A Review on AGC for Multi-Source Power System with Different Optimization Algorithms

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Abstract— The Fractional order controllers are capable of generating greater control in various dynamical systems, due to which these controllers are utilized widely in several areas of science and engineering. When these controllers are implemented then the control performance becomes much efficient. Fractional order PIDs are utilized in load frequency control, automatic voltage regulation, cardiac pacemaker and etc. In this paper, the FOPID controller is analyzed. However, in FOPID, AGC is the major problem which affects the performance of FOPID controller. In order to resolve this problem, various researchers had proposed various approaches which are scrutinized in this paper.
Keywords: Automatic Generation Control (AGC), Fractional Order PID

I. Introduction

Because of power divergence among load and generation, there occurs deviations in the frequency in the power system, while, because of reactive power disparity in system, there occurs variation in the voltage. The reactive power is created near to needs as consists of just capital cost and no fuel cost and is not transmitted on lines for preventing huge losses of transmission. Though, by controlling the generation the active power balance can be obtained for the efficient power system operation and it is known as automatic generation control (AGC). In interconnected power system's operation and design, the AGC is very significant control problem. Various factors which help to raise the significance of AGC are [1]:

- The changing structure and growing size
- power system's functionality
- intricacy
- expansion in power generation/utilization techniques
- the renewable energy sources' quick emergence (and ambiguity)
- Environmental restraints.

The AGC control process is very important which operates continuously for balancing the load and generation in the power systems at the lower price. The AGC controls the frequency, power exchange and also ED. An approach is provided by the AGC in order to regulate the generation for reducing the deviation of frequency and controlling the tie-line power flows.

By transmitting the signals to the controlled generating units, the AGC system comprehends the change in generation. On the basis of generating unit's speed and efficiency of responding to commands, the AGC system's performance varies.

Though, the generating unit's response features are related with various factors, like, what is the type of unit, control approach, operating point and fuel. As, in the power system, the frequency generated is relative to the generator's rotational speed, the frequency control problem can be transformed to the generator unit's speed control problem [2]. Firstly, it is accomplished by enhancing the governing approach which senses the speed of generator and regulates the value of input in order to change the mechanical power output for tracking the change in load and to restore the nominal frequency value.

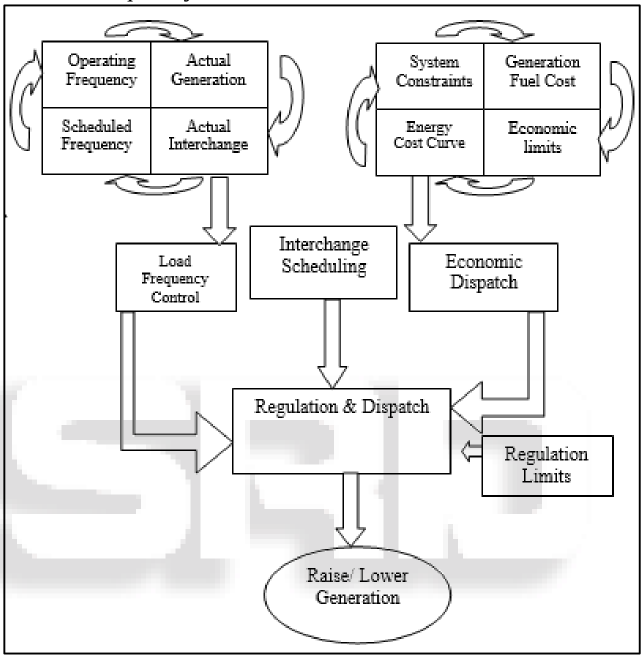

Fig. 1: Automatic Generation control

The major aim of AGC is to keep the interconnected tie-line power and frequency deviation in the scheduled confines. For the constant and secure power system operation, it is required that ISO must achieve several auxiliary services in a deregulated environment.

Amongst all other auxiliary services, regulation of frequency with the help of AGC is the most significant one. With the help of AGC, the balance among load and generation requirements of every area can be obtained and also the frequency and tie-line power flow in the definite confines are maintained. In the deregulated environment, the load frequency control problems are accounted.

The controller are very necessary and significant in the AGC system, thus, several control approaches were presented by various researchers in past years, though proportional integral derivative (PID) controller are utilized widely [3].

II. FOPID

In 1999, the FOPID was introduced initially by Podlubny. FOPID is the expansion of traditional fractional calculus based PID controller.

In 1989, the association of Japan Electric Measuring Instrument Manufacturer had conducted a state of process control systems' survey [4], according to which more than 90% of control loops are of PID type. In [5], it was represented that in Canada a usual paper mill consist of more than two thousand control loops and 97% utilize PI control. Thus, the capitalist had focused on PI/PID controllers and created a 1 button type relay auto-tuning methods for quick, reliable PID control with the acceptable performance [6], [7], and [8]. The design of PID controllers is very simple and it has fine performance like, less percentage overshoot and minimum settling time. As the power system's operating point continue varying, thus, it is needed to tune the PID controller after regular interval of time.

Instinctively, there is more flexibility in regulating the gain and phase features as compared to utilizing the IO controllers. Due to these flexibilities, the FO control becomes an influential tool for making the robust control system with minimum controller factors to be tuned [9]. The main thing is that with the help of only some tuning knobs, the FO controller obtains the same robustness which was obtained with the help of high order IO controllers. $PI^{\lambda} D^{\mu}$ Controller was scrutinized in time domain as well as in frequency domain. In usual type, the $PI^{\lambda} D^{\mu}$ controller's transfer function is represented as:

$$C(s) = \frac{U(s)}{E(s)} = K_v + T_i s^{-\lambda} + T_d s^{\delta} \quad (12)$$

In which, λ and δ are the positive real numbers; proportional gain is represented by Kp, integration constant is Ti and differentiation constant is Td. It is comprehensible that a typical PID controller is achieved by taking λ = 1 and δ = 1. When λ is taken as 0 (Ti = 0), then a PD controller, etc is achieved. These kinds of controllers are $PI^{\lambda} D^{\mu}$ controller's specific case. The formula of time domain is represented as:

$$u(t) = K_v e(t) + T_i D_t^{-\lambda} e(t) + T_d D_t^{\delta} e(t). (D_t^{*}) \equiv_0 D_t^{*} \quad (13)$$

It can be anticipated that control performance of the system can be improved by the $PI^{\lambda} D^{\mu}$ controller (13) because of bring in of extra tuning knobs. In fact, theoretically, $PI^{\lambda} D^{\mu}$ is an infinite dimensional linear filter because of fractional order in integrator.

Figure2 represents the structure of FOPID controller:

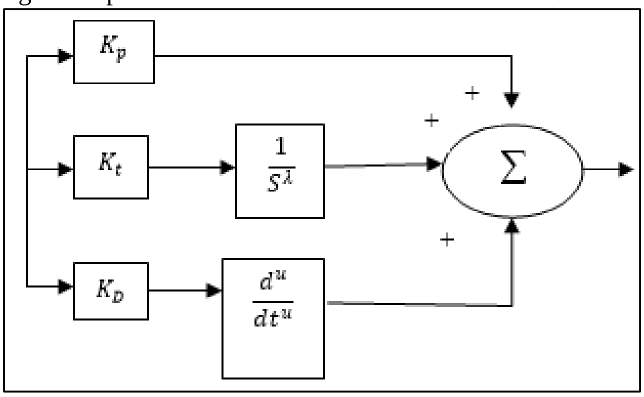

Fig. 2: FOPID controller structure

With the help of fractional calculus, the PID controller's performance can be enhanced. The derivative and integral terms' order, in the FO (fractional order) controllers, is not an integer. Flexibility in controlling function is the major advantage of FO controllers, with the help of which a robust control system can be designed. FO controllers can efficiently handle the parameter ambiguity, eradicate the steady state error and helps to achieve a better stability. FOPID (Fractional order proportional integral derivative) controllers are utilized in various engineering areas, like, automatic voltage regulator system, stabilizing FO time delay systems, and many more. The best value of controller factor like, proportional gain, integral gain, derivative gain, (λλ) non-integer integral order and (μμ) non-integer derivative order, are required to be resolute in order to design the best FOPID controller. In order to resolute the mentioned factors, various algorithms are proposed and utilized.

In order to deregulate the 3 area thermal power system, the authors in [10] have represented the FOPID controller using BFO method. The comparison is made between the FOPID controller's performance and other controller's performance. In [11], the supremacy and benefit of 2-degree-FO controller with firefly algorithm idea was analyzed in 3-area traditional power systems' AGC approach. In [12], the FOPID controller's performance altered by chaotic algorithm was contrasted with 2-area-LFC's (load frequency control) PID controller.

The FOPID controller was presented for the isolated and interconnected power system in [13], however, authors have not concentrated on the impacts of deregulated environment, reheat turbine and GRC (generation rate constraint). In addition, other various researches are carried out by various authors in whom the FOPID controller was enhanced in deregulated power system. The controller's factors are resolute by genetic algorithm-firefly algorithm (GA-FA) algorithm. Also, the comparison is made between FOPID controller's and PID controller's performance. Though, authors have not taken into account the nonlinearities' impacts. Moreover, the FOPID controller is compared with ANN (artificial neural networks), GA (genetic algorithm) and fuzzy logic, for 2-area interconnected power system which represents that FOPID based AGC approach is robust as compared to other approaches.

III. Related Work

L. C. Saikia, et.al, in the paper [14] focuses on interconnected 2 area thermal system's automatic generation control. In the control areas, suitable GRCs (generation rate constraints) were taken into account. The comparison was made between performances of various conventional controllers such as, Integral (I), Proportional plus Integral plus Derivative (PID), Proportional plus Integral (PI), and recently proposed typical controller in AGC called as Proportional plus Integral plus Double Derivative (PIDD) controller. It was comprehensible by the analysis that PIDD is more efficient as compared to other controllers.

R. Maurya and M. Bhandari proposed the design of FOPID controller for the linear system [15]. The FOPID controller was optimized with convetional PID controller which provides efficient result. In this paper, in order to assess the controller's parameters, 2 tuning method were utilized i.e Ziegler-Nichols and Astrom-Hagglund method.

I. Pan and S. Das had analyzed the FO (fractional order) AGC (automatic generation control) applicability for oscillation damping of power system frequency by using distributed energy generation, in paper [16]. The parameters of controller were tuned with the help of robust optimization methods using various PSO variants and the comparison was made between it and the other analogous best solutions. In order to minimize the function evaluations' number for robust optimization techniques, an archival-based approach was utilized. The way outs achieved with the help of robust optimization manages the huge alterations in controller gains and orders without degrading the performance of the system.

S. Debbarma and L. C. Saikia, had analyzed the impact of FOPID controller in AGC of interconnected 2 unequal or 3 unequal area thermal systems taking into account suitable GRC(generation rate constraint), in the paper [17]. In order to design the best controller by maintaining the setting of frequency bias fixed at the frequency response features, the ISE (integral square error) approach was utilized in the form of performance index. The FOPID controller's performance was analyzed and contrasted with various integer-order (10) typical controllers. The research made it clear that FOPID controller with 5 tuning knobs are robust and offers better dynamic performances with regards to settling time and minimization in frequency oscillation and dynamic response of tie line power deviation in contrast to all ten traditional controllers.

L. C. Saikia and S. Debbarma, in the paper [18], presented the FOPID controller in 2- equal area thermal system's AGC under bilateral policy approach based deregulated environment. In the system, suitable GRC was taken into account. The FOPID controller's performance was analyzed and contrasted with various integer-order (10) typical controllers. Bacterial Foraging (BF) approach is used in this paper in order to optimize various parameters. It was analyzed from the study that fractional order proportional-integral-derivative controller gives optimal performance with regards to magnitude oscillation, settling time in contrast to other ten controllers.

H. Shayeghi, et.al, proposed the optimization of FOPID controller with the help of SSO (Social Spider Optimization) algorithm to LFC of 2-area multi-source power system in existence of DGs (Distributed Generations) [19]. There are 3 major control parameters of FOPID controller i.e., integrator's fractional orders, known gain and derivate part which gives optimal performance than PID controller. Also, it was significantly required to tune these parameters in order to obtain the optimal performance in power system. Thus, with the help of SSO algorithm, the LFC controller based on FOPID was tuned optimally. Moreover, in order to enhance the LFC task's dynamic performance, the HVDC (High Voltage Direct Current link) was utilized.

Sanjoy Debbarma1, et.al, in the paper [20] had described the application and design of 2-DOF-FOPID (2-Degree-of-Freedom - Fractional Order PID) controller in order to resolve the problem of AGC (automatic generation control) of hydrothermal and multi-area system consisting of various sources like, thermal, gas and hydro units. For every unit, suitable GRC (generation rate constraints) was taken into account. The comparison was made between the presented two-DOF-PID controller's and various typical controllers' performance for the hydrothermal and multi-area system. With the help of CSA (Cuckoo search Algorithm) algorithm, every controller's optimal factors were selected. The presented controller provides minimum overshoots and oscillations and enhanced settling time which demonstrates that it is the optimal one. Moreover, the presented controller parameter's robustness was analyzed by the sensitivity scrutiny.

Thus, it was analyzed from all the traditional works that firstly the PID and PIDD controllers were proposed for the AGC of the system and then FOPID controllers were designed for linear systems in which convetional tuning parameters were regarded such as, Ziegler-Nichols and Astrom-Hagglund method. After that, the FOPID controllers for AGC of multi-area systems were designed in which the parameters of the controller were tuned using various optimization techniques such as, PSO, SSO, BFO, Cuckoo search optimization etc. Though, this work can be enhanced further by using various other optimization techniques for tuning of parameters.

IV. Conclusion and Future Scope

Various conventional works of different researchers on the FOPID controller are analyzed in this paper. In this paper, the brief description about FOPID controller and its structure is provided and the different variations of the fractional PID controllers are explored. From the analyzed works, it has been concluded that in the control areas, suitable GRCs (generation rate constraints) were taken into account and also, it is required to tune the parameters of controller so that the controller can provide minimum overshoots and oscillations and enhanced settling time. In the conventional works, the parameters of controller were tuned with the help of diffferent robust optimization methods such as PSO, BFO, Cuckoo search optimization, SSO.

It is regarded by the scrutiny that in future, this work can be enhanced further in order that the parameters of the controller can be tuned by using various optimization algorithms.

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