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Cultural Algorithm Based AGC of Distributed Generation System

Pooja Soni[1] and Virendra Jain[2]

[1]*M.Tech. Energy Technology Mandsaur University, Mandsaur*
[2]*Assistant Professor, Mandsaur University, Mandsaur*

Abstract—*Automatic Generation Control (AGC) is the key approach to frequency and voltage regulation in power systems. As electrical power generation and consumption are characterized by a continuous balance of momentary generation and usage their control becomes and is a leading issue of the operation of the electrical power system. Automation and control of a system appear in a transparent form whenever the possible disturbances and irregularities are defined and put forward as a challenge. Generally speaking there are external and internal sources of disturbances. Since the power system is geographically widely spread and exposed to nature there are influences due to weather, forestry and agriculture. On the other hand the system may be affected by human failures or malfunction of equipment. Finally, disturbances may due to aging of components. This research work deals with the load frequency control of Distributed Generation Systems (DGS) consisting of Wind, Solar and Diesel Generator. The power generation, power deviation and frequency deviation performance of the developed system has been evaluated by using different P, PI, PID and Cultural Algorithm (used for tuning of Ziegler-Nichols PID) controller.*

Keywords: *Automatic Generation Control, Distributed Generation Systems, Ziegler-Nichols PID, Cultural Algorithm.*

1. INTRODUCTION

Voltage regulation in power systems and distribution networks both at high and low voltage is a task that is performed daily for normal operation and without service interruptions to the user, now with the implementation of distributed generators Which are being located at points near the user, in many cases, located for the supply of the same user and with the possibility of delivering power to the distribution network, voltage regulation becomes the main point of investigation for an effective operation With these generators, that is why this research is important, since the voltage regulation will become a more complex problem with the integration of these types of generators.

With the introduction of distributed generators (DGs) the micro networks have changed their unique source structure and the radial mode of operation of the distribution systems; in addition the impact of these can be analyzed in many ways. From the output characteristics of the DGs depending on their position in the distribution network and the mode of operation. The secondary voltage regulation in an intelligent network is the process that is carried out according to the behavior of distributed generators (DG), which can be wind or photovoltaic, that regulator must be sure to maintain the voltage within a permissible range, In order to ensure the normal operation of the DG. Because of their intermittent form of operation, these DGs are not constantly injecting power to the system, and in these DGs they must at some point disconnect from the network due to some disturbance within the DG, to perform some kind of maintenance, or simply not this injecting power to the network.

Traditionally, the voltage regulation, either for high or low voltage, is normally performed with the tap variation, thus becoming a very simple on-off control type, where the tap is modified under load in order to maintain the voltage level Within a set range, causing this subject to possible problems in the instability of the power system by the unexpected variation of the load.

2. PROBLEM STATEMENT

The electric power system is undergoing a rapid transformation to a smart grid, the so-called Smart grid. Microgrid, as the building blocks of smart grids, is small-scale power systems that facilitate the effective integration of distributed generators (DGs). Proper control of a micro grid is a prerequisite for the stable and economically efficient.

Operations of smart grids. A Micro grid can operate in both connection modes, connected to the network and in island mode.

Conventional micro grid secondary controls assume a centralized control structure that requires a complex communication network, in some cases, with two-way communication links. This can adversely affect the reliability of the system. On the other hand, cooperative distributed control structures, with a poor communication network, are suitable alternatives for the secondary control of micro grids. Distributed cooperative control was recently introduced in power systems, to regulate the output power of multiple photovoltaic generators.

In the last two decades, system elements have gained a lot of attention because of their flexibility and computational efficiency. These systems are inspired by natural phenomena such as a swarm of insects, gathering in birds, laws of thermodynamics, and synchronization and phase transitions in physical and chemical systems. In this phenomena, the process of coordination and synchronization requires each element of information exchange with other elements according to some restricted communication protocols.

3. OBJECTIVE

1. Design an automatic generation control system of wind, solar and diesel generator using P, PI and Cultural Algorithm optimized Ziegler-Nichols PID controller.
2. Performance evaluation is recorded on the basis of power generation, power deviation and frequency deviation performance of the developed system.

3.1 PID CONTROLLER

PID regulators account for more than 90% of industrial requirements and the number of regulators installed in an oil plant, for example, is in the thousands. Unfortunately, in spite of the experience gained over the years, the values chosen for parameters P, I and D are neither always satisfactory nor adapted to the process to be regulated.

A PID controller essentially fulfills three functions:

- It provides a control signal (t) taking into account the change in the output signal (t) with respect to the setpoint (t).
- It eliminates the static error thanks to the term integrator.
- It anticipates the variations of the output thanks to the term derivative.

The conventional PID regulator directly connects the control signal (t) to the deviation signal (t). Its temporal description is as follows:

(t)=$(e(t)$+1Ti∫$e(t)dtt$0+$Tdde(t)dt$) (1)

With the difference defined as follows:

(t)=(t)−$y(t)$ (2)

It’s transfer function is written as:

(s)=$(s)E(s)$=Kp(1+1sTi+sTd) (3)

This combination of the terms P, I and D is also referred to as parallel or non-interactive form. The functional diagram of a process regulated by such a regulator is given in Figure 3.1. In addition to the signals described above, the disturbance (t), the measurement noise (T) and the non-noisy output signal (t).

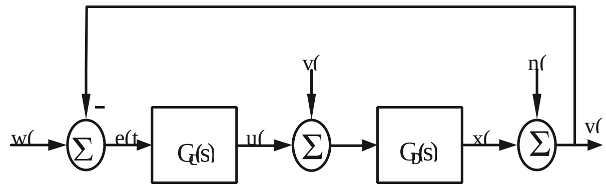

Figure 3.1: Block diagram of a process set by a conventional PID

4. PROPOSED METHODOLOGY

4.1 Ziegler-Nichols PID

In 1942, Ziegler and Nichols [20] proposed two heuristic approaches based on their experiment and some simulations to quickly adjust the parameters of the regulators P, PI and PID. PID regulators meet more than 90% of industrial requirements and the number of regulators installed in an oil factory, for example, is counted in thousands, the values chosen for the parameters P, I and D are not always satisfactory or adapted to the process to be regulated.

$$p(t) = K_P e(t) + K_I \int_0^t e(t)dt + K_D \frac{de(t)}{dt}$$

Where the $p(t)$ is the control input to diesel generator. $e(t)$the error i.e. change in frequency. K_P,K_I,K_D are the proportionalintegral and derivative constants. The Ziegler-Nichols method is a heuristic method of tuning PID controller. It was developed by John G. Zeigler and Nathaniel B. Nichol [21]. It is performed by setting theK_I and K_D to zero, the K_P gain is increased (from zero) until it reaches the critical ultimate gainK_U, at which the output of the loop begins to oscillate.

4.2 SYSTEM MODEL

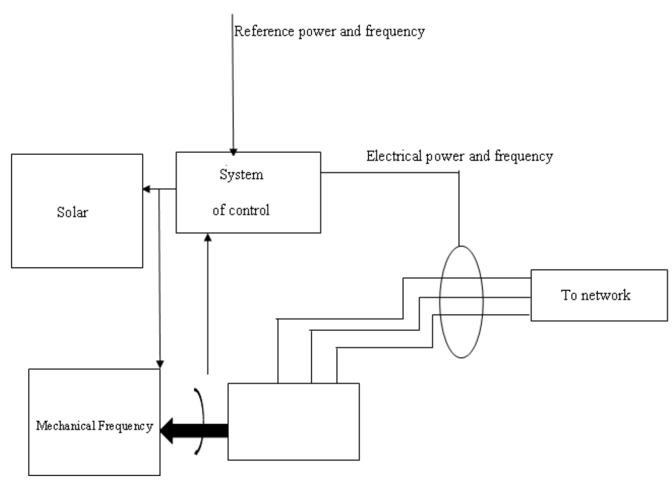

Figure 4.1: System Model

4.3 Optimization K_P, K_I and K_D using Cultural Algorithm (CA)

Inspired by the process of social and cultural changes, the CA was developed to enhance evolutionary computation. Besides the population component that evolutionary computation approaches have, there is an additional peer component belief space and a supporting communication protocol between these two components, which makes CAs perform better in some special optimal cases than other evolutionary algorithms (EAs). The following figure presents the basic CA framework.

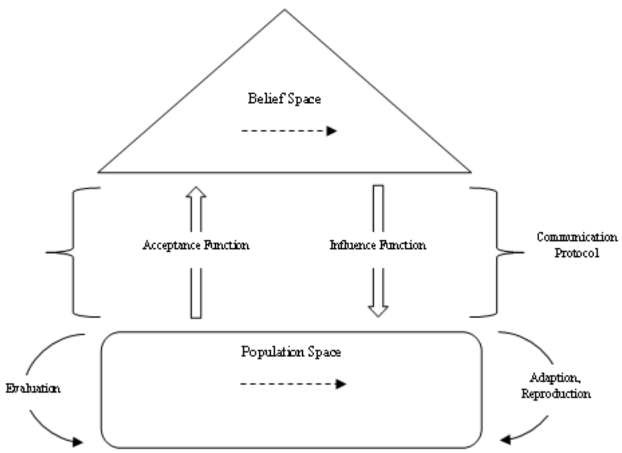

Figure 4.2: CA framework [35]

As Figure 4.2 shows, the population space and the belief space can evolve respectively. The population space consists of the autonomous solution agents and the belief space is considered as a global knowledge repository. The evolutionary knowledge that stored in belief space can affect the agents in population space through influence function and the knowledge extracted from population space can be passed to belief space by the acceptance function.

In the process of the CA evolution, the population space is initialized with candidate solution agents at random; meanwhile, the initial knowledge sources in the belief space are built. At first the two spaces evolve independently. Then the selected agents from the population space are used to update the belief space. After the knowledge sources being updated, the belief space will reversely guide the evolution of the population space. These procedures repeat till a termination condition has been reached. The CA pseudo code presented by [35] is given as follows:

t=0;

Initialize Population POP(t);

Initialize Belief Space BLF(t);

Repeat

Evaluate Population POP(t);

Adjust (BLF(t), Accept(POP(t)));

Adjust (BLF (t));

Variation(POP (t) from POP (t-1));

Until termination condition achieved

4.4 Fitness Function for Optimal K_P, K_I and K_D

Tuning methods based on integral error criteria consider the entire closed-loop response i.e. total DGs. The following performance indices are used to calculate the Integral of the Absolute square of the error (IAE).

$$IAE = \int_0^t |e(t)|\, dt \tag{1}$$

Integral of squares error (ISE)

$$ISE = \int_0^t |e(t)|^2\, dt \tag{2}$$

Integral of time weighted absolute error (ITAE)

$$ITAE = \int_0^t t|e(t)|\, dt \tag{3}$$

Integral of time squared error (ITSE)

$$ISE = \int_0^t t|e(t)|^2\, dt \tag{4}$$

5. SIMULATION RESULTS OF PROPOSED WORK USING CULTURAL ALGORITHM

5.1 Case-1

The load is suddenly increased at 100 seconds from 0.9pu to 0.95pu, Wind Power 0.6 pu and solar power is 0.3 is kept constant. In this case, a sudden increase of load demand from 0.9puto 0.95 pu is under taken at 100 sec. This change in load demand is met by diesel generator.

The Cultural Algorithm optimized controller is implemented and power generation, power deviation and frequency deviation are observed and presented in following figures. It is found that the response with PID controller is better than the P and PI.

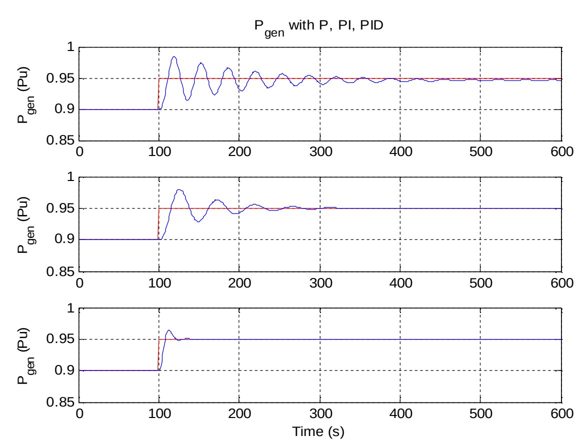

Figure 5.1: Power generation in system with P, PI and PID in case-1 using Cultural Algorithm

5.2 Case-2

Wind Power is suddenly decreased from 0.6 to 0.4 at 100 sec. and other remains constant at P_L=0.9pu and P_{sol}=0.3 pu

In this case the wind power reduces from 0.6 pu to 0.4 pu, at 100 sec. and the system dynamics are observed. The simulation results are presented in following figures:

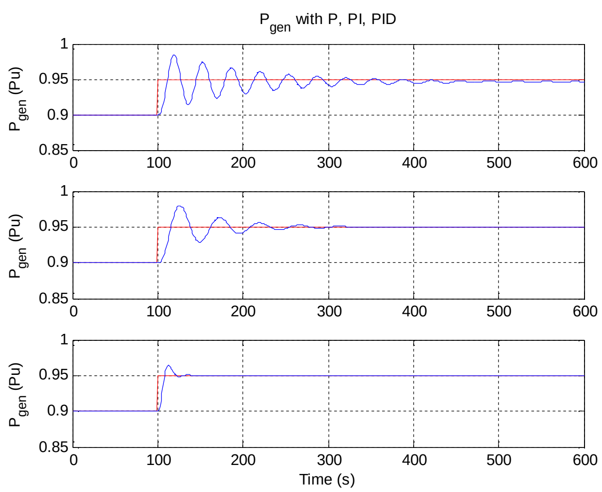

Figure 5.2: Power generation in system with P, PI and PID in case-2 using Cultural Algorithm

5.3 Case-3

Solar Power is decreased from 0.3 to 0.2 at 250 secondP_L=0.9 and P_w=0.6 is kept constant. In this case the solar power reduces from 0.3 pu to 0.2 pu, at 250 sec. The simulation results are presented in following figures.

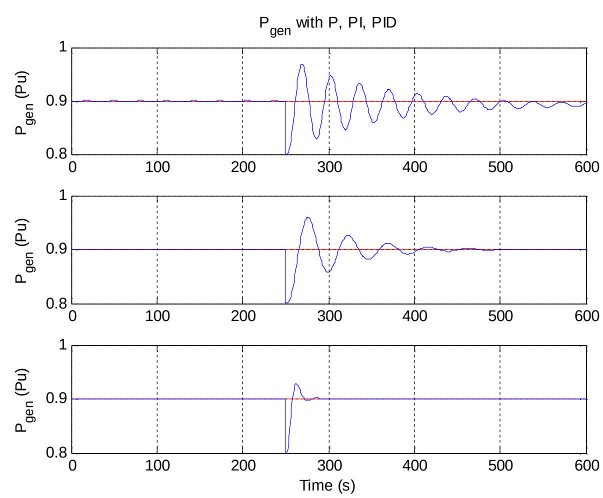

Figure 5.3: Power generation in system with P, PI and PID in case-3 using Cultural Algorithm

6. CONCLUSION

Automatic generation control (AGC) plays an important role in power system as its main role is to maintain the system frequency and tie line power flow at their scheduled values during normal period and also when the system is subjected to small step load perturbations. In this research work, the performance of automatic generation control of wind, solar and diesel generator can be evaluated by proposed controller. The Cultural Algorithm (For tuning of PID) controller is proposed to overcome the AGC problem. To demonstrate the effectiveness of proposed controller, the control strategy based on evolutionary (CA) and conventional (P, PI, PID) technique is applied. The performance of these controllers is evaluated through the MATLAB simulation and it shows that the proposed technique gives better dynamic performances on the basis of power generation, power deviation and frequency deviation. It can be concluded that the evolutionary technique (CAusing for tuning of Ziegler-Nichols PID controller) outperforms the conventional controllers.

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