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Applying Genetic Algorithm to Adjustment PID Coefficients in Order to Power Control of Micro-Turbine in Island Condition

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Abstract: The ever increasing energy demand, along with the necessity of cost reduction and higher reliability requirements, are driving the modern power systems towards Distributed Generation (DG) as an alternative to the expansion of the current energy distribution systems. This paper is aimed to introduce the new controller in order to control of output power of one of the most important types of distributed generation namely micro-turbine, during system load variations. Micro-turbine output power should be control against the load variations in island mode condition and a controller should be designed for this purpose. Here, the PID Controller is used which its coefficients are optimized based on Genetic Algorithm. Simulation results are done for various loads in time domain, and the results show the efficiency of the proposed controller.

Key words: Controller design, distributed generation, genetic algorithm, micro-turbine, optimization

INTRODUCTION

Power generation has seen an increased penetration of Distributed Generation (DG) in recent times. Distributed generation systems, powered by microsources, such as fuel cells, photovoltaic cells, and microturbines, have been gaining popularity due to their higher operating efficiencies, improved reliabilities, and lower emissions. A part of the distribution system with its sources and loads can form an isolated electric power system-a microgrid (Daniel Salomonsson and *et al*., 2009). During normal operating conditions, the microgrid is connected to the ac grid at the Point of Common Coupling (PCC). Although full benefits of high depth of penetration of DG units are gained if a microgrid or a smart grid can be operated in both grid-connected and islanded (autonomous) modes. The current utility practice and the existing standards do not permit such islanded operations. The main reason is the safety concerns associated with that portion of the utility grid that remains energized as a part of the island. However, there are provisions to permit islanded operation of a DG unit and its dedicated load, if the island does not include any portion of the utility grid. In this context, the DG unit operates analogous to an Uninterruptible Power Supply (UPS) for the load (Houshang Karimi and *et al*., 2008).

Until now, only few works were undertaken on the modeling, simulation and control of micro turbines in island mode. There is also a lack of adequate information on their performances. A dynamic model for combustion gas turbine has been discussed in (Rowen, 1983; Hannet and Afzal 1993; Working Group, 1994; Hannett *et al*., 1995).

In (Daniel Salomonsson and *et al*., 2009), in order to feed to vector controlled induction motor drive and other static loads, micro turbine based Distributed generation system is implemented. The Micro turbine provides input mechanical energy for the generator system. Aspects of dynamic modeling and simulation of fuel cell and micro-turbine units as a part of a multi-machine electrical network investigated in (Ahmed and István Erlich, 2003).

Lecture (Guda *et al*., 2005) demonstrated the development of a micro turbine model and its operation with a permanent magnet synchronous generator. A non-linear model of the micro-turbine is considered and implemented in NETOMAC software (Nikkhajoei and Iravani, 2002).

In Suter (2001), proposed an active filter for MT. Adaptive control of fuel cell and MT is well described in (Jurado and Saenz, 2003). Authors, Gaonkar and Patel (2006) demonstrated the development of a MT model from the dynamics of each part which is suitable for studying various operational aspects of the same.

In this study a simple PID Controller for micro-turbine power control has been used except that the controller design has not been achieved through trial and error. But the problem has been proposed as an optimization problem and then solved by using Genetic Algorithm. About the advantages of the proposed control, we can point followings:

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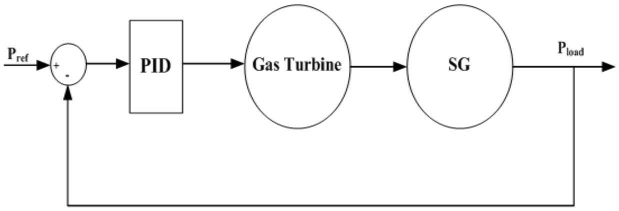

Fig. 1: Study system contain of gas turbine and synchronous generator

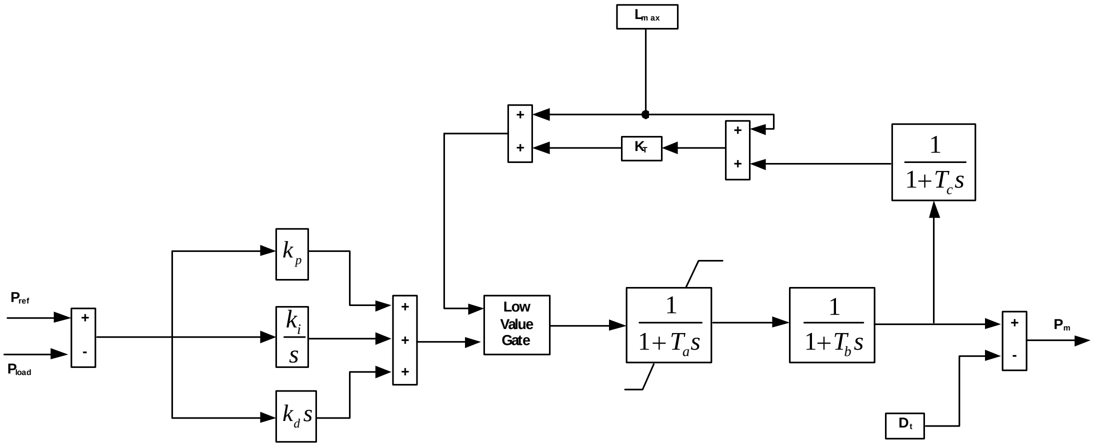

Fig. 2: Single shaft gas turbine including all its control systems

Table 1: Parameters of shaft gas turbine

Parameters	Value
Rated power	100 KW
Real power reference	1.0
Damping of turbine, Dt	0.03
Fuel system lag time constant , Ta	10.0 s
Fuel system lag time constant , Tb	0.1 s
Load limit time constant, Tc	3.0 s
Load limit, lmax	1.2
Maximum value position, Vmax	1.2
Minimum value position, Vmin	- 0.1
Temperature control loop gain, KT	1.0

- controllers are simple
- being robustness against load changes
- fast transient response
- zero steady error

METHODOLOGY

System description: Originally, there are two kinds of small gas turbines, high speed single shaft turbines and split shaft turbines. In the single shaft turbines, the alternator generates a very high frequency three phase signal ranging from 1500 to 4000 Hz. The high frequency voltage is first rectified and then inverted to a normal 50 or 60 Hz voltage. In the split shaft design, a conventional induction or synchronous machine is mounted on the power turbine via gearbox and the power inverters are not required (Saha *et al*., 2008).

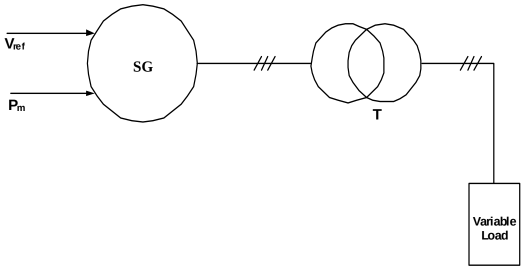

Fig. 3: Synchronous generator, transformer and local load

The study system in this paper that the proposed algorithm applied to this system is shown in Fig. 1. This system contain PID controller, split shaft gas turbine and synchronous generator. The simplified single shaft gas turbine including all its control systems is shown in Fig. 2. All of parameters in this figure are given in Table 1.

Figure 3 shows the synchronous generator, Transformer and local load. A step-up transformer is

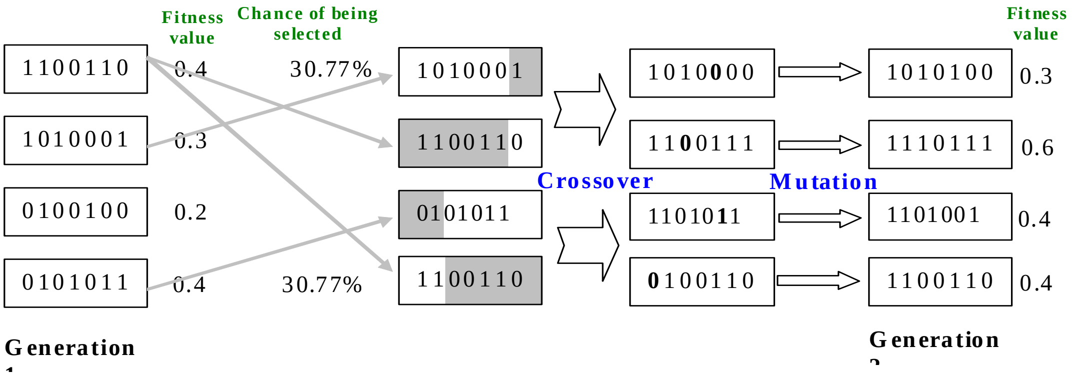

Fig. 4: Schematic genetic algorithms to solve a hypothetical problem

Table 2: Synchronous generator and load parameters

Parameter	Value
Rated power	100 KW
Rated voltage	440 V
Frequency	60 Hz
Number of poles	2
Damping factor,	KD0.06 p.u.
Inertia constant	0.822 s
Internal resistance,	R0.04 p.u.
Internal reactance, X	0.3 p.u.
3-ph source base voltage	11 KV
Dist. trans. nominal power	200 KVA
Frequency	60 Hz
Dist. trans. primary voltage	11 KV
Dist. trans. secondary voltage	440 V

located between synchronous generator and local load in order to change the voltage level. Vref and Pm are the input of Synchronous generator that Vref is set to 1 p.u and Pm provides bye gas turbine. All parameters of synchronous generator, transformer and local load present in Table 2.

Controller design:

GA algorithm: Genetic algorithm is a stochastic search method based on genetic concepts, that is used to solve the optimization problem to achieve optimal solution or a solution close to that optimal solution. In an optimization problem that its optimization parameters are $K = [k_1,k_2,\ldots,k_n]^T$. At first, some general points within the range which called population are selected randomly, and then these points are coded. Usually the code boxes are formed by from 0 and 1. Figure 4 displays optimal solution by genetic algorithm for a hypothetical problem in which the population consists of four code box. These boxes are called chromosomes. Each chromosome, is a volunteer to solve the optimum value. Chromosome growth should be in the direction that results in an optimal solution for the problem. For the next chromosomes producing, each chromosome is evaluated in the function value. Each of these chromosomes which have higher function values are more valuable. The probability of each chromosome selected for reproduction depends on the function value. For example, in Fig. 4 function value of each chromosome is equal to the number of 1s in the box. For each pair of parents from selective chromosomes, two infants are created by basic operator namely crossover (Haupt and Haupt, 2004). Crossover from single-point are different from the other crossovers. In a single- point crossovers, a crossover point is selected randomly, thenfrom the starting point, binary codes to the crossover point are carried from parent to parent and vice versa (Fig. 1). And in the next step (i.e., Mutation) a bit of chromosome is reversed. Then these processes continue and optimization is done (Russell and Norvig, 2007).

Using GA to adjust controller parameters: With so much development in controlling systems and making applicable of these controllers, in power system, simple controllers are still considered desirable controllers. In most cases in the power systems, compensators are PID controllers. And these controllers can be implemented easily in analog and digital systems. In this paper, PID controller is used to control voltage of load voltage of micro-turbine in island condition. The overall controller schematic is shown in Fig. 5.

Controller general form is expressed in Eq. (1). The controller parameters must be optimized include:k_p,k_i,k_d It is clear that the transient mode of the system in the load variations depends on the controller coefficients. Controller design methods are not viable to be implemented because this system is an absolute nonlinear system. So these methods would have not efficient performance in the system:

$$G_c(s)=k_p+\frac{k_i}{s}+k_d s \qquad (1)$$

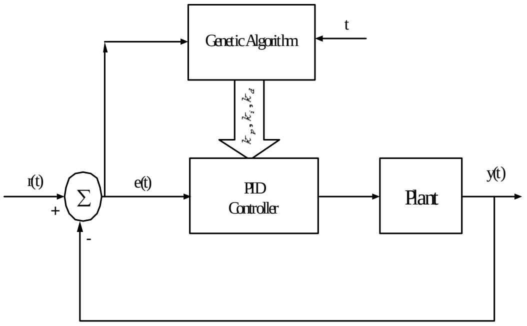

Fig. 5: Scheme of design proposed controller

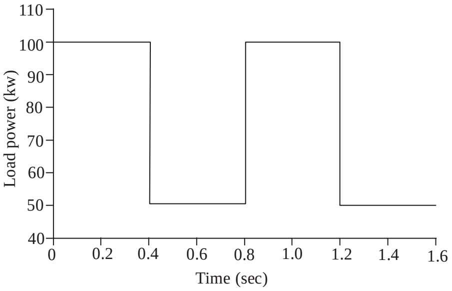

Fig. 6: Worst condition for load power

In order to design controller using Genetic Algorithm for the micro-turbine from the load power curve, we consider the worst condition for load design controllers for these conditions. Figure 6 displays the worst condition for load power in the system.

Now, problem should be written as an optimization problem and then be solved. Selecting objective function is the most important part of this optimization problem. Because, choosing different objective functions may completely change the particles variation state. In optimization problem here, we use error signal:

$$J = \int_{0}^{t=tsim} \left| P_{ref} - P_{load} \right| dt \qquad (2)$$

where, tsim is the simulation time in which objective function is calculated. We are reminded that whatever the objective function is a small amount in this case the answer will be more optimized. Each optimizing problem is optimized under a number of constraints. At this problem constraints should be expressed as:

$$\begin{aligned} &k_p^{\min} < k_p < k_p^{\max} \\ &k_i^{\min} < k_i < k_p^{\max} \\ &k_d^{\min} < k_d < k_d^{\max} \end{aligned} \qquad (3)$$

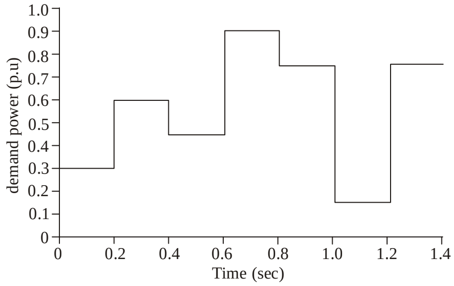

Fig. 7: Power demand for micro-turbine in island mode

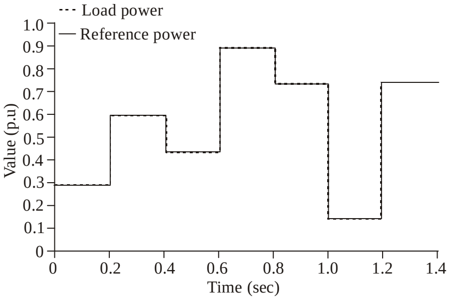

Fig. 8: Reference and output power related to the proposed controller

where k_p, k_i are in the interval [0.01 300] and k_d in the interval [0.001, 10].

In this problem, the number of particles, dimension of the particles, and the number of repetitions are selected 40, 3 and 50, respectively. After optimization, results are determined as below:

$$k_p = 157.2354 \quad k_i = 237.2285, \quad k_d = 0.027817 \qquad (4)$$

SIMULATION RESULTS

To show good performance of the proposed algorithm, we consider variable load in order to supply by micro-turbine in island mode. Desired load power is shown in Fig. 7. As can be seen, desired load is changing between the range of 0.15 to 0.9 per unit which change within 14 sec, and the numbers of its changes are considered more to show the performance of the proposed controller.

Simulation output results obtained from the proposed algorithm which is expressed in Eq. (4) are shown in Fig. 8, 9 and 10. Figure 8 depicted the output power of micro-turbine that provides the demand loads in island mode and reference power. From this figure, it can be seen that by changing load power; supplied power change quickly to keep stable the output frequency of the micro-turbine under the desired voltage and this show good performance of the proposed controller albeit simplicity. In Fig. 9

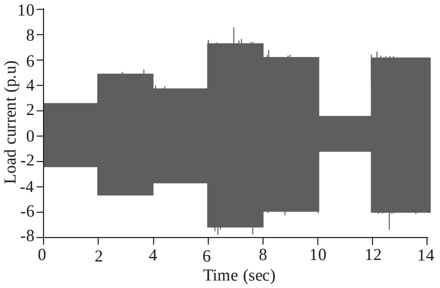

Fig. 9: Load instantaneous current related to the proposed controller

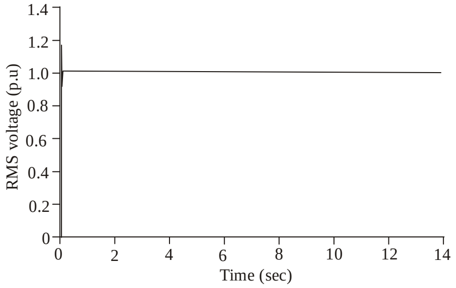

Fig. 10: Micro-turbine output voltage related to the proposed controller

instantaneous of output current of load for phase (a) is shown, according to the figure it is obvious that controller response is appropriate and it could control the output current of mention system properly. In Fig. 10, the load voltage is plotted which the high efficiency of the proposed algorithm shown clearly.

CONCLUSION

In this study, a new controller based on Genetic Algorithm and PID controller to control the micro-turbine output power in island mode was proposed. This controller is chosen because of its simplicity and because the implementation of this controller is simple and it could obviate the problem of the previous controller and its efficiency is higher than previous controllers. GA algorithm was utilized to design the PID controller to have the most optimized state. In solving this problem, at first problem was written in the form of the optimization problem which its objective function was defined and written in time domain and then the problem has been solved using GA. And the most optimal mode for gain coefficient of controller were determined using the algorithm.

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