Three Area Power System Load And Frequency Co-Operative Controlling By Using Differential Games

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Abstract- *Load demand is increased or decreased which results variation of speed and frequency accordingly. If there is any sudden load change occurs in control area of an interconnected power system then there will be frequency deviation as well as tie line power deviation. Hence control of load frequency is essential to have safe operation of the power system. . Main objective of this paper is to control load and frequency of power system by using Differential Game (DG) approach. Proposed strategies are then applied to a two-area power system and compared with traditional Proportional–Integral (PI) controller.Analysis of cooperative control by using differential games is done by MATLAB Simulink. Simulation results show that unlike the conventional PI controllers, DGs based cooperative controllers assign persuasive amount of LFC regulation to each CA to guarantee the stable and faithful implementation of control command.*

Keywords- Differential Game (DG), Control Area (CA), Load Frequency Control (LFC), Proportional Integral (PI)

I. INTRODUCTION

Power frameworks constantly impacted via programmed voltage controller to counter the impacts of aggravations and Generators depend on governor. Automatic Generation control (AGC) is a conveyed shut circle control technique that ideally suspends generator power set focuses to monitor frequency and tie-line streams at their predefined values. Smart grid further broaden the beforehand exceedingly circulated nature of power system by extending control to the consumer level. As roused by the new control execution standard (CPS) of North American Electric Reliability Corporation [1], the interconnection allows each control region (CA) to supply its apportioned portion of impermanent power support by means of the tie-line, when a control region (CA) interfere with the frequency infer able from the absence of Load frequency control (LFC) ability to Compensate quickly its own inner power inconsistency. In any case, the procedure of intensity bolster powers additional guideline trouble on the helping control regions (CAs') and manual for specific costs which are difficult to indicate or redress, for example, wear and tear of units [2]. Thus, a profitable technique for doling out the Load frequency control (LFC) guideline burden is basic to decrease the insult and to evade the control areas (CAs') deviation from the help order that may prompt undesirable power system execution. Load frequency control (LFC), a bit of Automatic age control (AGC), is likewise experiencing changes. In interconnected power frameworks, Load frequency control (LFC) continues the security of the power system frequency by settling the total load and complete burdens [3]. At that point the inadvertent power trade could be considered for and paid back, in order to satisfy the tie-line trade plan over the long haul, which is likewise a goal of the Load frequency control (LFC)[4]. The procedure for getting open-circle and input Nash equilibrium in non-lose-lose non agreeable differential games (DGs) were first contemplated [5], and are similarly full grown at this point. The agreeable control procedure which is first concentrated by Rufus Isaacs, proposed in this paper will be based on differential game (DG) hypothesis [6].The developments of the differential game (DG) hypothesis and its usage in different segments have been developing at an expanding rate [7][8]. The allotment technique is prevailing generously in a circumstance with huge scale irregular vitality coordinated, where the bury region power supports would be amplified regarding frequency and magnitude. A strategy is spread for acquiring pitifully time steady arrangements in agreeable differential games (DGs) with fundamental settlements [9]. Furthest point, helpful game arrangements are increasingly thorough and unmanageable, generally when the dynamic individual soundness is assessed [10]. In addition, the Linear quadratic differential games (LQDGs) are efficiently utilized [11].The smart grid can be surrounding as a broad digital physical framework that helps and thusly increasing controllability and responsiveness of very dispersed assets and resources inside electric power frameworks.

II. MAJOR DRAWBACKS OF CONVENTIONAL INTEGRAL CONTROLLER

The drawbacks can be summarized as

- They are very slow in operation.
- There is some inherent nonlinearity of different power system components, which the integral controller does not care. Governor dead band effects,

generation rate constraints (GRCs) and the use of reheat type turbines in thermal systems are some of the examples of inherent nonlinearities.

- While there is continuously load changes occur during daily cycle, this changes the operating point accordingly. It is generally known as the inherent characteristic of power system. For good results the gain of the integrator should has to be changed repeatedly according to the change in operating point. Again it should also be ensure that, the value of the gain compromises the best between fast transient recovery and low overshoot in case of dynamic response. Practically to achieve this is very difficult. So basically an integral controller is known as a fixed type of controller. It is optimal in one condition but at another operating point it is unsuitable.

Therefore, the control rule applied should be suitable with the dynamics of power system. So an advance controller would be suitable for controlling the system.

III. PROBLEM STATEMENT

- Load frequency control (LFC) is a key issue in the traditional interconnected power systems, which constantly requires different control areas (CAs) to share the regulation burden of the control area (CA) that lacks regulation capacity by providing the power supports via the tie-line.
- Such a process imposes extra regulation costs on the helping control areas (CAs), for example, the wear and tear of generating units, which may result in the unfairness and the control areas (CAs) deviation from the Load frequency control (LFC) command.
- This situation becomes even more serious with the integration of intermittent renewable energy such as wind and solar power.
- The cooperative control by using differential games (DGs) is proposed as a possible solution to this problem. With a two-area and a three-area Load frequency control (LFC) models, two cooperative solutions with different time consistency properties are derived.

IV. OBJECTIVE

- The main essence of this project is to rectify the problem associated in load frequency control by different control areas to share regulation burden.
- Cooperative control by using differential games (DGs) is proposed as a possible solution to this problem.
- With a three-area Load frequency control (LFC) model solution, two cooperative equilibrium solutions with different time consistency properties.
- The analysis of cooperative control by using differential games is done by MATLAB Simulink.

V. NEED OF LOAD FREQUENCY CONTROL

The active and reactive power demands are never steady and they continuously changes with the rising or falling trend of load demand. There is a change in frequency with the change in load which causes problems such as:

1. Most AC motors run at speeds that are directly related to frequency. The speed and induced electro motive force (e.m.f) may vary because of the change of frequency of the power circuit.
2. When operating at frequencies below 49.5 Hz; some types of steam turbines, certain rotor states undergo excessive vibration.
3. The change in frequency can cause mal operation of power converters by producing harmonics.
4. For power stations running in parallel it is necessary that frequency of the network must remain constant forsynchronization of generators.

VI. LOAD FREQUENCY CONTROL

The power systems means, it is the interconnection of more than one control areas through tie lines. The generators in a control area always vary their speed together (speed up or slow down) for maintenance of frequency and the relative power angles to the predefined values in both static and dynamic conditions. If there is any sudden load change occurs in a control area of an interconnected power system then there will be frequency deviation as well as tie line power deviation. The two main objective of Load Frequency Control (LFC) are

1. **To maintain the real frequency and the desired power output (megawatt) in the interconnected power system.**
2. **To control the change in tie line power between control areas.**

If there is a small change in load power in a single area power system operating at set value of frequency then it creates mismatch in power both for generation and demand. This mismatch problem is initially solved by kinetic energy extraction from the system, as a result declining of system frequency occurs. As the frequency gradually decreases, power consumed by the old load also decreases. In case of large power systems the equilibrium can be obtained by them at a single point when the newly added load is distracted by reducing the power consumed by the old load and power related to kinetic energy removed from the system.

VII. PROPORTIONAL INTEGRAL CONTROLLER

The proportional integral controller is yield of the mix of yields of the proportional and integral controllers. PI controller will expel stressed motions and unfaltering state blunder bringing about activity of on-off controller and P controller separately. Exhibiting fundamental mode has a negative outcome on speed of the reaction and general firmness of the framework. Consequently, PI controller won't expand the speed of reaction. It very well may be normal since PI controller does not have intends to foresee what will occur with the mistake in not so distant future. This issue can be settled by propelling Derivative mode which can possibly conjecture what will happen with the mistake in last mentioned and along these lines to diminish a response time of the controller. PI controllers are all the time utilized in industry, particularly when speed of the reaction isn't make any difference. A control without D mode is utilized when: a) rapid reaction of the framework isn't required b) enormous diversions and clamor are there all through working of the procedure c) just a single vitality stockpiling in task (capacitive or inductive) d) there are wide transport delays in the framework.

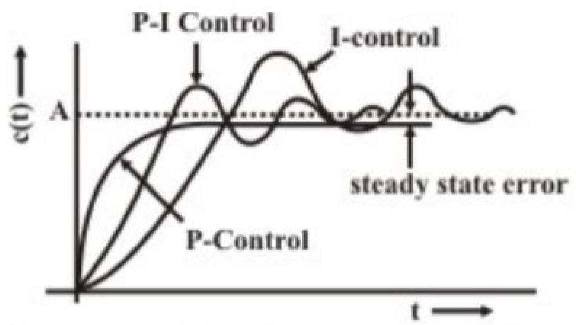


Figure 1. Comparison among the Transient Responses with P,I,P-I Control.

VIII. SYSTEM DESIGN AND MODELLING

As shown in Fig.2, A two-area LFC system is moderately reconstructed, where the control command inputs are changed from the demanded deviation of generator output ΔPci to its altering speed *ui*. It is more suitable to limit the damping rate of the units and to reflect the wear and tear of the units in the control objective function by using *ui*.

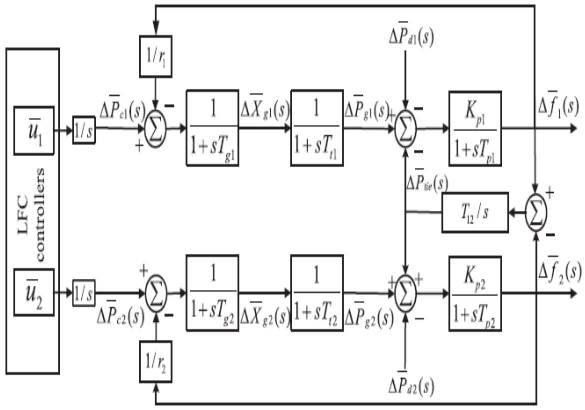


Figure 2. Block diagram of a two-area LFC system.

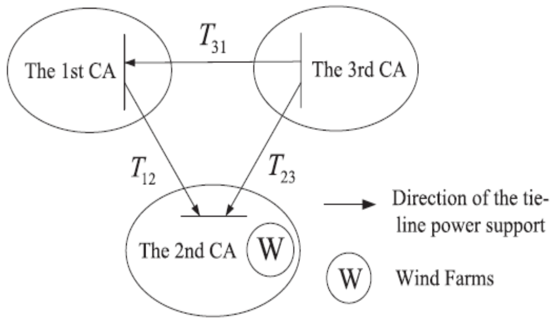


Figure 3.Diagram of a three-area LFC system

IX. PROPOSED SYSTEM AND DESCRIPTION

The ith control area (CA) parameters ΔPgi, ΔPtie, Δfi, ΔPci, ΔXgi, are the deviation of Generator mechanical output, tie-line power, frequency, requested generator output, generator mechanical output, respectively. Where *Kpi*, T_{12},*Tgi*, *ri*, *Tti*and*Tpi*are the electric system gain, the tie-line synchronizing coefficient, the time constant of the governor, the speed drop, the time constant of the turbine, , the electric system time constant respectively. Case studies are firstly carried out based on the two-area LFC system as shown in Fig.2 To obtain a three-area LFC system, we add a new CA to the original two-area LFC system shown in Fig.2.The third CA is connected to the first CA and the second CA via tie-lines, respectively, as shown in Fig.3. In this case the meanings of the symbols in the model are consistent with the two-area cases.The values of all other elements in these three matrices are zero. Parameters of the three areas have exactly the same values, which are listed in Table 1. The tie-line synchronizing coefficients *T*31 and *T*23 are much smaller than *T*12, and this indicates that the third CA is weakly connected to the first CA and the second CA.

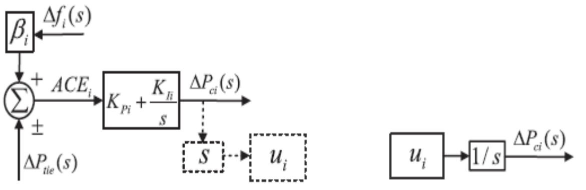


Figure 4. Block diagrams of two kinds of controllers. (a) PI controller. b) Controller based on DGs or optimal control.

Table 1.Parameters of three areas LFC Scheme.

Parameters	T_{gi}	T_{ti}	k_{Pi}	T_{Pi}	r_i	T_{12}	T_{23}	T_{31}
Values	0.08	0.3	12	20	2.4	0.545	0.0545	0.0545

Assuming that at most of time, perturbations occurred in the second CA are more frequent than the other two areas, which means that the second CA receives the power support from other areas. Hence, the first and the third CAs are concerned with the restriction of both frequently error and tie-line power error, while the second CA only considers the frequently error as it needs the tie-line power support. Accordingly, we set $Q1(1, 1) = Q1(10, 10) = Q1(12, 12) = Q2(4, 4) = Q3(7, 7) = Q3(11, 11) = Q3(12, 12) = 1$, and other elements of the three metrics equal zero. The control cost penalty metrics R1, R2, and R3 are set as follows:

$$R_1=\begin{bmatrix}5&0&0\\0&0&0\\0&0&0\end{bmatrix},\quad R_2=\begin{bmatrix}0&0&0\\0&10&0\\0&0&0\end{bmatrix},\quad R_3=\begin{bmatrix}0&0&0\\0&0&0\\0&0&5\end{bmatrix}.$$

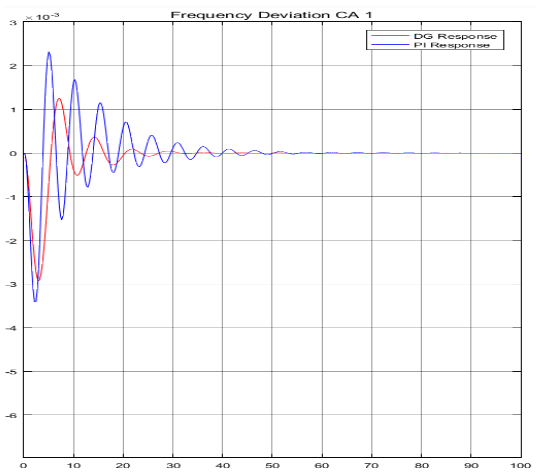
Similarly, the following five LFC schemes are simulated, which all use the objective function in (3)–(11). Scheme 1(PI Controller):The three CAs provide *_Pci* by identical PI controllers shown in Fig. 2(a). We set the proportional gain $KP1 = KP2 = KP3 = 1$, the integral gain $KI\,1 = KI\,2 = KI\,3 = 0.2$, and the frequency bias factors $\beta 1 = \beta 2 = \beta 3 = 0.45$. The adjusting speed ***ui (t)*** is obtained for comparison by differentiating ΔPci .

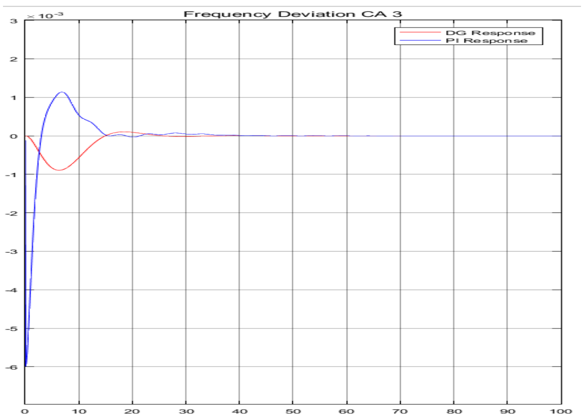
X. NASH EQUILIBRIUM

Hypothesis where the ideal result of a game is one where no player has inspiration to veer from his chose system in the wake of thinking about an adversary's decision, he has no reason, nothing to pick up, by exchanging his procedure. In the Nash equilibrium every player's methodology is brilliant when thinking about the choices of different players. Each player wins since everybody gets the result they wish. Nash equilibrium show up when every player is endeavoring his or her most ideal system, while completely exceptional of the procedures that every other person is following . The Nash equilibrium is named after John Forbes Nash Jr. (1928-2015), an American mathematician who shared the 1994 Nobel Memorial Prize in Economic Sciences with two other game scholars. By and large, an individual can gather no gradual benefit from evolving activities, assuming different players stay consistent in their strategies.it have various Nash equilibrium or none by any stretch of the imagination. To quickly test if the Nash equilibrium endure, uncover every player's arrangement to different players. In the event that nobody changes his arrangement, at that point the Nash equilibrium is demonstrated. It is a key thought in game hypothesis As soon as the Nash equilibrium is picked up, there is no rationale for anyone to ponder changing their technique.

XI. RESULTS AND DISCUSSIONS

Results of Frequency deviation in control area 1 & 2 & 3 resp. is shown in fig.5.and tie line power deviation in CA 1&2, 2&3, 3&1 using both Conventional PI Controller and Differential game is shown in fig.6.





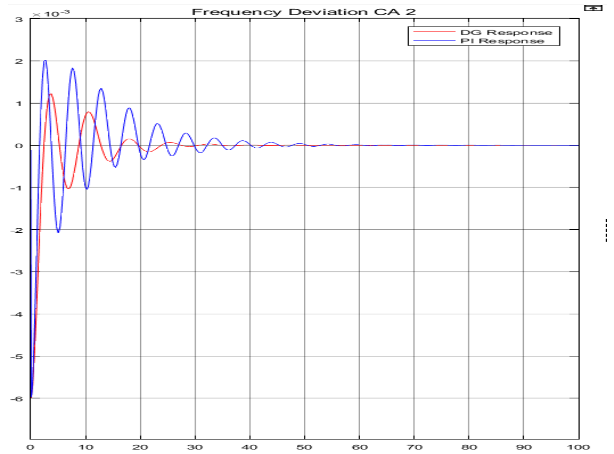
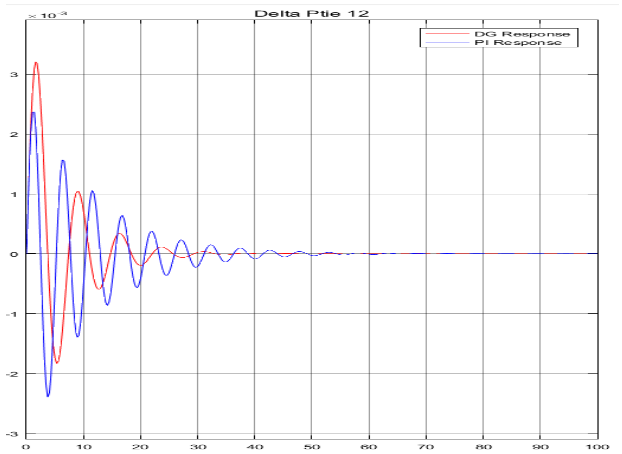
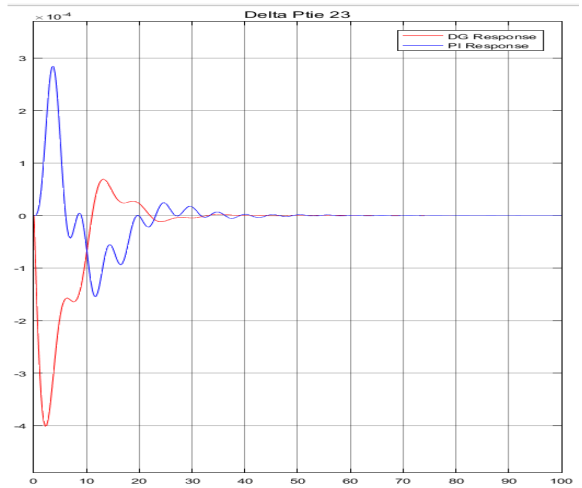


Figure 5. Combine results of Frequency deviation in control area 1 & 2 & 3 using conventional PI Controller and Differential Game Theory in Three Area LFC system.





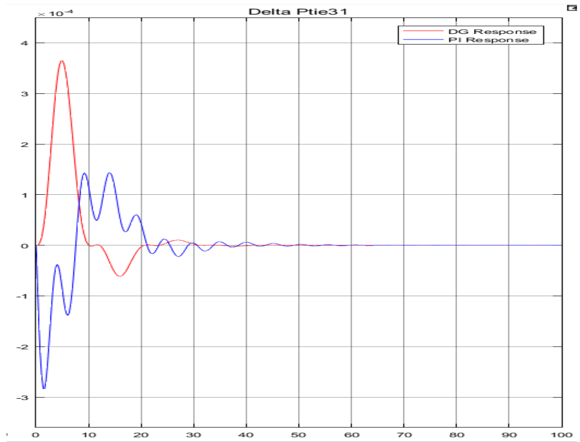


Figure 6. Combine results of Tie line power deviation in control area 1&2, 2&3, 3&1 using conventional PI Controller and Differential Game Theory in Three Area LFC system.

XII. CONCLUSION

In the proposed work, the Three-area (LFC) problemsare investigated under the architecture of differential games (DGs) based cooperativecontrol for the first time. Simulation results show that unlike the conventional proportional–integral (PI) controllers and the differential games (DGs) based cooperative controllers allocate the effective amount of Load frequency control (LFC) regulation to each control area (CA) to warranty firm and precise execution of control instruction.

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