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Optimizing Automatic Load Frequency Control Parameters Using Bacteria-based Optimization Algorithm: A Simulation Study

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Abstract: This study presents an analysis of the operation of the Automatic Load Frequency Control (ALFC), in which load fluctuations cause frequency and voltage deviations, which in turn cause generation losses due to grid intervention and also outages of energy. These deviations can be minimized by Automatic Generation Control (AGC), which consists of two sections, namely Charge Frequency Control (LFC) and Automatic Voltage Regulation (AVR). Here, the simulation evaluation is done to find out how the LFC works by creating models in SIMULINK, which helps us to understand the principle of LFC, including the challenges. In addition to the two-surface systems, the three-surface system, the one-surface system, is also considered. Several important ALFC parameters, such as the integral controller gains (KIi), the parameters for the controller speed control (Ri), and the parameters for the frequency deviation (Bi), are optimized using an optimization technique which is the algorithm to optimize the search for bacteria. (BFOA), because the use of the general hit and try method in simulation has certain drawbacks that insisted on the use of BFOA to obtain the desired values of the different parameters.

Keywords: *Load fluctuations, grid intervention, automatic generation control, load frequency control, automatic voltage control and speed control*

I. INTRODUCTION

Power systems are very large and complex electrical networks, composed of production networks, transmission networks and distribution networks, as well as loads distributed in a large geographical area throughout the network [1]. Power systems are used to convert natural energy into electrical energy. They bring electricity to factories and homes to meet all kinds of electrical needs. To optimize the performance of electrical devices, it is important to ensure the quality of electrical power. It is known that three phase alternating current (AC) is generally used to carry electricity. During transportation, the active power balance and reactive power balance between the generation and use of alternating current should be observed. These two equilibria correspond to two equilibrium points: frequency and voltage. If any of the balances are broken and restored to a new level, the breakeven points will fluctuate. A good quality of the electrical network requires that both the frequency and the voltage are kept at standard values during operation. For North America, the standard values for frequency and voltage are 60 Hertz and 120 volts, respectively. However, electricity consumers change their load randomly and temporarily. It will be impossible to balance active and reactive power without control. Due to imbalance, voltage and frequency levels vary with varying loads. Therefore, a control system is essential to cancel the effects of random load changes and keep the frequency and voltage at their default values. Although active power and reactive power have combined effects on frequency and voltage, the problem of frequency and voltage regulation can be decoupled. Frequency is highly dependent on active power, while voltage is highly dependent on reactive power. Therefore, the problem of control in energy systems can be decoupled into two independent problems. One is for frequency and active power control, the other is for voltage and reactive power control. The control of active power and frequency is called load frequency control (CFL) [1]. In the electricity grid, the system load changes from time to time according to the needs of the consumer. Therefore, to maintain the stability of the electrical network and ensure its reliable operation, properly designed controllers are required to regulate fluctuations in the system. The rapid growth of industries has further increased the complexity of the energy system. Frequency is highly dependent on active power and voltage is highly dependent on reactive power. Therefore, the difficulty of controlling the energy system can be divided into two parts. One is related to the control of active power and frequency, the other to reactive power and voltage regulation [2]. Active power control and frequency control are commonly known as Automatic Load Frequency Control (ALFC).

1.1 Properly Designed Power System Characteristics:

- You must provide electricity virtually anywhere the customer needs it.
- You must always provide electricity.
- You must always meet ever-changing load requirements.
- The electricity supplied must be of good quality.
- The energy supplied must be cheap.
- The necessary safety requirements must be observed.

The electrical energy supplied must meet minimum supply quality requirements. The superiority of the diet can be decided as follows:
a) The frequency of the network must be increased by the specified value, i. H. 50 Hz.
b) The bus voltage level remains within the prescribed limits around the normal value.
The voltage and frequency controls are the prerequisites for the correct operation of the electrical network.

1.2 Control Area Concept

A control is interpreted as a system to which we can apply the common generation control or the load frequency control scheme. A self-managed zone is generally called a control zone. The electrical connection in each control zone is very strong compared to the connections in the center of the adjacent zones. In a control zone, all generators come and go in a logical and coherent way, which is represented by a certain frequency. The difficulty of automatically adjusting the load frequency of a large and cohesive power system has been investigated by dividing the entire system into a series of control ranges and defining them as multi-range ranges [3].

1.3 Control Types

1) Primary control: this type of control is sought locally to maintain the balance between production and demand in the network. It is detected by the speed of the turbine regulators, which regulate the generator power in response to the frequency deviation in the area. In the event of a serious interruption, the primary control balances the power generated and consumed with a frequency differentiable from the set point to stabilize the network.
2) Secondary control: this type of control is carried out by an automatic process centralized in the control module.
It has two objectives:

- Maintains the exchange power by connecting the control block and adjacent blocks according to the expected value.
- If the frequency drops sharply, point to the frequency reference

As a result, the pressure will rise more and the liquid will be ejected at the impeller's outlet with a high pressure head where the impeller's radius is greater. The liquid will be discharged to a high level thanks to this high pressure head.

1.4 Problem Statement

1.4.1 Estimation Problem to Optimization Problem

The estimation problem relies on empirical or measured data to approximate the values of unknown parameters used by the measured data set. The optimization problem is based on the process of finding the best solution among the possible solutions related to a particular objective, which is reached in several steps. The best solution is called the optimal value. Here the optimization technique is used to find the values of the controllable factors that determine the behavior of the system and minimize the objective function that represents the errors that occur due to load variations.

1.4.2 Tie Line Power Problem

In the case of a system of two machines and two loads, the load variation of the two machines must be taken into account so that both machines participate equally in the transverse power distribution and also maintain the stability of the system value error.

1.4.3 Load Frequency Problem

When the load on a system changes, the system frequency also changes. Closed-loop control would not be necessary if it were not important to keep the system frequency constant. Typically, the frequency would vary by about 5%. from light load to full load.

II. LITERATURE REVIEW

Yao Zang, "Load Frequency Control of Multi-Range Power Systems", Tsinghua University, July 2007, Master of Science in Electrical Engineering. In an interconnected network, as the electrical load demand changes randomly, the span frequency and power exchange between the lines also change. The objectives of load frequency control (LFC) are to minimize transient variations of these variables (span frequency and link power exchange) and ensure that their steady-state errors are zero. In solving the LFC problem of power systems, unexpected external disturbances, parameter uncertainties, and power system model uncertainties pose major challenges for controller design. Little system model information is needed and it is resistant to disturbances and uncertainties. This work presents an ADRC-based solution to the LFC problem. The controller is designed for a three-zone power plant with multiple turbine units, including plumbing, heating, and non-heating units in different zones. The dynamic model of the network and the design of the controller based on it are elaborated in the graduation thesis. The results of the simulation and the frequency domain analysis showed that the ADRC controller is interesting for the LFC problem in terms of its stability and robustness.
Adil Usman BP Divakar "Simulation study of load frequency control of single and double flow systems". IEEE Global Conference on Humanitarian Technology, pp. 214-219, 2012 Unpredictable load variation in an electrical system causes frequency and voltage to deviate from their nominal values, leading to generation losses due to line faults and even blackouts. Frequency and voltage drifts can be minimized and kept within tolerable limits thanks to automatic generation control. The automatic generation control of a system consists of two parts; Charge Frequency Control (LFC) and Automatic Voltage Regulator (AVR). In this document, a simulation study is carried out to understand the operation of the charge frequency regulato through the development of models in SIMULINK. Simulation study helps students understand the principle and challenges behind charge frequency controllers.
H. Bevrani, Y. Mitani, and K. Tsuji, "Robust Decentralized Control of Charge Frequency Using an Iterative Linear Array Inequality Algorithm", IEE Pro. General Transfer. Distribution, volume 151, nº 3, p. 347-354, 2004. During magnetic inrush or overexcitation, saturation of the transformer core draws a large exciting current that can cause an

RCD to malfunction. The article describes a solution, its implementation in a current compensated residual current relay and its evaluation using an EMTP-based simulator and relay test equipment. The relay uses the same holding current as a conventional relay, but the differential current is modified to compensate for the effects of the excitation current. Before the core saturates, the relay calculates the core leakage current and uses it to modify the measured residual current. If the core then goes into saturation, the initial value of core flux is obtained by inserting the modified differential current at the beginning of saturation into the magnetization curve. The actual core flow that occurs during a fail or no-fail event, such as g. The magnetic inrush current, or overdrive, is derived and used with the magnetizing curve to calculate the magnetizing current. A modified residual current is then derived which compensates for magnetizing and core leakage currents. The operating performance of the current compensated residual current relay was compared with that of a conventional residual current relay. The results show that the compensated relay remained stable during overexcitation and high magnetic inrush current because the excitation current was successfully compensated. The document ends with the implementation of the relay in a hardware platform based on a digital signal processor. The relay correctly distinguishes magnetic inrush current and overexcitation from an internal fault and is not affected by the amount of residual flux.

UKRout, RKSahu, S. Panda, "Design and Analysis of Automatic Generation Control Based on the Differential Evolution Algorithm for Interconnected Networks", Ain Shams Engineering Journal, Vol. 4, No. 3, p.409, 2013. This article presents the design and performance analysis of a proportional-integral (PI) controller based on differential evolution (DE) algorithms for automatic generation control (AGC) of a composite fuel system. For the purposes of design and analysis, an unheated two-zone heating system equipped with PI controllers is considered, which is widely used in the literature. The design problem is formulated as a control optimization problem, and DE is used to find optimal control parameters. To improve the performance of the controller, three different objective functions are derived using the integral time by multiplying the absolute error (ITAE), the damping ratio of the dominant eigenvalues, and the settling time with appropriate weighting coefficients. The superiority of the proposed DE-optimized PI driver was demonstrated by comparing the results with some recently published modern heuristic optimization techniques, such as the Bacterial Search Optimization Algorithm (BFOA) and the Genetic Algorithm (GA)-based PI driver for same interconnected network.

Where, **MA Pai and IA Hiskens**, "Simulation and optimization in a post-deregulation AGC system," IEEE Transactions on Power Systems, vol. 16, p. 481–489, August 2001. This study presents a conventional controller-based method for automatic generation control (AGC) of power systems, including superconducting magnetic energy storage devices. In conventional studies, frequency transients are minimized by using traditional proportional and integral controllers for secondary control in the AGC and, after sufficient latency, zero steady-state error is achieved.

III. METHODOLOGY

A. The Power System Dynamics

Automatic charging frequency control circuit is mainly associated with large generators. The main purpose of automatic load frequency control (ALFC) may be to maintain the desired fixed frequency for load sharing between generators, as well as manage cross-energy sharing based on predicted values. Various components of the charging frequency automatic control circuit are shown in Fig. 1

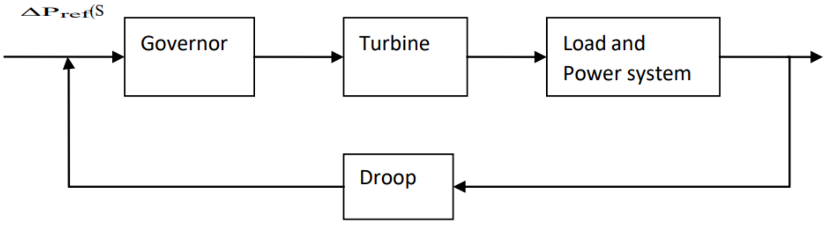

Fig. 1: Block diagram of Automatic load frequency control

B. Turbines

Turbines are used in electrical systems to convert natural energy, such as energy derived from steam or water, into mechanical energy (Pm) that can be easily supplied to the generator. The model shows the turbine,

$\frac{\Delta Pt(S)}{\Delta Pv(S)} = \frac{Kt}{1+Tt}$ - (1)

Where,
$\Delta(S)$ = the output from the turbine
$\Delta(S)$ = the input to the turbine

C. Load

The power system load consists of a large number of electrical devices. Resistive loads, such as lighting loads and heating loads, are not dependent on frequency, but motor loads respond to frequency based on speed load characteristics, as shown below:

$\Delta Pe = \Delta PL + D\Delta\omega$ - - - - - - - - - - - - - - - - - - - (2)

Where,
ΔPL = non frequency responsive load change
DΔω = frequency responsive load change

IV. RESULT AND DISCUSSIONS

Simulation Result of Automatic Load Frequency Control

Using simulation models, we can quickly and easily obtain system performance indicators for analysis. Below are the Simulink models of the various systems with their responses plotted over time. Here we consider one-zone, two-zone, and three-zone systems.

A. Single Area System without Using Secondary Loop

TABLE 1: System parameters for single area system without using secondary control

Name	Kg	Tg(S)	Kt	Tt(S)	H(S)	D(puMW/Hz)	1/R
Value	1	0.20	1	0.50	5	0.80	30

B. Single Area System By Using Secondary Loop

TABLE 2: System parameters for single area system by using secondary control

Name	Kg	Tg(S)	Kt	Tt(S)	H(S)	D(p.u.MW/Hz)	1/R	K1
Value	1	0.20	1	0.50	5	0.8	20	7

C. Two Area System without Using Secondary Loop

TABLE 3: System parameters for two area system without using secondary control

Name	Kg	Tg(S)	Kt	Tt(S)	H(S)	D(p.u.MW/Hz)	1/R	ΔPL(p. u)
Area 1	1	0.20	1	0.50	5	0.60	20	0
Area 2	1	0.30	1	0.60	4	0.80	16	1

D. Two Area System by Using Secondary Loop

TABLE 4: System parameters for two area system by using secondary control

Name	Kg	Tg(S)	Kt	Tt(S)	H(S)	D(p.u.MW/Hz)	1/R	ΔPL(p. u)	K1
Area 1	1	0.20	1	0.50	5	0.60	20	0	7
Area 2	1	0.30	1	0.60	4	0.90	16	1	7

E. Three Area System without Using Secondary Loop

TABLE 5: System parameters for three area system without using secondary control

Name	Kg	Tg(S)	Kt	Tt(S)	H(S)	D(p.u.MW/Hz)	1/R	ΔPL(p. u)
Area 1	1	0.80	1	0.30	10	1.00	15	1
Area 2	1	0.20	1	0.50	5	0.60	20	0
Area 3	1	0.30	1	0.60	4	0.90	16	0

F. Three Area System by Using Secondary Loop

TABLE 6: System parameters for three area system by using secondary control

Name	Kg	Tg(S)	Kt	Tt(S)	Tp(S)	H(S)	D(p.u.MW/Hz)	K1	1/R	ΔPL(p. u)
Area 1	1	0.80	1	0.30	20	10	1.00	7	17	1
Area 2	1	0.20	1	0.50	10	5	0.60	7	20	0
Area 3	1	0.30	1	0.60	8	4	0.90	7	16	0

V. CONCLUSION

The thesis mainly studied the frequency variation as well as the connection power variation due to load variation and also the techniques that can be used to obtain the optimized values of various parameters in order to minimize the variations. On the one hand, a secondary control is introduced to minimize frequency deviations. This is often essential in the case of a single zone system or an isolated system, because the secondary control circuit, i. H. an integrated controller, generally responsible for reducing variations in frequency deviations and maintaining system stability. Therefore, without the presence of a secondary loop, the system loses stability.

The interconnection of two or more systems is introduced to deal with load variations due to cross-energy exchange. The interconnection of two or more zones ensures the distribution of energy between the systems during periods of load variations that can occur in any zone at any time. Therefore, the load on the drives to minimize frequency variations is reduced because the increased power demand can be met by acquiring power from neighboring domains, thus maintaining system stability. Third, an optimization technique, i. H. An algorithmic program to optimize the search for bacteria in order to modify the values of the different parameters present in the electrical system studied so that it can cope with variations in load demand. This reduces frequency variations as well as cross line power and also maintains system stability. It can also be seen that the BF technique has faster convergence properties. The BF technique is very useful to obtain optimized values of different parameters compared to the general punch and try technique, which is an extremely tedious and time-consuming method. Surveys have been conducted for one zone systems, two zone systems and three zone systems and the results are provided accordingly.

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