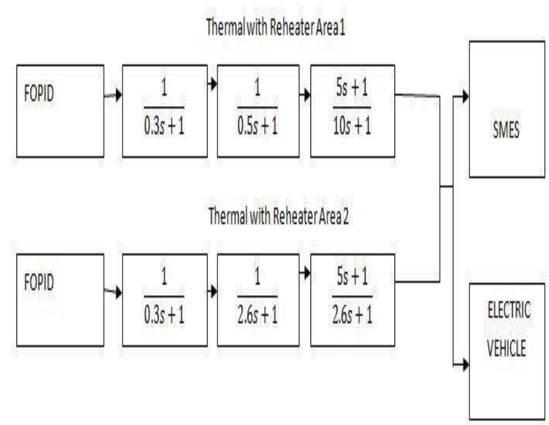

Fig. 1 Schematic Diagram of Proposed Controller

Multi area:

- In the proposed paper two thermal along with reheating system is considered.
- The appropriate generation rate constraints (GRC) of 3% /min. The nominal parameters of the AGC systems are depicted. The transfer function of two area system is shown in Fig 1.

- To study the dynamic performance of the system with FOPID controller, PID controller is replaced by the FOPID controller
- In this paper MATLAB software has been used for simulink model to obtain dynamic responses for
- Δf_i, ΔP_{gik} &

The parameters such as controller gain parameter etc are optimized using flower pollination Algorithm. This optimization is done using ITAE criterion given by

$$\int ITAE = \int_{o}^{T} \{|\Delta f_i| + |\Delta P_{tiei}|\}\, t\,dt \text{--------(4)}$$

FLOWER POLLINATION ALGORITHM:

Flower pollination Algorithm is based on the context of evolutionary behavior exhibited by the flowers in the recess of pollination. Flowers do exist as number of species in nature which involves the phenomenon of reproduction. The prime objective of FPA is the survival of the fittest and to obtain optimal fittest solution enabling for reproduction. The reproduction of flower takes places through the process of pollination which involves transfer of pollens through agents namely insects, birds, Honey bees etc. It is fortunate some of the flowers would attract specific insects or animals that aid them for successful pollination and in turn their reproduction.

Pollination can be broadly clarified into two types namely biotic and A-biotic. Among these 90% of the flowering plants are characterized under the biotic pollination due to the fact the pollination takes place through insects or other species, they are often termed as pollinator. These pollinators contribute mostly to obtain the optimal solution for the process of reproduction hence theses pollinators are known as pollen vectors.

Honey bees are found to one of the best kind of pollinator which exhibits the characteristic of flower constancy. This natural behavior aids the pollination to visit certain flowers of exclusive nature while ignoring the other species. The prime advantage of flower constancy will maximize the transfer of pollens from same or diverse flower to converge at optimum reproduction. This also reduces the cost of learning and exploration of search spaces.

The process of pollination falls under two categories likely self pollination and cross pollination. Cross pollination often expressed as allogamy, is defined as process where-in the pollination occurs among flowers of different species. In contrast self pollination is the process involving sharing of pollen grains of same flower or different flowers of the same plant. Cross pollination takes place for long distance since the pollinator travels long distance in transition of pollen grains from one flower to the other. These pollinator's poses levy flight behavior with characteristics of jump or fly distance which obeys the rule of levy distribution.

The FPA involves two process termed as global pollination and local pollination. Global pollination relates to the transfer of pollens through pollinator over a long distance, this in turn ensures reproduction using the most optimal fittest solution.

The process of pollination occurs both at local and global space. In certain cases the adjacent flowers are pollinated by the pollens of local flower. Hence we switch probability (or) proximately probability P to alter between global and local pollination.

Differential Evolution Algorithm:

Differential evolution is Meta heuristic optimization algorithm that optimizes a problem by iteratively trying to improve candidate solution as a measure of quality. The problem involved strategies parameters to travel through a large search space in order to obtain global optimal solution. Unlike classic optimization technique it does not involves any gradient (or) query Newton methods which nude's gradient optimization problems to be differentiable.DE optimizes a problem to converge at best fitness solution by comparison of candidate solution with the existing fitness solution.

New candidate solution through search space sums to be better than the existing one that it is accounted for next level of iterations or else if it does not meet out requirements it is simply ignored or discarded. The control parameters involved in the process are population size NP, scaling factor F and cross over fate (CR) which greatly influence the performance of DE.

Practical Swarm Optimization:

PSO is a population based heuristic algorithm depending on the movement of fish and bird flock in search of food. It was originally proposed by Doctor Kennedy and eberhart in 1995. The basic idea is the fact of migration of birds from one place to another in search of food. It is a peculiar behavior of certain birds to identify the source of food from distant location and the other birds tend to follow the bird towards the destination of food source. The replica is behavior when the optimal solution is obtained.

The algorithm relies on three variables.

1) Target value (or) condition
2) Best fitness solution indicating data close to destination.
3) Stop command to terminate iteration

Every particle should comprise of.

1) Data which is capable of providing possible solution.
2) Velocity corresponding to amount of data transfer.
3) Selection of P best fitness value when the particle data approaches close to the target.

Each solution is considered as bird, called particle. All the particles possess fitness function calculated using objective function.

The iterations are carried until optimal best fitness solution is obtained.

Simulation Results:

The Proposed controller is tested under MATLAB Environment and two Area Thermal System along with SMES and Electrical vehicle are considered. The Results has been presented as appended below,

PID		K_p	K_i	K_d	b_{fit}
DE i)	SMES	1.2006	1.1544	0.8513	0.3952
ii)	SMES EV	0.1725	1.2195	0.5614	0.3463
PSO i)	SMES	1.1167	3.1624	2.7077	0.4678
ii)	SMES EV	2.7129	3.3861	0.9149	0.1696
FP i)	SMES	4.9023	4.6901	4.1203	0.1249
ii)	SMES EV	4.9028	4.6912	4	0.1447

Fig2.Parameters of PID Controllers.

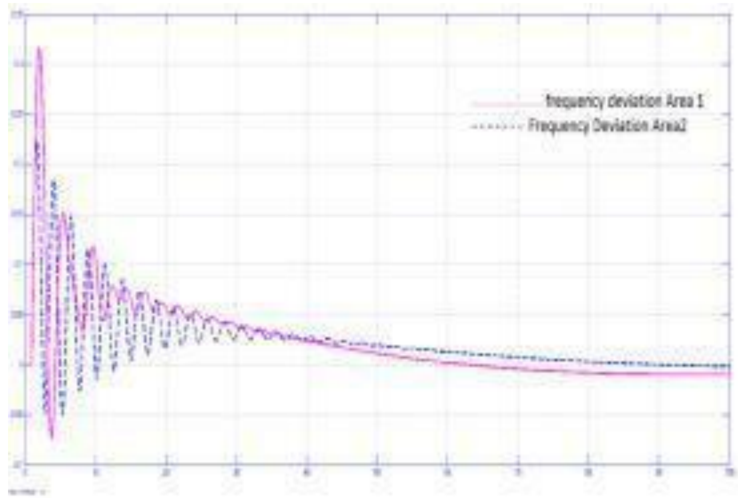

Fig. 3 depicts the frequency deviation of area1 and area2 obtained for the system with DE tuned PID controller.

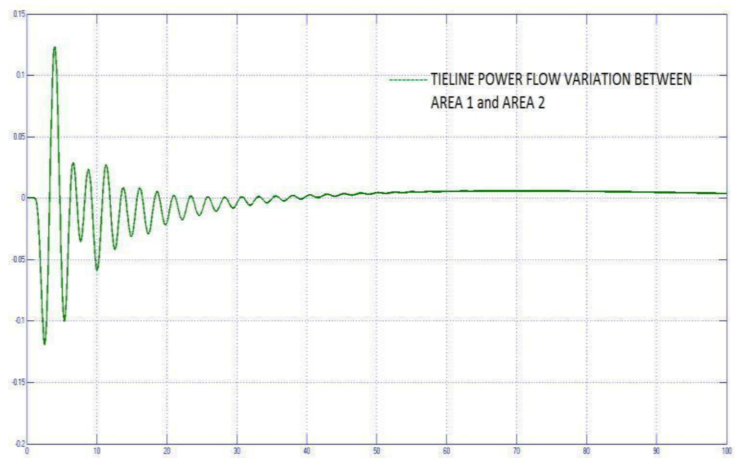

Fig .4 represents the Tie line Power flow variation between area 1 and area 2 for the same system considered with PID Tuning using DE algorithm.

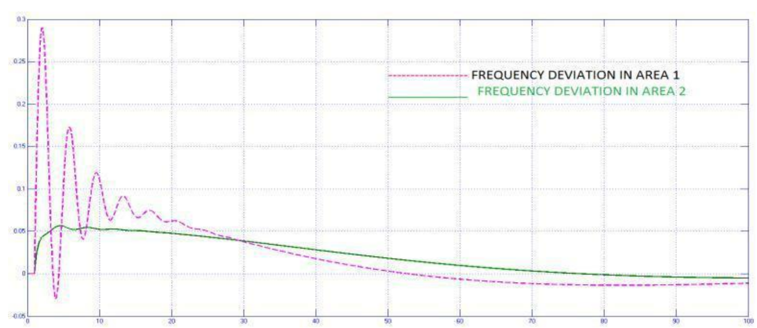

Fig. 5 illustrates the Frequency deviation of area 1 and area 2 for the Thermal system along with Electric Vehicle being considered as individual area for the system with DE Algorithm tuning.

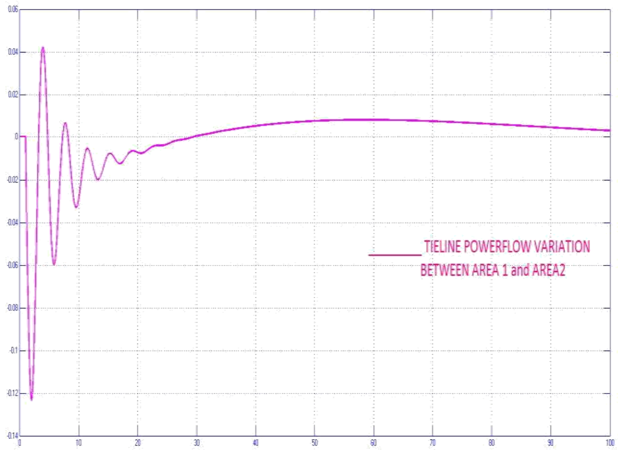

Fig .6 illustrates the Tie-line Power flow variation between area 1 and area 2 for the Thermal system with Re-heater and Electric vehicle.

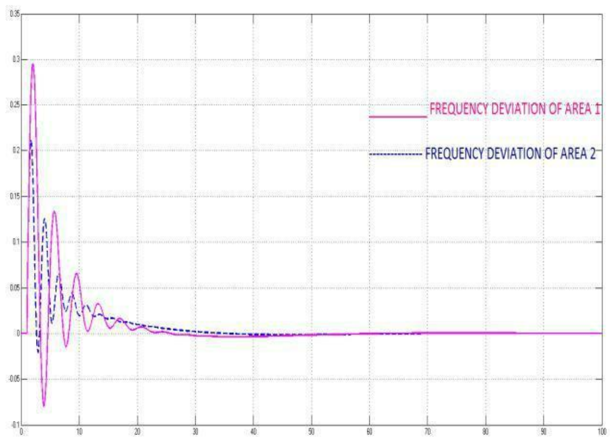

Fig. 7 depicts the frequency deviation of area 1 and area 2 for the Thermal System along with reheater and SMES. The system has been tuned with PID Controller employing Particle Swarm Optimization algorithm.

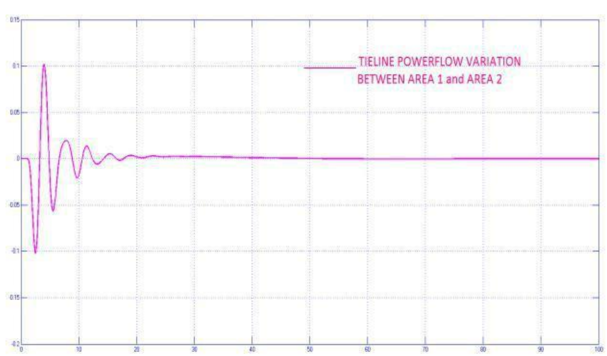

Fig. 8 depicts the Tie-line power flow variation between Area 1 and Area 2 with for the Thermal system with Re-heater and SMES using PSO algorithm.

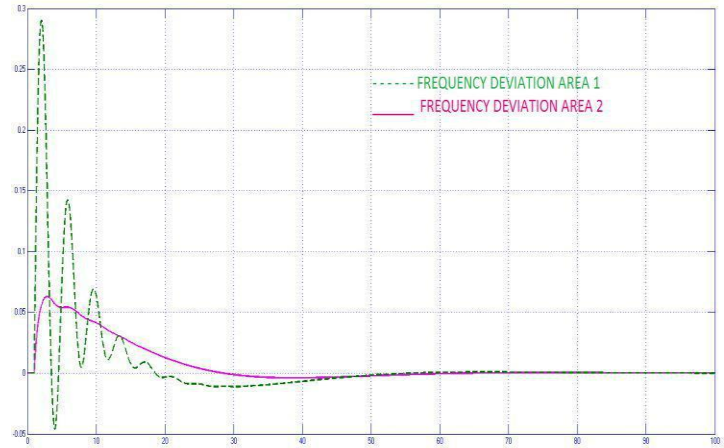

Fig. 9 depicts the Frequency deviation of area 1 and area 2 for the Thermal System with SMES and Electric Vehicle being considered as individual Area using PSO algorithm.

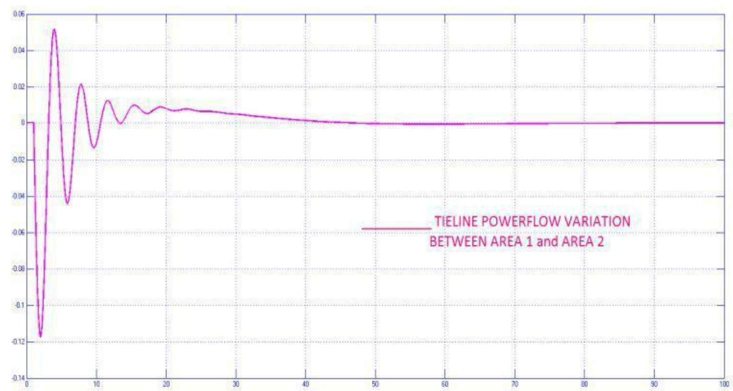

Fig. 10 represents the Tie-line power flow variation between area 1 and area 2 for PID tuning with PSO Algorithm for the Thermal System with Re-heater and Electric vehicle.

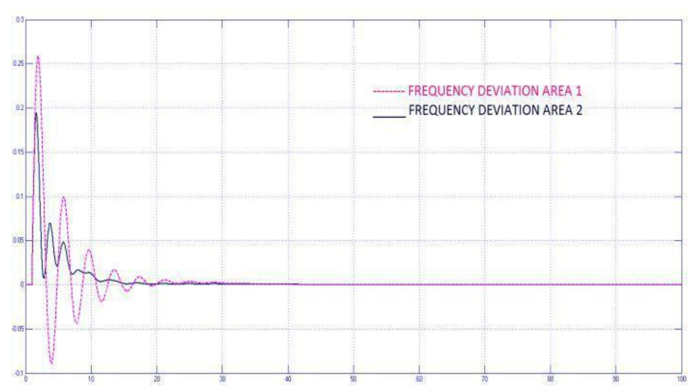

Fig.11 illustrates the frequency deviation of area 1 & area 2 for PID controller Tuned by Flower Pollination Algorithm for the thermal re-heater system with SMES.

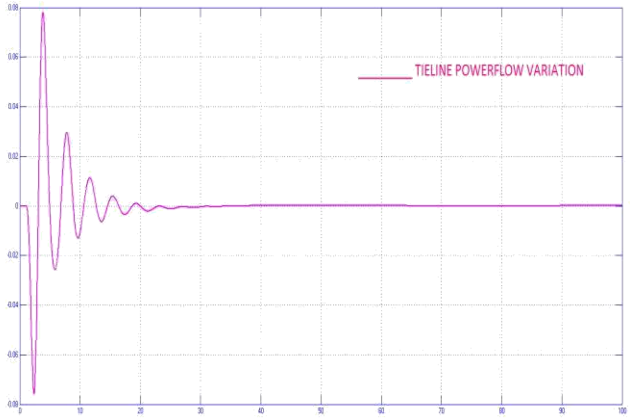

Fig 12. represents the Tie line power flow variation between area 1 and area 2 for PID controller employing Flower pollination algorithm tuning for the system with SMES.

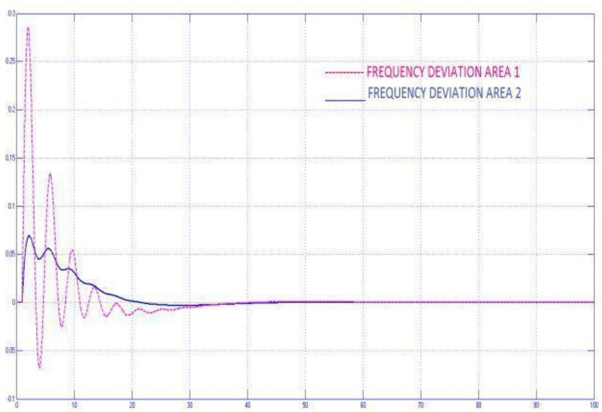

Fig. 13 represents frequency deviation of area 1 and area 2 when the PID controller tuned using Flower Pollination Algorithm for the Thermal with re-heater unit and electric vehicle.

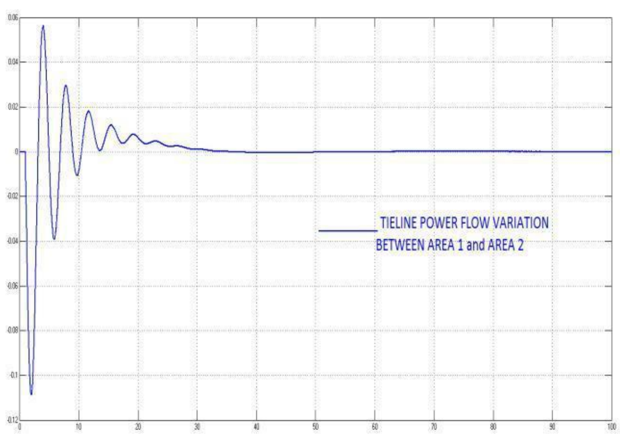

Fig .14 depicts the Tie line power flow variation between area 1 and area 2 considering the thermal System with electric vehicle.

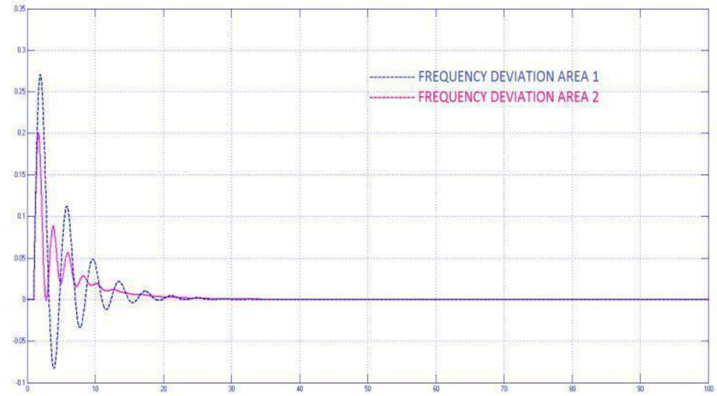

Fig. 15 depicts the frequency deviation for the Thermal system with re-heater unit with FOPID Controller utilizing Flower Pollination Algorithm for the system with SMES.

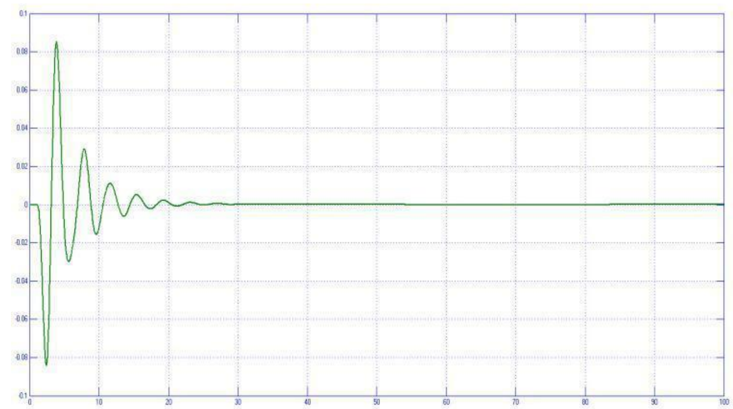

Fig. 16 depicts the Tie line power flow variation when the system with SMES having FOPID Controller tuned with FPA algorithm.

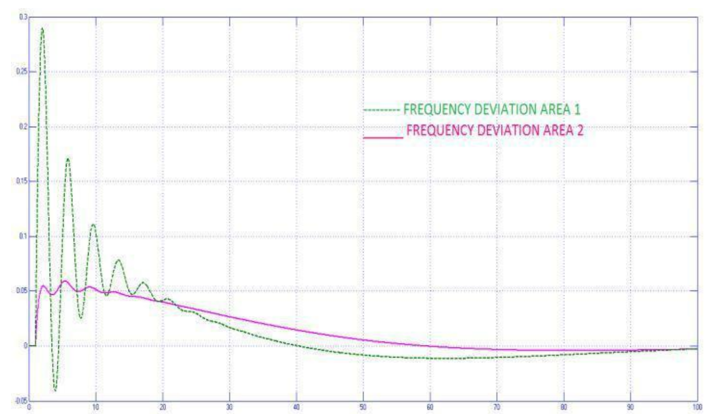

Fig .17 depicts the frequency of oscillation for the thermal system with Electric Vehicle and FOPID tuning using FPA algorithm.

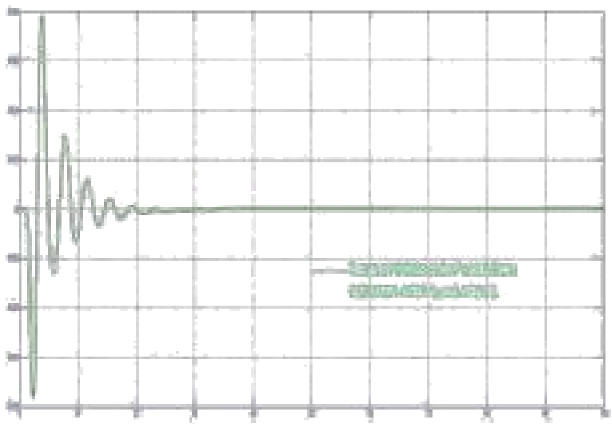

Fig .18 depicts the tieline power flow between area 1 and area 2 for FOPID Controller tuning for the system with SMES and Electric vehicle.

Conclusion:

To conclude the proposed paper the Performance Analysis of FOPID controller whose performance is being validated in opposition to Conventional PID controllers. The controller performance is chosen as Flower Pollination Algorithm which possesses optimal convergence Characteristics with reduced Frequency oscillation and tieline power flow variations. Simulations have been performed on Sequence of PID controllers with various computational algorithms. The results focuses FOPID controller accomplish better system performance compared with PID controller with shortest rising and settling time along with reduced overshoots. Future work would be concentrated on application of External load disturbances to the existing system and investigation of system performance may be accounted in further areas.

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