Optimal Control Strategy for Performance Improvement of Hybrid Power System using Grey Wolf Optimised PIID Controller

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The problems of load frequency control (LFC) using optimal controllers are discussed in this paper. Two area power systems are implemented and analysed in each region as a result of abrupt load changes. The goal is to prevent errors caused by frequency and tie- line electric supply disruptions with the aim to assure cost effective power generation. P/ PI/ PID/ PIID compensating schemes have been developed and successfully tested. The gains of P/ PI/ PID/ PIID controllers are optimised using Grey Wolf algorithm on a two area power-network. The generating Stations used in this whole operation are Wind Thermal and Solar Thermal. The performances of said controllers are compared and an optimal one is chosen. When the findings of the suggested approach are compared to those of some recently published approaches, the benefits of the proposed approach become clear. The sensitivity analysis is carried out, demonstrating the proposed approach's ability to cope with large changes in device parameters. This method is tested under a variety of load conditions.

Keywords: Load frequency control, Optimised Controller, Tie-line power, Grey Wolf Algorithm, PIID Controller.

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1 Introduction

The basic motive of electric power- network is to provide electricity to users at frequency defined by power quality standards. But usually there is imbalance between supply and demand due to load fluctuations which leads to variations in scheduled frequency. Load keeps on varying as it depends on consumer choice, so control is done at generating stations. Frequency and load has inverse relation so increase in load leads decrease in frequency and vice versa, both the situations lead to system instability. Mathematical models were earlier used as controlling techniques. However, due to difficulties in dealing with system uncertainties, these strategies proved ineffective [1]. So to avoid this instability in system primary control comes into action to keep balance between generation and demand by speed governor. However this mechanism is slow as mechanical parts get involved. Hence secondary control action as Load frequency control (LFC) is done in generating stations to make balance between load demanded and generation by adjusting generation output. This maintains the ACE (area control error) time average at low value. The basic grail of LFC is to keep the power- network in a real power balance by managing the system frequency [2]. The transitory reactions in both these primary and secondary control actions are in the seconds and minutes range [3].

The electric power systems are inter connected with each other to maintain reliability .This inter connected system is known as grid. For this multi-area power-system, which ordinarily comprise of inter- connected control area, AGC is an key feature to maintain the model frequency and the inter linked area tie-line power as near as we can to the intentional value [4]. These inter connected areas one or the other is subjected to load change, so to maintain its frequency it takes power from other areas. The tie-lines are utilities that provide inter area support in the event of an emergency and are used for contracted energy exchange across areas [5]. The area should be capable of regaining the equilibrium or there will be disturbance in that area too. Hence controller is needed in each area to avoid this problem of frequency divergence and other errors of tie- line power flow.

A review of the literature suggests that a lot of work has been done in the domain of LFC using traditional controllers like PI, PID [6]. Several scholars have discussed the work of LFC of inter-linked power houses in recent years. In an inter-meshed hydrothermal system, Nanda et al [7] have delineated system dynamic control using conventional controllers. Saika et al reported on a multi area inter linked system with a contrast of various traditional controllers [8]. For the thermal power plant, Golpira et al [9] considers generation rate constant and time delay to be practical restrictions. Parmar et al [10] recently applied an optimum controller to LFC of a realistic power system with many power generation sources. Mohanthy et al [11] investigated DE algorithm controller parameters tweaking and its application to the optimisation of I, PI and PID controllers in multi area power system. These controllers make the power system more reliable and efficient. In two-area non reheat thermal system Ali and Elazim recently published a BFOA based proportional integral controller that outperforms a GA based PI controller.

The most generally used type of load frequency controller is the standard proportional integral controller, although their efficiency degrades as the system becomes more complex due to disturbances such as load changes, boiler dynamics [14]. The traditional controllers having constant gain perform poor over varying working state due to which they posses substandard dynamics [15]. Here various controllers like P, PI, PID & PIID are used and their results are compared and an optimal one is selected. The parameters of these controllers are tuned using Grey Wolf algorithm technique. In this paper two area systems are taken into consideration with two generating stations each. The first area comprises of wind and thermal generating units and area second consists of solar and thermal generating units. The loading conditions and system characteristics are varied to perform the sensitivity analysis. Finally, the proposed technique is used to analyse the effective presentation of LFC under fluctuating load conditions. These controllers are simulated in MATLAB/SIMULINK.

2 System Under Study

The system here presented is made up of two inter connected power systems. For the drawing and study of pre-programmed load frequency control of inter connected areas, the system is generally employed in the compositions. Traditional wind- thermal and solar- thermal generating facilities are found in areas 1 and 2. Wind- thermal and solar- thermal areas are in the ratio of 4:1 and 1:3 respectively. A time delay of 0.2 sec is provided for each control region. GRC (generation rate constant) of 3% per min is taken into account in a traditional thermal plant. There is time delay of 0.5 sec in solar- thermal power plant.

In Fig frequency bias parameters are represented by B1 & B2, area control errors by ACE1 & ACE2, controlled outputs by U1 &U2, governor speed regulator parameters by R1 & R2 and speed governor time constants in sec. by TG1 &TG2. Governor, system turbine and generator are present in both the areas. Integral squared error (ISE), given below in equation 1 is taken as a basic consequence for the optimisation and scrutiny to be accomplished.

$$ISE = \int_0^T [\Delta f_i^2 + \Delta P_{tie\ I\ -j}^2]dt \quad (1)$$

3 Proportional Double Integral Differential Controller (PIID)

Various performance requirements must be met while creating a control system, therefore double integral control system naturally provides lead over a customary single integral control system by reducing the rise time and thus eliminating steady state error. The aggregate of the proportional, integral and derivative measures on the relevant contrast signals, with each measures weighted as per to the set gain framework, is the controller output. Changes in tie-line power (p_{tie}) and frequency (f) by ACE are provided to the controllers as input in the LFC loop. For a particular area "i" the input ACE in LFC loop is given by equation 2. Fig 2 shows the Block diagram of PIID controller and its transfer function is given below in equation 3.

$$ACE_i = B_i * \Delta f_i + \Delta P_{tie\ i} \quad (2)$$

$$U_k = U(s)/E(s) = P + I_1/S + I_2/S + DN/1 + N/S \quad (3)$$

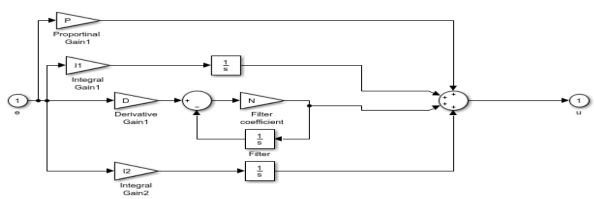


Fig. 1. Structure of PIID controller

4 Methodology

The controllers in one and all area for the proposed two-area power installation are optimised with Grey Wolf Algorithm (GWA) technique.

4.1 GREY WOLF ALGORITHM

Mirjalili et al. [28] created the grey wolf optimization (GWO) method, which imitates the management structure and coursing method of grey wolves. Grey wolves which are members of Canadae family are regarded as intruders at the top of their group. Grey wolves of the alpha (α), beta (β), delta (δ), and omega (ω) varieties have a social dominating hierarchy. Grey wolves form various groups for different activities, such as staying together and coursing prey.

Grey wolves which are attending the topmost pose of the grading are known as alpha heading wolves and are regarded as group's commander. They have ability to make decisions regarding hunting, sleeping, waking up time and so on. The other members of the group are informed of their decisions.

Grey wolves on following extent of the ranking are known as beta heading wolves, and are the former class wolves' subordinates. They assist alpha heading wolves in designing decisions. In the event that the alpha class wolves die or grow, the beta category wolves take their place.

The omega types of wolves are those who reside in the next stage of the ranking. They always do what other superior wolves tell them to do. Though omega wolves are not particularly essential in the group, if the omega is lost, the entire pack may face internal strife. Omega category wolves constantly preserve the hierarchy's dominating structure.

Delta category wolves are wolves that are not included in the alpha, beta, or omega wolf families. Delta wolves always behind alphas and betas, but they command omegas. This ranking includes five fundamental types of wolves: [1] Scouts, [2] Sentinels, [3] Elders, [4] Hunters and [5] Care takers.

Scouts are in charge of keeping an eye on the perimeter and alerting the pack if there is any threat. The second group mentioned above confirm the pack's safety. The third group mentioned above are more expert wolves who use their knowledge to frame animals or other chosen factors. Hunters assist in the capture of prey and the provision of food for the pack. Lastly, the 5th ones are in power of the weak, unwell, and out of sort wolves [15].

The GWA can be summarised as:

- A population is defined as the number of grey wolves or search agents.
- Initialise the search agent's position vector for hunting and encircling the prey in the grey wolves' upper and lower boundary areas. The maximum number of duplication is also set.
- Identify the fitness values of each solution. Each fitness value shows the interval interlinking the wolf and the prey. Three efficient wolves are recognised as α, β, δ categories of wolves based on their fitness value. The hunting behaviour of different types of grey wolves is altered in order to catch prey.
- Then the position of search agents should be updated.
- Steps like 3 & 4 should be repeated until they reach to the prey.
- When a certain number of duplications are reached, the process is concluded.

4.2 Advantages of GWA from standard one

The GWA has a superior conveyance system and forming capability. For improved results it uses a random function and evaluates three candidate solutions, and it converges quickly by jumping from local minima to global minima [16].

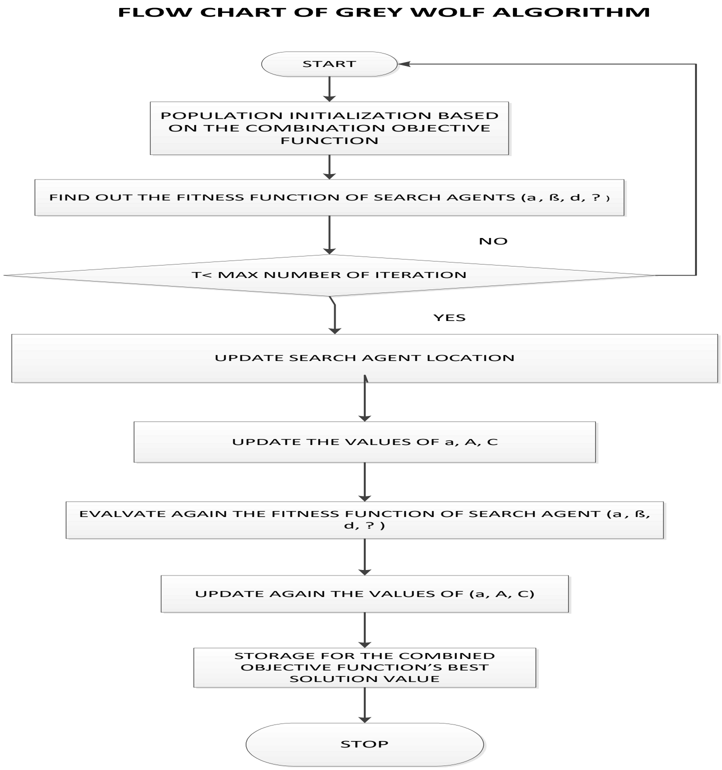


Fig. 2. Flow chart of Grey Wolf Algorithm

5 Outcome and Exchange of Views

The present suggested two-area power systems subsume wind thermal and solar thermal power plants is outlined and imitated in MATLAB Simulink environs. The present research establishes the concurrent power of structure frequency and tie-line power.

5.1 Controller Gains

Table 1.

controllers	**K_i**	**K_d**	**k_p**	**N**
I	1.2635 1.9298	-	-	-
PI	1.6790 2.9279	-	0.1635 0.775	-
PID	4.8934 3.5635	1.0009 0.9422	0.4899 0.1679	5.9619 68.1972
PIID	1.4480 0.3848 0.7587 2.6519	5888 0.364	1.8491 6.1625	63.4956 45.1697

5.2 Selection of Superlative Secondary Controller under formal state

For the proposed two area power system, various controllers like I, PI, PID and PIID are taken as secondary's. For the structure analysis, each of these controllers is taken individually, one by one. Grey wolf approach is utilised in concurrent maximization of the gain parameters for each and every controllers in both areas. This is done to achieve the best possible outcome. The Grey Wolf optimised controller gains for multiple controllers taken one by one are mentioned in table 1 given below. The symbols mentioned k_p , k_i , k_d are proportional gain , integral gain , derivative gain and N is filter coefficient. Although in PIID there are two integral gains and two filter coefficients. The dynamic outcome analogous to one as well as other areas are acquired. The acquired results are shown in figure [7] and are studied for differentiation. The outcome differentiation discloses that PIID has maximum gain and hence is superlative one. This is called to be acquired as outcomes are non-swinging with least rise time and steady state error.

The overall observations obtained from the result differentiation and ISE values differentiation suggests that PIID is acting as a superlative controller and much more superior than traditional controllers.

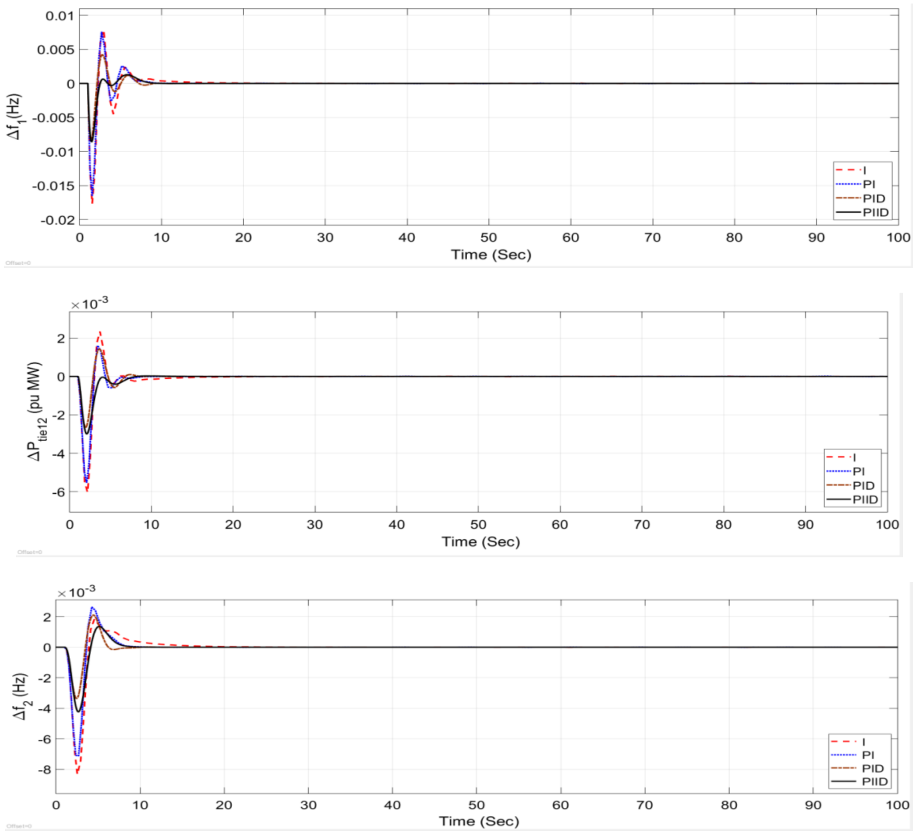


Fig. 3. Dynamic outcome of differentiation for I, PI, PID, PIID controllers at formal states

6 Sensitivity Analysis

The sensitivity analysis of a power system is investigated using a diverse set of system characteristics and operational load situations. It is used to examine how system responses changes as system parameters are varied. This aids in the verification of the robustness of P/PI/PID/PIID controller improvements optimised using the Grey Wolf Algorithm technique under nominal system conditions.

6.1 Real Time VS offline Optimisation for solar power plant

Improving energy system performance in the face of uncertainty and disturbances.

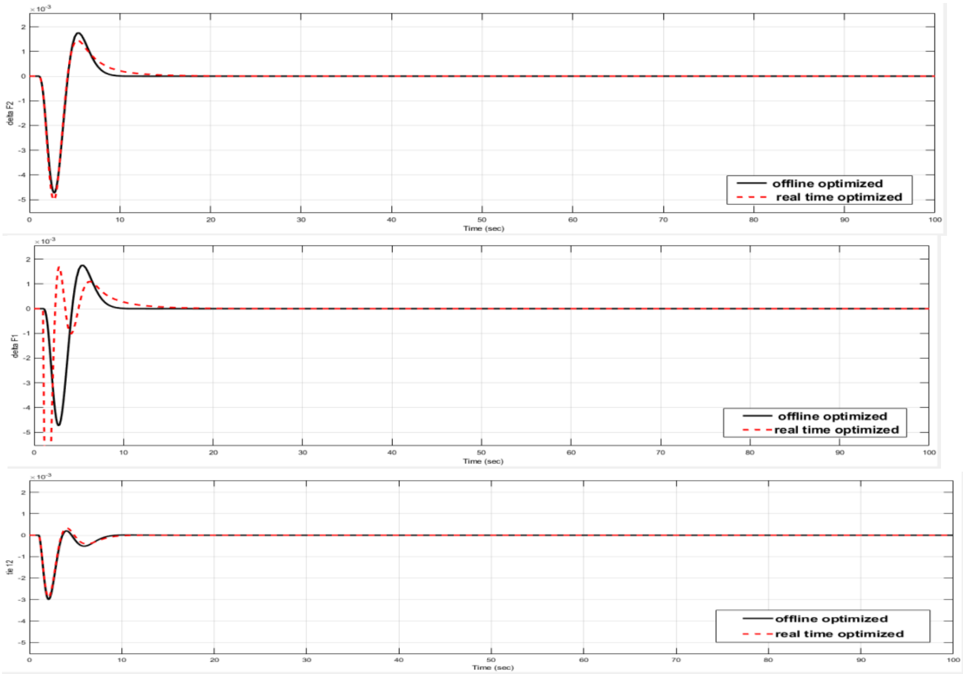
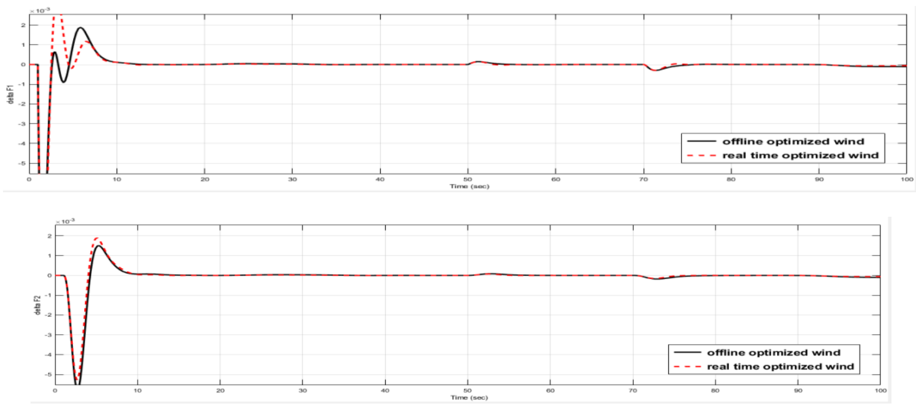


Fig.4 Real time vs offline optimisation for solar power plant depicting the less settling time for RTO

6.2 Real time VS offline optimisation of wind power plant



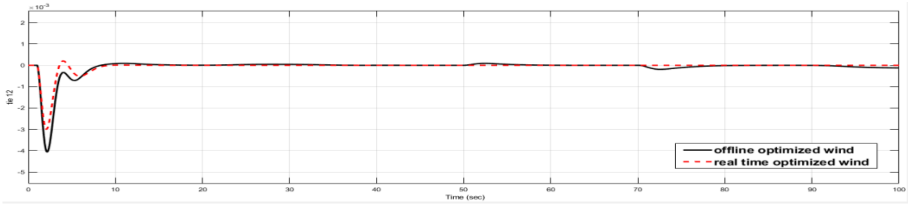


Fig. 5. Real time vs offline optimisation of wind power plant. Depicting the less settling time of RTO

7 Conclusion

Here an attempt is performed to use superlative PI, I, PID, PIID controller for LFC of an inter-linked network. Grey Wolf technique is taken first time in this discipline and the gains of controller are optimally set. The supremacy of the suggested view is proved by differentiating the outcomes of a two area system with classic controllers and put-forward controller. The robustness testing subsequently shows the soundness of the optimised controller variables to vast fluctuations in operational loading conditions and time constants of the speed governor, turbine, tie-line power, governor speed balancing, frequency influenced variables. In addition, the said technique is widened to an additional pragmatic power network representation with several electric sources. The simulation outcomes show that the proposed system performs better in terms of dynamics than conventional controllers for the same power system. Finally, utilising the put-forward procedure, the active responsiveness of the electric system under unplanned step load variations was confirmed. It has been discovered that the proposed controller technique is quite effectual and provides high ranking presentation when contrasted to other controllers.

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