Security Constrained ALFC of Multi-Area Power System: A Survey

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ABSTRACT: -Power structures are the most complicated frameworks that have been made by men in history. To work such frameworks in a steady mode, various control circles are required, voltage and frequency plays a crucial role in power structures which need to be well controlled. primaryand secondary frequency control loops are applied to control the frequency of the voltage in power systems to this end. Secondary frequency control, which is called Load Frequency Control (LFC), is dependable for keeping up the frequency in a permissible level after an aggravation.The objective is to get best results of the fluctuations using appropriate controllers. In this paper, a literature review is given for the designing of a PID controller of load frequency control. In recent decades, many control approaches have been suggested for LFC in power system.The authors have gone through various control strategies concerning the LFC problem which are based on classical, optimal, adaptive, robust, and AI based on soft computing. Therefore, the quality of power system can be improved by choosing a better computing method which will be applicable in our modern system by considering all physical constraints.

Keywords: -ALFC, Controller, Security Constraints, Survey

I. INTRODUCTION: -The power system is an arrangement consists of generation, transmission and distribution. It is a complex network which notably changes human life and society development.Power systems provide energy to loads that perform a function. These loads range from household appliances to industrial machinery. The main components of the system are powerplant, transformer, transmission lines, substation, distribution line and distribution transformer. The major function of automatic generation is frequency control. Safe and reliable operation of the LFC is the crucial concern in power generation.

A power system is extremely non-linear and large-scale multi-input-multi-output dynamic system with several variables, protection devices and control loops. Therefore, it needs to be controlled in proper way. The LFC is a control mechanism usually appropriate to both the single area and multi-area power systems. In case of the single areaisolated power system, the source of power generation may be of single type orthere may be diverse source of power generations like thermal, hydro, nuclear etc [1]. In the isolated case, the frequency bias has no effect on the operation of LFC. For the multi-area power system, a group of generators are closely united internally and swing together. Each area may embrace of single or multiple power generating units with different types for providing the load demand. Different areas of multi-area power system are connected via tie-line which is the basis for load sharing between them.The power system control is used to outline the application of control theory and technology, optimization methodologies to improve the performance and functions of power systems during the normal and abnormal conditions. Maintaining frequency and power interchanges in multi areas at the planned values are the two main primary aims of a power system LFC. These aims are encountered by measuring a control error signal, called the area control error (ACE). The ACE is used to perform an input error signal for a usually proportional integral controller whereas the parameters of PI controller are tuned based on experiences, trail-and-error approaches. The PI controller are incapable of obtaining good performance for a large range of operating condition.

It is known to us that active power and reactive power are not constant as the industrial and consumer loads are changing in a regular way. Thus, input supply, i.e., steam input to turbo generators or water contribution to hydro generators should be controlled appropriately, else there can be change in machine speed and consequently frequency will be changed which is not acceptable in power system operation. Now-a days there is an interconnection between allthe networks. Accordingly, there will be a multi-area system problem in power system. Manual regulation is not viable in a modern interconnected system.

II. ALFC MODEL: -The schematic block diagram of LFC system with basic frequency control loops is depicted in Fig. 1[1, 2].

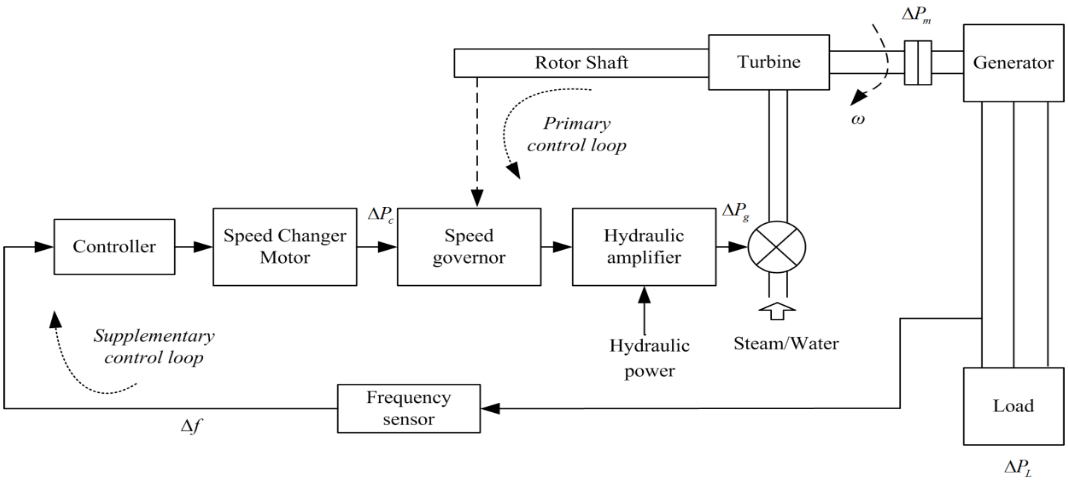

Fig. 1Schematic block diagram of LFC system with basic frequency control loops [1, 2]

In general, primary control and supplementary or secondary control i.e.LFC is used to maintain power system frequency.If there is any load-generation mismatch related with significant frequency change, the primary control will firstly try to reestablish the normal operating condition. When the primary control fails,the remaining frequency and power deviation will be handled by supplementary controlafter a few seconds the nominal frequency and specified power exchange between neighbouring areascan re-established. Herespeed governor is used to sense the change in speed/frequency via primary and supplementary frequency control loops. The steady state power output setting is provided by speed changer for the turbine and the amplifier provides the required mechanical forces to position the main valve against the high-pressure steam or water. The supplementary control loop is used to deliver feedback via the frequency deviation and adds it to the primary control loop through a controller. In order to minimize the frequency, change the resulting signal (ΔP_c) is used. [1-4]. The frequency will change (Δf) from its specified valueIf there is any load deviation(ΔP_L). Therefore, the feedback mechanism is used and offers suitable signal for the turbine to make generation (ΔP_m) track the load and keep the frequency constant.

Power systems are highly non-linear and time varying in nature.The simplified block diagram for single area power system is achieved by reducing Fig. 1 and the reduced block diagram is shown in Fig. 2.

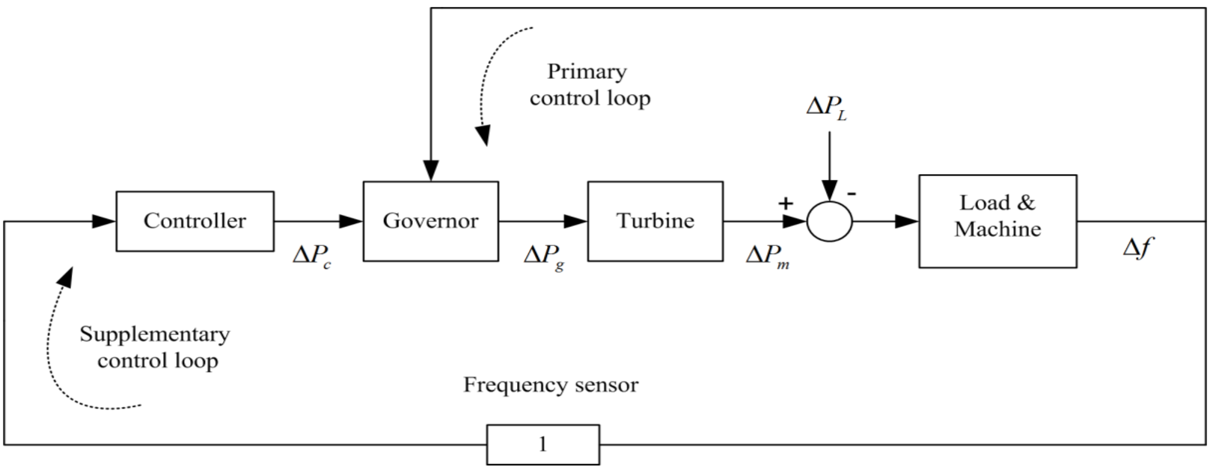

Fig. 2. Simplified block diagram of Fig. 1 [1, 2]

Governor: -Governors are used in power systems to sense the frequency bias produced because of load change and cancel it by changing the turbine input.

Governor transfer function is $\frac{1}{1+sT_g}$ where T_g is the time constant of the governor.Ris the speed regulation characteristic or droop characteristic (Hz per pu MW).

Turbine: -In power system a turbine unit is used to convert the natural energy, for instance the energy from steam or water, into mechanical power (ΔP_m) which is supplied to the generator., There are three kinds of generally used turbines in LFC model: non-reheat, reheat and hydraulic turbines.

The transfer function of the non-reheat turbine is represented as $G_{NR}(s) = \frac{\Delta P_m(s)}{\Delta P_g(s)} = \frac{1}{1+sT_t}$

Where T_t is the turbine time constant and $\Delta P_g(s)$ is the valve/gate position change.

The transfer function of the reheat turbine is represented as $G_R(s) = \frac{\Delta P_m(s)}{\Delta P_g(s)} = \frac{T_{rh} K_{rh}\ s+1}{(1+sT_t)(1+sT_{rh})}$

Where T_{rh} stands for low pressure reheat time and K_{rh} stands for high pressure stage rating.

The transfer function of the hydraulic turbine is in the form of $G_H(s) = \frac{\Delta P_m(s)}{\Delta P_g(s)} = \frac{1-sT_w}{1+s(\frac{T_w}{2})}$

Where T_w stands for water starting time.

Generator and Load: -The transfer function of load & machine model is $\frac{1}{2Hs+D} = \frac{k_p}{1+sT_p}$

Where$k_p = 1/D$is gain of the power system, Hz/pu MW, $T_p = 2H/D$is the time constant of the power system in sec.

When there is a load change, the mechanical power generated by the rotation of turbine will no longer match the electrical power generated by the generator. This error between the mechanical (ΔPm) and electrical powers(ΔPe) results into the rotor speed deviation (ω_r)[1-3]. The generator dynamics for the incremental power change ($\Delta P_m - \Delta P_e$) can be expressed as

$$\Delta P_m - \Delta P_e = 2H\frac{d\Delta f}{dt} \qquad \text{(i)}$$

Where $\Delta P_m =$ mechanical power change, $\Delta P_e =$ electrical power change,

$H =$ inertia constant of the generator

The power system loads can be considered as resistive loads (ΔP_L), which remain constant with the changing of rotor speed, and motor loads that varies with motor speed. The overall composite load can be expressed as

$$\Delta P_e = \Delta P_L + D\Delta f \qquad \text{(ii)}$$

where D is the load damping constant. The damping constant is defined as a percent change inload for 1% change in frequency.

So the relationship between incremental power change and frequency deviation for overall generator-load or load & machine dynamic can be expressed as

$$\Delta P_m - \Delta P_e = 2H\frac{d\Delta f}{dt} + D\Delta f \qquad \text{(iii)}$$

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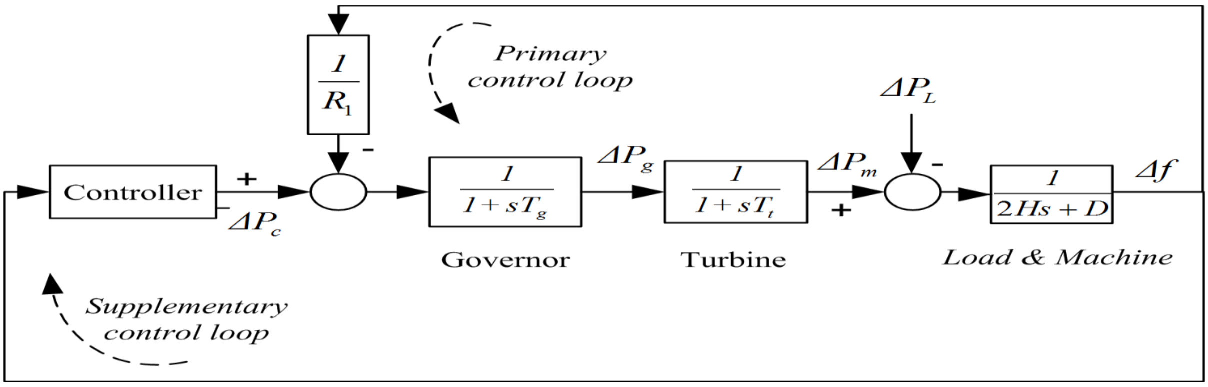

Fig 1.3Block diagram model of non-reheat steam generator unit [1, 2]

Constraints: -The non-linear physical security constraints present in the power system are generation rate constraints (GRC), governor dead band (GDB) and time delay (TD).

Generation rate constraints (GRC):-Although it is difficult to consider all dynamicsto attain an accurate perception.The main inherent requirement and the basic constraints imposed by the physical system dynamics to model/evaluate the LFC performance is important. An necessary physical constraint is the rate of change of power generation due to the limitation of thermal and mechanical movements, which is known as generation rate constraint (GRC).

Governor dead band (GDB):-When the input signal of a speed governor is changed, it may notrespond instantly until the input reaches a definite value. This phenomenon is recognized as speed governor dead-band. All governors have a dead-band in response, which is vital for LFC systems. Governor dead-band is described as the total magnitude of a continuous speed change, within which there is no subsequent change in valve position.

Time delay (TD):-In new power systems, there is communication delays which are becoming more significant challenge in system operation and control. However, under a traditional LFC scenario, the problems linked with the communication delays may be ignorable, considering the problem that may arise in the communication system in use of an open communication infrastructure to support the ancillary services in a restructured environment is important. The LFC performance can be degraded by time delays seriously. The LFC performance degradeswith the increase of time delay.

III. LITERATURE SURVEY: -The research on LFC problem of power system has a long history and expected much reputation in control theoretic viewpoint. The work carried out so far in LFC is so vast that it is not possible for one to widely review the literature covering all features of its design and control while functioning in various conditions. Thus, the brief literature review on the current position of the design and control of the LFC is carried out to find out the recent philosophies of LFC strategies in power system. Over the years, several control strategies had been effectively used to address the LFC design problems in order to advance the dynamic behaviour of the power system. the most widely used controller is the conventional proportional integral (PI) controller. The tuning of PI controller was done by trial-and-error approach. The most popular and widely used method of controller parameter tuning is Ziegler-Nichol's method. Ziegler-Nichols tuning of controller parameter for LFC was reported in [5,6]. Among the several controllers used till now, Though the tuning method is straightforward and easy for practical implementation but it is cumbersome and time consuming. The main drawback of this controller is that the dynamic response is highly dependent on selection of control gains. A high gain may cause large oscillations. The operating points of a power system may change very much randomly during a regular cycle. As a result, a fixed controller is certainly not suitable. Therefore, some authors have suggested variable structure and robust control to make the controller insensitive to changes in the plant parameters [7-10].However, these methods require information about the system states, which are not usually known or available. Recently, to overcome the mentioned shortcomings, various adaptive control techniques have been proposed to deal with large parameter variations [11-13].Kazemi, et al. have proposed a new model reference-decentralized robust adaptive-output feedback controller for the load frequency control (LFC) of large-scale power systems with unknown parameters. This control strategy requires only local input–output data and can follow random changes in the operating conditions [14].As the world's population grows and energy demand rises, it is necessary to increase the scale of the electrical system, which is more difficult. Consequently, adopting automatic generation control (AGC) scheme to meet the demand becomes unavoidable. In this article named "Application of a New Fusion of Flower Pollinated with Pathfinder Algorithm for AGC of Multi-Source Interconnected Power System" by Oladipo, et al. have been implemented the fusion of flower pollinated algorithm (FPA) and pathfinder algorithm (PFA), to achieve maximum control efficiency [15].Similarly, Nasiruddin [16] et al. designed the AGC for a two-area interconnected power system with multi-energy sources. Thebacteria foraging optimization(BFO) algorithm was used to optimize the gains of the PID controller considering 1% step load disturbance in one of the control areas. It is observed that the BFO-based PID surpassed the GA-based PID controller in terms of the system dynamic performance.

Now-a-days, PSO techniques have given much importance for optimization of complex control problems. PSO technique is used broadly for the design of numerous LFC problems [17-27]. Recently, lots of other newly developed soft computing techniques and their hybrid forms like differential evolution (DE) [28-30],artificial bee colony optimization (ABCO), emotional learning-based intelligent controller,firefly algorithm (FA), teaching learning based optimization (TLBO), ant lion optimizer algorithm, BAT algorithm, quasi-oppositional harmony search algorithm, grey wolf optimization, hybrid GA-PSO, Fuzzy-GA, PSO-pattern search (PS), bacteria foraging optimization algorithm-pattern search (BFOA-PS) algorithm, hybridized gravitational search algorithm, fire fly-pattern search (FF-PS) algorithm, local unimodal sampling-TLBO (LUS-TLBO) [31-51]that have been used successfully to design LFC problems with or without considering constraint scenario.I. Ibraheem et al. and H.Bevrani et al. have presented a critical review based on classical, advance, centralized, decentralized and multilevel control for both the linear and non-linear models by using critical LFC approaches. All the control strategies like digital, self-tuning, adaptive/robust, optimal, variable structure control (VSC) and intelligent/soft-computing control were deliberated for the conventional and deregulated market scenario[52,53]. In 2015, Shankar et al. [54] represented the synchronization of LFC theory and economic load dispatch of the interconnected power system. The sharing of entire change within the specific control area was handled by means of every unit, in accordance to their contribution factor that gained from the economic load dispatch's calculation. This research work has considered two control areas, where the initial control area was incorporated with the mixing of thermal, hydro and gas unit and the second control area has incorporated the mixing of the hydro and thermal producing units.In 2019, Dev et al. [55] have introduced a model for designing the continuous-time event-triggered adaptive integral higher-order sliding mode control for the problems related to load frequency in multi-area power system within parameter uncertainties and loaddisturbances. In 2019, Mohamed et al. [56] has detailed over the huge interest on wind energy between researchers as because there is increased use of RES all over the world. Though, in power systems, because of its extended usage, many stability issues and power system dynamics issues were provoked.In 2019, Deepesh Sharma et al.[57] has mainly concerned on representing the LFC for Two-area interconnected power system that comprised of Thermal, Hydro and Gas. In this research an optimal design of FOPI controller using Lion with Levy Update was presented. Hence, it was represented as a LLUFOPI controller for LFC in two area multi source interconnected power system.

IV. RESEARCH GAPS AND CHALLENGES: -During transportation, the reactive power balance and the active power balance needs to be maintained among using and generating the AC power. These active and reactive power balances are linked over two equilibrium points: voltage and frequency. There is a need of better electric power system quality during operation for both the voltage and frequency to remain at benchmark values. Though, the electric power users change the loads momentarily and arbitrarily. It is very crucial to maintain balance among the active and reactive powers. As there is imbalance, because of load change, the voltage and frequency levels will be changed. Therefore, a control system is very much important, to disregard the certain load change effect and for keeping the voltage and frequency at benchmark values.

However,there is an impact on frequency and voltage by the combined effects of the active power and reactive power, the control issue of the voltage and frequency may get dissociated. The frequency is largely dependenton the active power and thevoltage is largely depend on the reactive power. So, in power systems, the control problem might be divided as two independent issues. The first is on the frequency control and active power whereas the second is on the voltage control and reactive power. In this, the frequency control and active power is termed as LFC.

The primary aim of LFC is keeping the frequencyconstant over the arbitrarily change of active power loads which is termed as unidentified explicit disturbance. The additional target isregulating the tie-line power exchange error. Typically, a power scheme of huge-scalewhich is comprised of various areas of producing units. HereTransmission lines (TLs) are used for associating these producing units for enhancing the fault tolerance of the whole power system. The tie-line power usage has incorporated a novel error within the control issue, i.e., tie-line power exchange error. Undesirable load change in active power occur over an area, the energy obtained within the area is through TL from erstwhile areas. Still ultimately, with no external support, the balance needs to be handled among the area that is processed to load change. Or else, there pose some economic divergence among the areas. Therefore, every area needs a separate LFC for regulating the tie-line power exchange error, and hence that the entire areas within an interconnected power system may place their set points diversely. One of the other issues is that the interrelation of the power systems that resulted in enormous increase over the system order and the tuning controller parameter's count. As the consequence, while designing such complicated high- order power systems, the approximation of parameter and model parameter cannot be prevented. Thus, the LFC requirement is more robust over the system model uncertainties and the system parameter's variations in certainty. In outline, the LFC is contributed with two main tasks and that are to maintain the tie-line power exchange and to sustain the frequency benchmark value in the occurrence of varied load changes[57].

So, the major gaps in load frequency control which need to be give attention are

(i) Different control techniques need to be robust in context of load frequency control.

(ii) Suggestingfinest control methods for LFC which can handle bothpower generation variations and differentparameters.

(iii) Apply new control methodologies that can improve reliability of LFC systems.

(iv) The ability of LFC system has to be increased which can handle cyber-attack issues.

(v) Development of new fault analysis methods suitable for LFC.

(vi) Developing new adaptive control techniques such as soft computing and AI based techniques which can improve the system performance with or without considering physical constraints.

(vii) New objective functions for LFC have to be developed that can improve power system performance.

Therefore, a suitable arrangement between the demand-side and generation-side involvement in LFC can be suggested for modern power systems. Likewise, the infrastructures of modern power systems require more surveys to provide demand-side participation in LFC.

V. CONCLUSION: -A brief literature review of load frequency controlusing different types of control techniques is done in this paper. The authors have givendifferent ideas of controller design, but omission of certain conditions is observed in large number of papers that are published in this area each year. The primary task in LFC is to develop a highly robust controller that maintains frequency deviation strictlyin specified limits even in the presence of nonlinearities like Governor deadband (GDB) and Generation Rate constraint (GRC), physical constraints and uncertain environment by using hardware setup. Further,there is a necessity of appropriatestudy on the effect of communication delayfrom control center to remote terminal unit for transmitting the control signal and to minimize the delay. Thus, for future improvement, there is an ample scope of research in this area that can be focusedin order tomake the power system robust.

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