



A Peer Survey on Load Frequency Control in Isolated Power System with Novel Topologies

Namburi Nireekshana, R. Ramachandran, G. V. Narayana

Abstract: Electrical Power systems are paramount intricate system which built by human beings, therefore this type of systems should maintain stable and to get upgrading for upcoming days need multiple control techniques. In these convoluted power systems voltage frequency plays a major role. Hence frequency has to control proper. To control frequency of voltage has three control techniques are primary, secondary and also tertiary frequency control techniques. Thereby second technique also known as Load Frequency Control[1], It is to maintain the desirable frequency even after occurrence of disturbance. Several techniques have been used (like classical, adaptive) to mitigate the power flow disturbances, but drawbacks (parameters tuning, cyber-attacks) are having in these methods. This paper proposes soft computing techniques to build up the operation, control and then stability of the electrical power system.

Keywords: load frequency controlling, power system structure, control methods

I. INTRODUCTION

The novel power systems status is growing inch by inch because of emergence of low cost, profuse wind, solar and fossil cell energy sources in distributed energy systems[2] as renewable energy sources are giving boosting and digitalization grow thing. These factors may lead to growing of structural power systems[3].

Primary frequency helps out in sustaining the frequency stability of frequency, balancing of the power generation and load consumption pertaining to the grid[3] [4]. When the lack of balance occurs in between load and generation, the frequency of power systems will get change, at that time primary frequency control responds in fastest way. It is automatic control and the purpose is to clear unbalance conditions between source and load, in order to take the system in stable mode[1]. This control is compulsory for all generators in power systems areas. Once primary frequency control finished its work, if the frequency value different from nominal value and power exchange between interconnected systems different from predefined value, therefore it is necessary to restore the nominal frequency[5]. In this situation secondary control comes into picture.

The secondary frequency control is plays lead role in controlling the frequency in power systems structures like 1,2, 3 4 and multi area electrical power systems[6]. Every single area will be allotted with set of generators coupled with each other, which helps in forming an organised group[7]. So that all machines will react simultaneously to changes in load. Firstly, any changes in load are governed by speed governing system[3].

Tertiary frequency control is supreme to restore the session in transmission system operator (TSO).The tertiary control is not automatic but it needs when grid operator's request, its importance follows the same rules of rest of the frequency control techniques_[1]_[8]. In power systems Automatic generated control is a system for adjusting the power flow deviations and frequency of different generators at multiple power plants. Load Frequency Control helps to maintain stable frequency[9] [8]. Therefore Automatic Generated Control is called as Load Frequency Control[10].

A. Objective of Load Frequency Control

Govern the nominal frequency variations and power flow deviations then outcomes give improvement of the power system stability, operation and control.

II. REVIEW METHODOLOGY

Multiple papers reviewed to learn about the importance of load frequency control and knowledge has gained. As a part of extensive review, a reputable and honoured database such as IEEE, Scopus, SCI, Energies, Elsevier. This database has been very helpful to write the article on load frequency control strategies. These are tabulated in table 1.

Table.1 illustration of review methodology adopted

ID	Number	Usage
IEEE	12	60%
Elsevier	8	60%
Energies	8	50%
Books	5	50%
Articles	7	70%

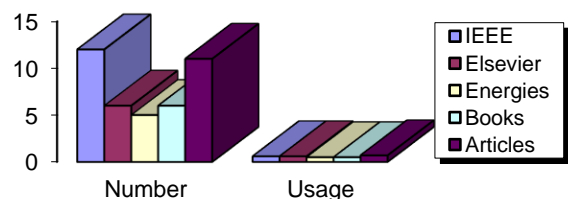


Figure 1 .Chart for review methodology adopted

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Correspondence Author

Namburi Nireekshana*, Department of Electrical Engineering, Annamalai University, Annamalai Nagar (Tamil Nadu), India. Email: nireekshan222@gmail.com

R.Ramachandran, Department of Electrical Engineering, Annamalai University, Annamalai Nagar (Tamil Nadu), India. Email: ramachandran.auee@gmail.com

G.V.Narayana, Department of Electrical Engineering, JNTU Kakinada, Guntur (A.P), India. Email: gv1.venkata@gmail.com

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1. Necessity of frequency as constant value

Few reasons are examined for control the frequency variations.

- The speed of synchronous and asynchronous motors depends on the frequency of supply. Here speed should maintain consistency with follows constant frequency [10].
- If the turbine blades are damaged the generator will stop because of nominal frequency 50 Hz falls down to 47 Hz or goes up to 52hz. Therefore should maintain frequency in stable mode.
- In case of power transformer frequency operation conditions, if frequency gets below nominal value, the power transformer winding is over heated and will give low efficiency. Hence frequency values should maintain desired level to get the constant flux for constant voltage [11] [12]
- Most of the AC machines runs by particular speeds which are straight correlated to frequency. Their speed and developed EMF may vary with respect to change in the nominal frequency [13] [14].
- Many devices connected to the grid will only work properly when the input frequency is within certain range[15].
- For parallel power stations running , it is mandatory that frequency of the generators must remain constant for synchronization [16].
- Frequency effects the transmission of interconnected lines[17] [18].
- Household appliances are most sensitive to frequency variations and also gets damaged with changes in frequency.

III. LITERATURE REVIEW

3.1 Control Area Concept Isolated Power System

Most of the machinery (Generators) in any area incorporate a well-organized family so, that their speed can be controlled with respect to power angle [19] in the sense

all the generators are unison with their speed changer setting, load variations, maintaining constant frequency under steady state and dynamic responses .Control area has speed governing , turbine and load models. As shown figure 3.1

Consider

- K_p = gain of the system
- T_p = Power system time constant
- K_g = Generator gain
- K_t = Turbine gain
- T_g = Generator time constant
- T_t = Turbine time constant
- ΔP_d = Power change in load
- ΔP_g = Power change in generation
- $\Delta F(s)$ = Change in frequency
- $\Delta X_t(s)$ = Change in steam valve opening
- R = speed regulation of the governor

3.1.1 Steady state analysis [20]

Three possible steps are there to get steady state response

1. Constant speed changer setting & variable load (uncontrollable) [20]
2. Constant load (controllable) & variable speed changer setting [20]
3. Constant speed changer setting & constant load[20]

3.1.2 Dynamic state analysis

Dynamic response gives the relation between variations in frequency with respect to time for a small change in load for a particular load frequency system[20].

3.2 Speed governing system[21] mainly controls real power flow, which consists of (shown in figure 3.2)

- First stage of Speed governing system
- Second stage of Linkage tool system
- Third stage of Hydraulic elaboration system
- Final stage of acceleration of speed system

3.2.1 First stage of Speed governing system

The heart of this system is a fly ball type governing system, which senses the speed or else frequency [20] [21].

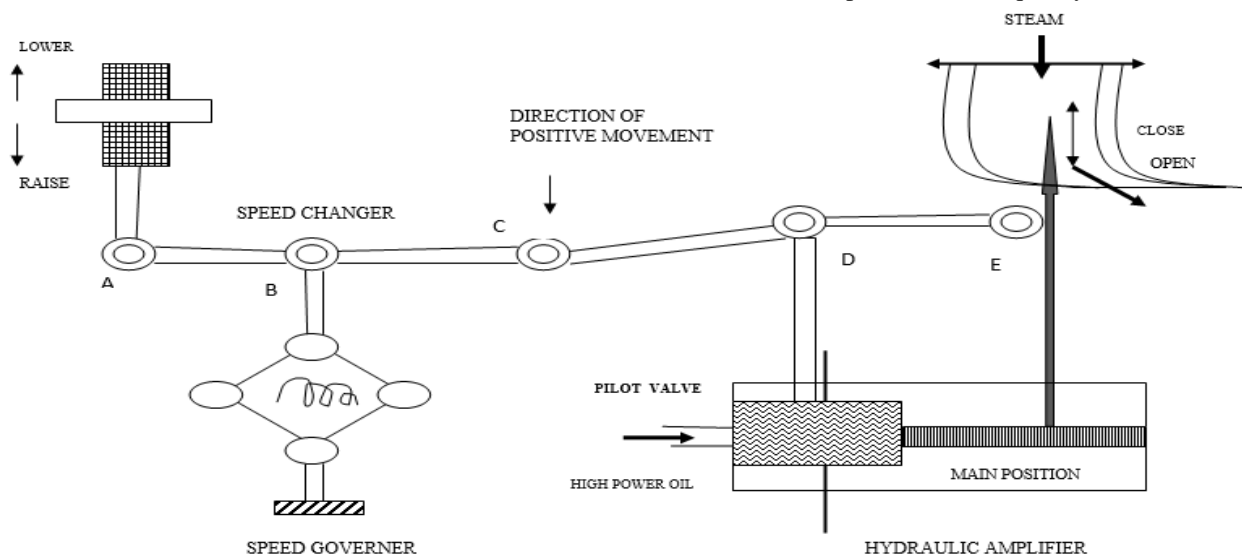


Figure 3.2 Speed governing system

3.2.2 Second stage of Linkage tool system

This system yields a moment to control valve position in corresponding to changes in the speed [20] [21].

3.2.3 Third stage of Hydraulic elaboration system

Which consists of main piston and pilot valve[20] [21].

3.2.4. Final stage of acceleration of speed system

An acceleration of speed system produces the steady state power output[20] [21].

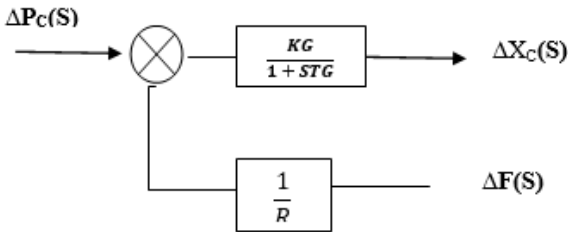


Figure3.2.1. Block diagram of speed governing system

3.3 Turbine Model

This model gives the relation between varieties in steam turbine power output and change in steam valve position ΔXt [20].

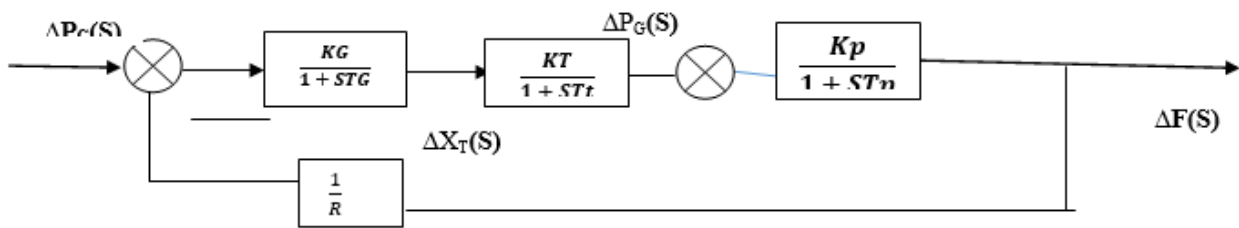


Figure 3.1.Complete diagram of isolated power system

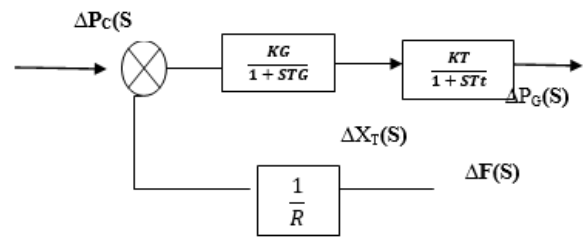


Figure. 3.3. block diagram of turbine model

3.4 Load Model

This model offers the relation between time and change in the nominal frequency results in change in generation[21] [20].

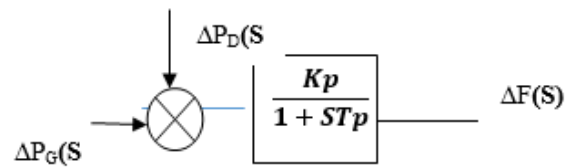


Figure .3.4.Block diagram of load model

IV. ADOPTED PROPOSAL

4.1 Mathematical model of LFC

Basically, an optimization problem, which of these can be written like F1(t),F2(t)...,Fm(t)[22]

t= (t1, t2...tm)

Generally

Hn(t) equal to 0, (n=1, 2...)

Kn(t) less than or equal to 0, (n=1, 2...)

And, where F1, F2...Fm are the objectives, and Hn, Kn are the equality and inequality constraints, respectively [22].

If m=1 ... single-objective

m = 2, it becomes a multi objective problem and solution scheme is different from single objective [22].

Load frequency control mechanism is basic and simple used in power system operation and control when load varies where an unbalance between active and reactive powers occur. Which control the active power through interconnecting line by sensing the changing power flow[23] [24]. In Interconnected power systems, all areas are interconnected through tie line systems, here any area controlled by control area and tie lines allows power flow among the interconnected systems [25]. If get any small variations in load in any interconnected areas so that the tie line power flow will be disturbed, thereby all areas of output frequencies will be affected. In such type situations must gathered all information about all areas transient state to

restore the nominal tie line powers and area frequency in interconnected systems [26]. In interconnected power systems are tied with all other neighbouring systems shown in figure 4.1.

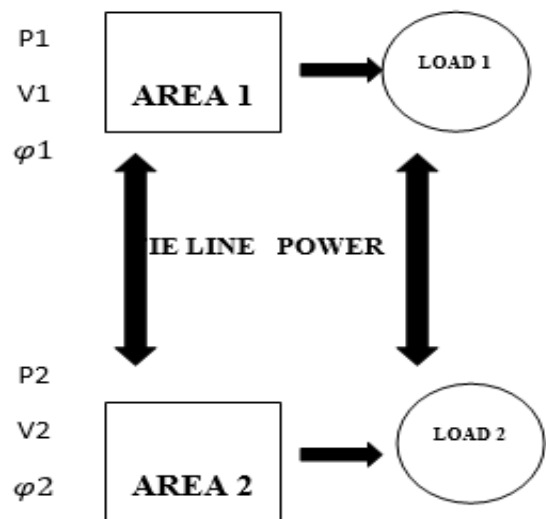


Figure4.1. Two area structured power system



Consider two generators are running parallel, in which load changes occurs. to get balancing of generators production have various frequency control methods as follows

1. If the P1 generator alone is regulated to have constant frequency, this type of regulation is called flat frequency regulation [21] [27].
2. If both generators P1, P2 are regulate to maintain constant frequency, it is called parallel frequency regulation [21] [27].
3. the generator takes care of the variations in a particular area, there by maintaining the tie line load constant, here to maintain constant frequency is known as flat tie line loading control[21] [27].

Consider

ϕ_1 & ϕ_2

= power angles of equivalent machines of two areas

P_{r1} = rated capacity of area 1

P_{r2} = rated capacity of area 2

P_{tie1} = power transmitted from area 1

P_{tie2} = power transmitted from area 2

T_{12} & T_{21} are the synchronous co efficient

Power transmitted from the area 1 is given as

$$P_{tie1} = \frac{V_1 V_2}{X_{12}} \sin(\phi_1 - \phi_2)$$

Power transmitted from the area 2 is given as

$$P_{tie2} = \frac{V_2 V_1}{X_{21}} \sin(\phi_2 - \phi_1)$$

For the incremental changes in power angles the incremental line power can be represented as [27]

$$\Delta P_{tie1} = T_{12} (\Delta \phi_1 - \Delta \phi_2)$$

$$\text{Where } T_{12} = \frac{V_1 V_2}{P_{r1} X_{12}} \cos(\phi_1 - \phi_2)$$

For the incremental changes in power angles the incremental line power of area 2 can be represented as

$$\Delta P_{tie2} = T_{21} (\Delta \phi_2 - \Delta \phi_1)$$

$$\text{Where } T_{21} = \frac{V_2 V_1}{P_{r2} X_{21}} \cos(\phi_2 - \phi_1)$$

4.2 Classification of LFC adoptive techniques

To bring the frequency under one palm in all areas of this interconnected system, LFC will be adopted few control strategies [10] [28]. These techniques will be helpful in maintaining constant tie line frequency and control the power flow disturbances. These control techniques are beneficial for the normal and abnormal conditions of loads to get the real frequency and power of pre specified value [29] [30]. Control techniques are classical, adaptive, intelligent and soft computing types [31]. Based on application of control will be picked from them. The total classifications shown in figure 4.2

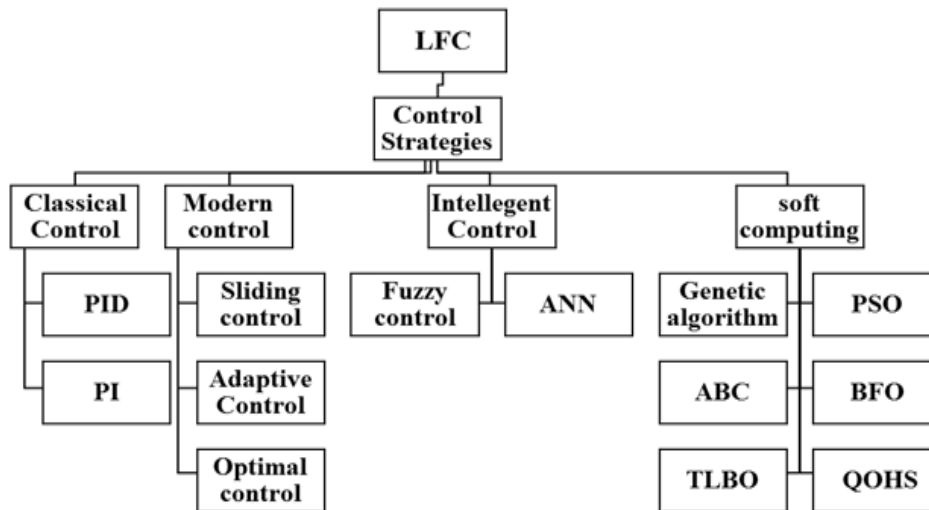


Figure 4.2. Classifications of LFC control techniques

In classical control strategies mostly used techniques are PID and PI. These techniques help to set the actual frequency and power from a process predefined value or set point as possible. And also help to analyze the phase margin and gain margin using nyquist and bode plot methods. But these classical techniques are poor in optimally tuning the parameters of load frequency, robustness and cyber-attack issues [32].

In modern control or optimal control strategies commonly involved methods are sliding control, adaptive control and optimal control [33]. These methods are developed to provide the solution, system has state variable models such as system state vector, therefore this type of control techniques are given accurate solutions, if all the state variable are consider to design closed loop control systems. But these strategies are lag performance in large scale power system applications [9].

In intelligent control strategies fuzzy and ANN are strongly involved. This type of techniques help to govern the frequency and power issues [9]. In order to mitigate the load

frequency and power of tie line of interconnected systems in power system structure, have to be analysed the peak over shoot, peak undershoot and setting time [34].

Therefore intelligent control strategies can easily analyse the above responses and establish the solution. But these techniques are lag in explicit parameters identification. Sometimes controller is complicated and unrealistic [35].

Finally **soft computing methods** are frequently used and get benefited in inter connected systems for load frequency control [31]. In which mostly used control schemes are G.A, PSO, ABC, BFO, TLBO and QOHS. These techniques are made to solve nonlinear problems and introduced the human intelligence such as cognition, recognition, understanding, and learning by means of these control schemes involve to reach tractability and robustness on simulating the human decision-making behavior with desirable cost [36].



Genetic algorithm provides consistency of tuning of parameters, the load parameters changes accordingly load. Conventional control schemes cannot maintain consistency of tuning of parameters[37], but GA can do.GA provides desirable dynamic response for the control system.

PSO stands particle Swarm Optimization is one of the finest method in soft computing control scheme family to supervise the frequency and power. It is helps to find approximate solution to difficult maximization or minimization problems. It is easy and simple algorithm to implement. Which scheme is used to solve the frequency regulation problems in inter connected systems[38].

ABC stands Artificial Bee Colony have investigated from the intelligent scavenge honey bees behaviour. This ABC algorithm is specifically based on model of scavenge behaviour of honey bee colonies [39]. The model contains three parts such as employee and unemployed foraging bees, and food sources. The first two components, employed, unemployed foraging bees search for third component i.e. rich food sources. Therefore in this method, a colony of artificial forager bees like agents search for wealthy artificial food sources. In order to analyze the system nominal frequency and tie-line power flow with respect load changes, ABC scheme have been used[40].

BFO stands Bacterial Foraging Optimization was developed based on nature-inspired optimization method, this one is taken based on the bacteria’s foraging behavior. In LFC this scheme provides clampdown of oscillations in power system. And also helps to analyze for optimal controller parameters by keep down the time domain analysis.

TLBO stands Teaching Learning Based Optimization is a teaching-learning process developed algorithm and it is made on the impact of a teacher on the outcomes of students in a the lecture hall. TLBO involve to solve continuous as well as disjointed optimization problems in single or multiple objectives. This scheme consists of two modes of operations such as teacher and learner point of views. This mechanism is used to brush up the transient response of the structure of the power systems [41].

Generally Fertilizers are used to kill insects on the cotton field and many methods have been adopted to market the cotton for good profit using natural fertilizers and farming methods as well as There are several methods used to obtain quality power by controlling the frequency based on various load applications in the power system areas[42]. Some of them are listed in the table2

Table 2 Load Frequency Analysis

Structural Power Systems	Control techniques	Novel Applications
<p style="text-align: center;">↓</p> <ul style="list-style-type: none"> • multi area power systems • Single • Two • Three 	<p style="text-align: center;">↓</p> <ul style="list-style-type: none"> • PID • Centralized & decentralized • GA • PSO • FUZZY • ANN • Variable structure control 	<p style="text-align: center;">↓</p> <ul style="list-style-type: none"> • HVDC • Deregulation • Distributed energy generation • Smart grid • Micro grid

V. CONCLUSION

Soft computing methods are increasingly playing a major role in controlling the frequency of the load in the electrical structured power system area to suit the present days conditions. Therefore better results can be obtained by using soft computing techniques for govern the nominal frequency and power flow disparities and also mitigate these problems.

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AUTHOR'S PROFILE



Namburi Nireekshana, graduated from JNTU Hyderabad with 75% aggregate and received Master of Technology from JNTU Hyderabad with 76%, research scholar in Annamalai University under the esteemed guidance of Dr. M. Ramachandran and Dr. GV. Narayana. He is working on load frequency control area.



Ramachandran.R., working as Assistant Professor in Annamalai University in Electrical Engineering Department. He awarded PhD degree on deregulated power system, power system analysis, transmission system. He has 19 years of teaching experience.



G.V. Narayana, is working as Professor and HOD, in Guntur Engineering College in Electrical and Electronics Engineering Department. He received PhD on advances in min-max fair power flow tracing for loss allocation.