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PI Controller Design for Photovoltaic Systems in Islanding Mode Operation

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Abstract:-In this paper, an optimal controller to control photovoltaic system using Genetic Algorithm (GA) is proposed. First, this problem will be formulated as an optimization problem consisting of objective function and constraints and then to attain the most desirable controller, GA technique could be used to solve the problem. Simulation results are performed for load variations in time domain and by depicting the obtained results this controller's robustness will be verified. Also, simulation results show the proper performance of the proposed controller to reach this goal.

Key words: Renewable energy · Controller design · Genetic Algorithm (GA) · Photovoltaic systems

INTRODUCTION

Due to the consumption growth of fossil fuels in recent years and given that these fuels will be exhausted in future, it is essential to use the renewable energy sources, such as water and wind power and photovoltaic system. To utilize these kinds of energy sources, it is required to convert them into electrical energy. Water and wind usually produce the electrical energy by turning the prime movers [1-2].

Some of these distributed generation sources are connected to the network directly and/or others through the power electronic interfaces which the latter is used commonly to connect the distributed generations to the network [3].

The major challenge of a DG performance, with connected and separated local load, is that the DG should be equipped with a VSC having the controls meet the following conditions:

- The inverter should be able to maintain the voltage and frequency of the DGs.
- Regardless of the plant parameters, the inverters should be able to feed the predetermined load.
- VSC control should be on the feedback from the local load [4].

In [5], a controller is proposed to keep constant voltage and frequency for wind turbine connected to the network through the power electronic devices. An adaptive controller has been proposed in [6] to reduce losses and increase reliability of DC Micro-grids. Small signal dynamic model and transient mode of Micro-grid including distributed generations with electronic interfaces is discussed in [7 and 8]. Current control strategies for the DG units in islanding mode of Micro-grid based on active/frequency and reactive power/voltage drops is the method which has been founded in [9] base on it.

In this paper, a simple PI controller is used to control the output voltage of photovoltaic systems in islanding mode, except that this controller's coefficients are not obtained using trial and error method, but for optimization in this study the genetic algorithm (GA) is adopted to obtain the coefficients but GA technique is utilized. First the problem is formulated as an optimization problem and then the optimization problem is solved using a genetic algorithm and the optimal results of PI coefficients are obtained. Simulations using MATLAB /Simulink have been carried to test the effectiveness of the proposed controller.

Study System: The study system is shown in Figure 1, in which the DG has been depicted equally as a DC source and a VSC connected through low pass filter to the local load. Total impedance of the low pass filter is displayed as Rt and Lt. The system parameters are given in Table 1.

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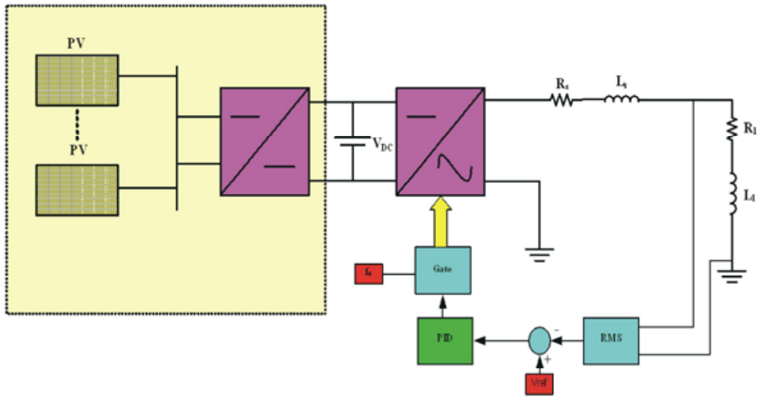

Fig. 1: Photovoltaic system with battery, inverter and load

Table 1: The value of the study system parameters

Parameter	Value
V_{DC}	350v
R_s	1 Ω
L_s	7mh
R_l	50 Ω
L_l	35Mh
V_{ref}	220v
f_0	50HZ
Nominal Power	1KW
Nominal Frequency	50HZ

The system should be able to operate in off-grid mode. In grid-connected mode, the intermediate VSC will be a current-controlled voltage source controller, i.e. the typical strategy operates for VSC unit. In this paper, the goal is to achieve a desirable controller which is able to keep constant the load voltage in islanding mode for load variations. And because the generated energy by photovoltaic system is stored in a battery, therefore the photovoltaic system can be considered as a constant voltage source.

Genetic Algorithm (GA) Introduction: algorithm is a stochastic search method based on genetic concepts which 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 optimizaion parameters are . 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 (2) 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 Figure (2) function value of each chromosome is equal to the number of 1s in the box. For each pair of parents from

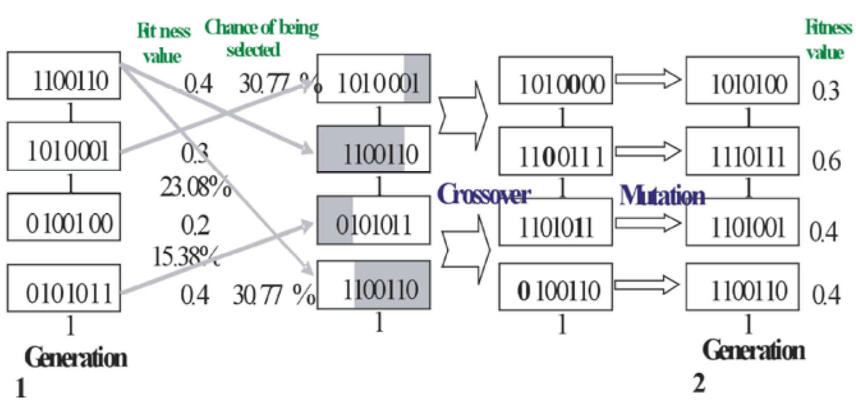

Fig. 2: Schematic representation of genetic algorithm for an assumptive optimization

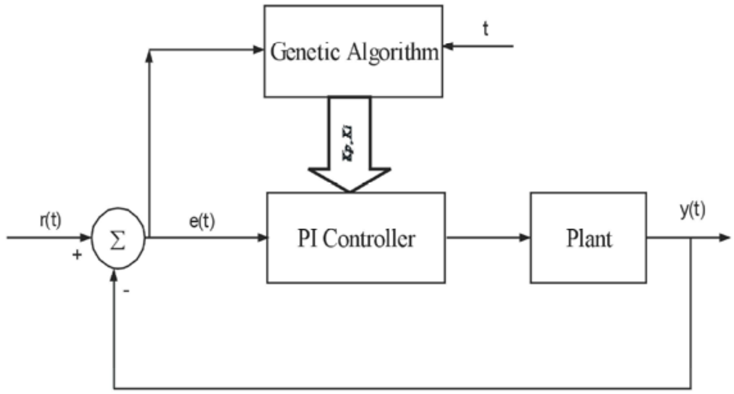

Fig. 3: Block diagram of the proposed controller to control the system

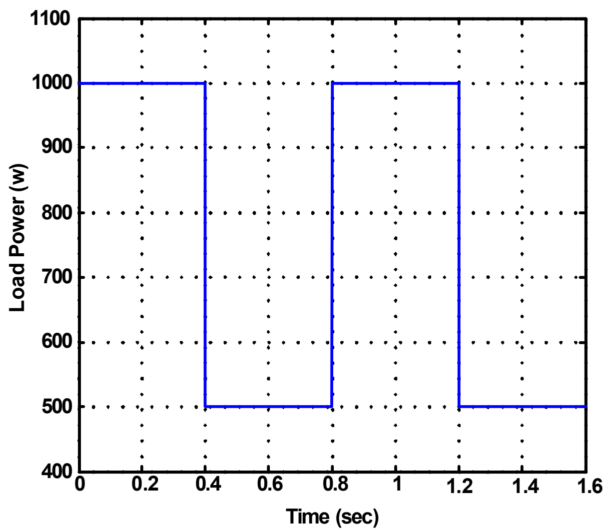

Fig. 4: The worst load condition for the system

selective chromosomes, two infants are created by basic operator namely crossover [10]. 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 (Figure 2). And in the next step (i.e, Mutation) a bit of chromosome is reversed. Then these process continue and optimization are done.

Using Ga to Adjust Controller Parameters: With the 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. And these controllers can be implemented easily in analog and/or digital systems . In this paper, PI controller is used to control the system. The overall controller schematic is shown in figure (3).

The controller parameters must be optimized include: It is clear that the transient mode of the system in the load variations depends on the controller coefficients. Controller design method 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.

In order to design controller using genetic algorithm for the system for the load variation curve, we consider the worst condition for load and design controllers for these conditions. Figure (4) displays the worst condition for load variation in the.

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, the selection of different objective functions may completely change the particles variation state. In optimization problem here, we use error signal.

$$J = \int_0^{t=tsim} |v_{out} - v_{ref}| dt \quad (6)$$

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:

$$\begin{aligned} &\textit{Minimize J subject to} \\ &K_p^{\min} \le K_p \le K_p^{\max} \\ &K_i^{\min} \le K_i \le K_i^{\max} \end{aligned} \quad (7)$$

Where, Ki, Kp in the range of [0 5].

In this problem, the number of particles, dimensionof the particles and the number of repeatations are selected 40, 2, 30, respectively. After optimization, results are determined as below:

$$K_p = 0.002, K_i = 0.045 \quad (8)$$

RESULTS AND DISCUSSION

In this section, simulation results are performed for different loads and output power results show the proposed controller robustness. First the load of system is 550W and 120Var and the DG could supply the mentioned load. At instant t = 0.4sec, a load with active and reactive powers P = 130W and Q = 30Var respectively is added to the system and also the same amount of load in at t = 0.8sec and t = 1.2sec is added to the system and finally the active and reactive power of systems reach P = 940W and is Q = 210Var, respectively. Simulation Results are shown in terms of these values in figures (5), (6) and (7). According to the figure (5), it is clear that during load variations the load voltage has constant value. Figure (6) depicts the load current in terms of load variations. According to the figure it is obvious that the system response is fast and current increases rapidly with load variations. In figure (7), active and reactive power of load is shown which according to the figure, the good performance of system can be realized.

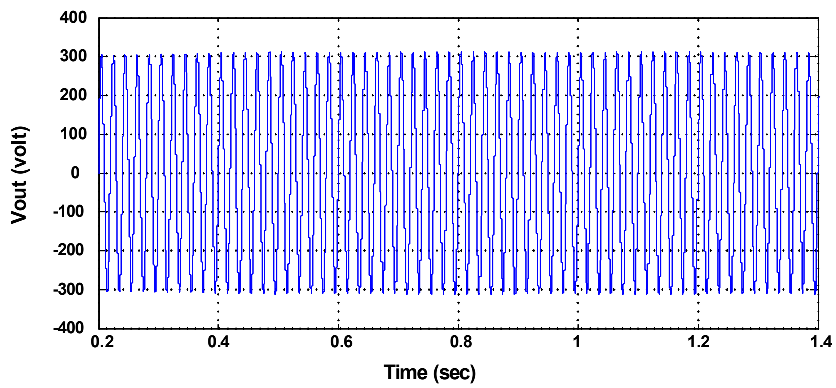

Fig. 5: The instantaneous load voltage in terms of load variations with proposed controller

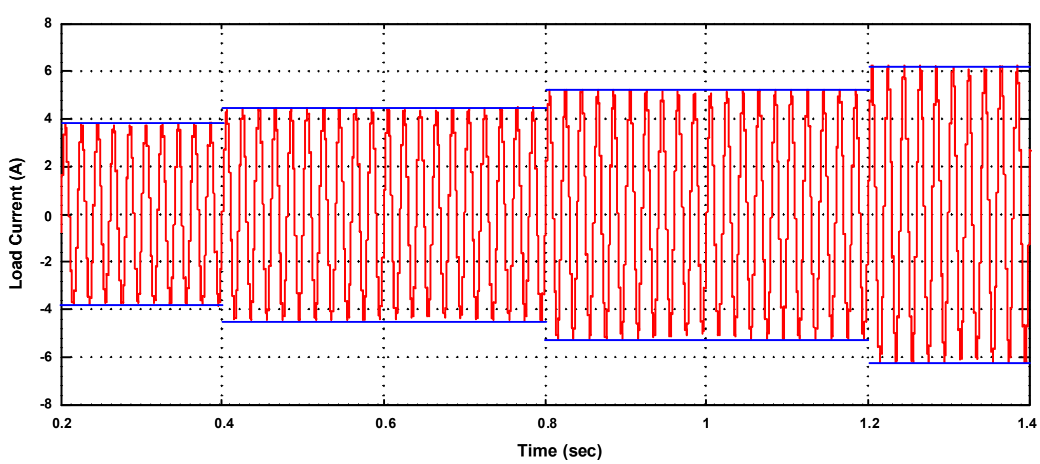

Fig. 6: The instantaneous output current of DG in terms of the output load variations with the proposed controller

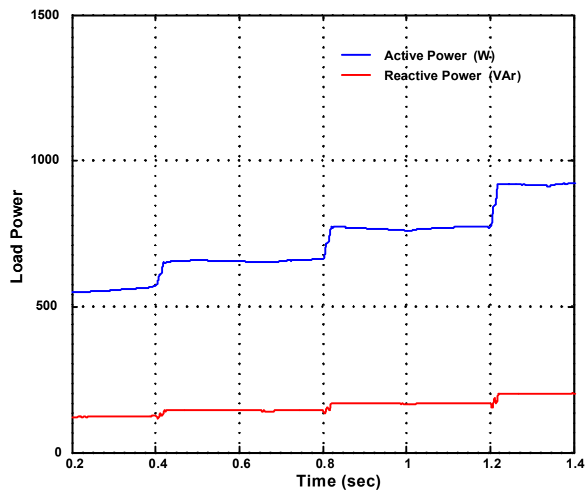

Fig. 7: Distributed generation output power in terms of output load variations with the proposed controller

CONCLUSIONS

In this paper, a new controller based on genetic algorithms and PI controller to control the photovoltaic system output voltage was proposed. This controller is chosen because of its simplicity and because it could obviate the problem of the previous controller and its efficiency is higher than previous controllers. GA algorithm was utilized to design the PI 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 genetic algorithm.

This controller could control properly the output voltage of the system for load variations. Which this claim was verified in MATLAB/Simulink with simulations for different loads.

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