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New Control Method of Islanded Microgrid System: A GA & ICA based optimization approach

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Abstract

Microgrids are small-scale, low voltage (LV) power networks which employ renewable distribution energy resources (DERs) with power electronic interfaces (PEIs). Microgrids as single controlled units and active distribution networks require flexible control systems to ensure reliable and secure operation in different modes. These various operations of microgrid cause variations in voltage and frequency especially in island mode. In this paper, a new control method with two optimization algorithms (genetic algorithm (GA) & imperialist competitive algorithm (ICA)) are proposed to eliminate both voltage and frequency disturbances. Also, a new concept of conventional droop control in format of fast droop controller (FDC) is designed to guaranty the microgrid system reliability with cooperation of a modern frequency controller. Simulation results show the truth behavior of proposed approach in comparison with previous methods.

Keywords :Distribution energy resources (DERs); microgrid; fast droop controller (FDC); optimization algorithm; genetic algorithm (GA); imperialist competitive algorithm (ICA).

Nomenclature

LV	Low Voltage
DER	Distributed Energy Resource
PEI	Power Electronic Interface
GA	Genetic Algorithm
ICA	Imperialist Competitive Algorithm
FDC	Fast Droop Controller
PI	Proportional-Integral
PSO	Particle Swarm Optimization
ANFIS	Adaptive Neuro-Fuzzy Interface System
RMS	Root-Mean-Square
DG	Distributed Generator
PWM	Pulse-Width Modulation
PLL	Phase Locked-Loop
ITAE	Integrated Time-Weighted Error

1. Introduction

Microgrids are the best vision of the future performance of electrical energy systems. Microgrids enable power networks for integration of renewable DERs. Concerns over global climate change and environmental pollution cause increment of integration of renewable DERs. The use of developed data transformation networks and control technologies in smart grid level and the use of advanced PEIs in microgrid level lead to improved performance of microgrid [1-11-18]. Therefore, microgrid needs flexible control systems with PEIs to operate as an autonomous entity in stand-alone mode [1-3].

Microgrid is normally operated in two modes. From grid point of view, microgrid voltages and frequency are fixed by grid then it can be treated as a single aggregated load [1]. This matter causes microgrid regulation according to grid rules to provide reliable power. When a fault occurs in grid, microgrid can be disconnected from grid and supply locally its electrical demands. Also, it can provide uninterruptable power for enhancing reliability and security [1-17-18]. This paper uses load changing method to simulate the transient states in island mode.

In this case, general grid does not exist and voltages and frequency of microgrid must be set locally. For this objective, this paper proposes a controller which controls both stable and transient states in one structural design. Droop control has grid supporting role to properly fix amounts of voltages and frequency without communication with other units [4-18].

The frequency control of power system is a vital issue for network reliability. Therefore, many recent researches concentrate on this problem by suggesting centralized and decentralized controlling methods [7-8-14]. In this way, two distributed case studies were proposed in our previous paper [13].

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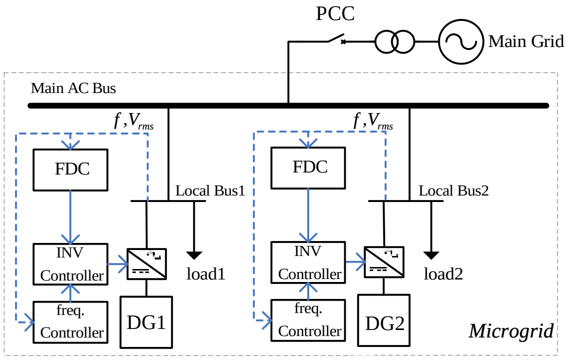

Figure 1. Schematic diagram of controllable microgrid network

With consideration to the effectiveness of these schemes, this paper develops a novel frequency controller which is coordinated with a FDC.

In [24], an intelligent droop controller was introduced in the 3-phase framework. The performance of this controller has severe dependency to the inverter and transmission line impedances. This paper represents a FDC to create a flexible control system with changeable control parameters for faster injecting the demanded powers. The only limitation of this idea is the range of droop rated powers. For solving this defect, an extra frequency controller is added into the inverter control path to quickly set the system frequency on nominal value. Moreover, the major concern over this scheme is the coordination between controllers.

Two smart optimization algorithms are suggested to modify all control parameters. GA and ICA are applied with a time-weighted error-integrating cost function. The reason of using two algorithms is to compare and argue based on outcomes of applied methods and select the more fitness analysis. The obtained results are represented to validate the algorithms performances based on the power quality and minimum amount of cost function.

The rest of this paper is organized as follows. Section 2 discusses the general requirements for the analysis of microgrid system. Section 3 depicts the microgrid control system in island mode. Section 4 describes the proposed optimization algorithms for obtaining the optimal control parameters. Sections 5 and 6 involve the procedure of optimization of two GA and ICA. Section 7 shows the results of implementation of these two algorithms. Section 8 includes the summarized discussion on the control and optimization methods in studied microgrid system.

2. Problem Statement

The aim of this paper is to apply proportional-integral (PI) controller with $d-q$ technique to control the inverter output and satisfy the power quality. This performance can be optimum when the control parameters are optimized. But because of the nonlinearity of microgrid system and in spite of stable and transient modes, any optimization method could not be applied to obtain the best control parameters values. Another principal goal is the proper coordination between various types of controllers.

In [3], a small-signal method was used for linearization of microgrid state-space equations. This model could not cover the overall operation of microgrid due to this fact; it acts in some specific operating points. In recent researches, the particle swarm optimization (PSO) was applied directly to a microgrid simulation model instead of small-signal technique [17-18]. With respect to the importance of the appropriate selection of optimization algorithm, these researches just applied PSO algorithm without any comparison to the other algorithms results.

The concentration of this research is on two GA and ICA algorithms. GA employs operators called chromosome and its approach is based on natural selection. ICA algorithm uses population individuals as country and simulates imperialist competition. In equal condition of load changing, both models are applied to studied microgrid system. The optimization objective is to improve the overall performance of inverter and enhance power quality.

Paper [24] applied an intelligent droop control method which is affected by some variables and parameters such as transmission line impedance. Hence, the operation of droop controller is not independent and this methodology could not rectify the voltage and establish the system frequency. ANFIS with virtual impedance method were implemented for overall system stability. In the current research, a modular control scheme is represented for droop and frequency controllers. In this structure, the performance of each controller does not be influenced by other parts and the impact of each controller is obvious on the system outputs. All these objectives are satisfied by coordination of PI controllers.

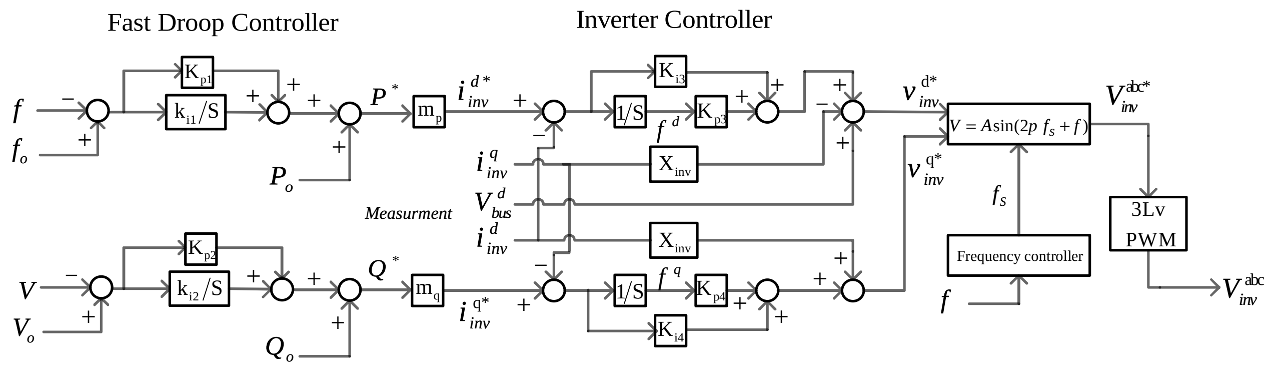

Figure 2. Control block diagram for fast droop and inverter controllers of microgrid system

3. Mathematical Formulation

An electrical diagram of a microgrid system is shown in Figure 1. which includes simulated model of two distributed generators (DGs). This schematic compromises general parts such as inverter and control blocks in island mode. Voltages and frequency of microgrid are regulated by droop and frequency controllers. The DGs of microgrid network are equipped with three modular controllers to damp the voltages and frequency deviations.

Three modular controllers are utilized in this model. The first controller is FDC which sets reference values for inverter controller as a next controller. Inverter controller calculates voltage values using these references for enhancing the power quality.

In the end, the frequency controller checks the system frequency and quickly eliminates deviations based on a simple and practical use of PI controller.

In the grid connected mode, frequency and voltages of microgrid are firmly adjusted. In the island mode, there is not grid supporting condition and therefore microgrid must satisfy load demand with locally measurement. Droop control is the common technique which can adjust active and reactive powers based on local information.

The equation of this novel droop controller is mathematically represented as:

$$P^* = P_o + k_{p1}(f_o - f) + k_{i1}\int (f_o - f)dt \qquad (1)$$

$$Q^* = Q_o + k_{p2}(V_o - V) + k_{i2}\int (V_o - V)dt \qquad (2)$$

Where, k_{p1}, k_{p2}, k_{i1} & k_{i2} are droop parameters. P_o and Q_o ,V , and f are locally measured active and reactive powers, the root-mean-square (RMS) voltage, and the system frequency, respectively.

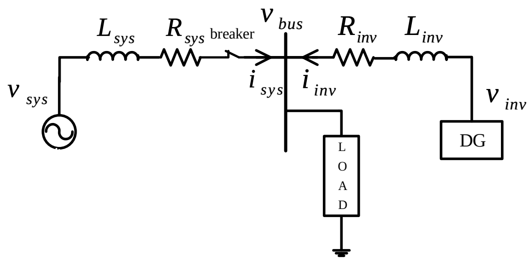

Figure 3. Single-line diagram of simplified microgrid system [18]

f_o and V_o are the nominal values. When a transient state occurs in microgrid, FDC attempts to balance the voltages and frequency values based on droop parameters. These parameters performance is confined by droop power range. When the droop controller could not establish the system stability in critical conditions, the frequency controller completes the operation of FDC. It is formed by two PI controllers in both $P-f$ and $Q-V$ diagrams. When an event occurs, system frequency deviates from nominal value and in this case, microgrid works in the new operating point. Droop control based on its parameters changes output active power to balance the system frequency. This scenario is repeated for voltage droop by changing the output reactive power. In general, this strategy allows microgrid to locally meet and supply the load demand in island mode.

Microgrid control system is designed in $d-q$ reference frame. In fact, $d-q$ technique provides two separate control paths in one design however this chance does not be created by $a-b-c$ reference frame. Figure 2 shows this control block diagram for droop and inverter controllers. $D-q$ Transformation with utilization park matrix makes current references for inverter controller using resultant active and reactive power of FDC.

The current references are generated as:

$$i_{inv}^{d*} = \frac{P^*}{V_{bus}^d} \tag{3}$$

$$i_{inv}^{q*} = \frac{Q^*}{V_{bus}^d} \tag{4}$$

The bonding factor which connects these two controllers is bus d −axis voltage.

The first controller is FDC which works with consideration of PI parameters. The frequency and voltage inputs create active and reactive powers as references for the next controller. In inverter controller, PI controllers with system equations are applied for covering both transient and steady states. The outputs of this stage are suitable voltages for tuning pulse-width modulation (PWM) operation.

The equations of the inverter performance are described as [18]:

$$\frac{d}{dt} f^d = i_{inv}^{d*} - i_{inv}^d \tag{5}$$

$$\frac{d}{dt} f^q = i_{inv}^{q*} - i_{inv}^q \tag{6}$$

$$v_{inv}^{d*} = K_{p1}.(i_{inv}^{d*} - i_{inv}^d) + K_{i1}.f^d - X_{inv}.i_{inv}^q + v_{bus}^d \tag{7}$$

$$v_{inv}^{q*} = K_{p2}.(i_{inv}^{q*} - i_{inv}^q) + K_{i2}.f^q - X_{inv}.i_{inv}^d \tag{8}$$

For better controlling and detracting variables, the angle of $d - q$ transformation is synchronized with the angle of measured bus voltages. In microgrid control system, phase-locked-loop (PLL) measures the frequency of bus voltage and determines this angle. Hence, this technique reduces one variable of system equations with assigning zero value to the bus q −axis voltage. In addition, the values are definite in $d - q$ environment whereas 3-phase voltages are alternative and variable in each time.

Figure 3 shows a simplified single-line diagram of microgrid system from DG viewpoint using Thevenin method. The circuit equations from Figure 3. could be mathematically represented as [18]:

$$\frac{d}{dt} i_{inv}^d = -\frac{R_{inv}}{L_{inv}} i_{inv}^d + w_S.i_{inv}^q + \frac{1}{L_{inv}}(v_{inv}^d - v_{bus}^d) \tag{9}$$

$$\frac{d}{dt} i_{inv}^q = -\frac{R_{inv}}{L_{inv}} i_{inv}^q - w_S.i_{inv}^d + \frac{1}{L_{inv}}(v_{inv}^q - v_{bus}^q)$$

(10) $$\frac{d}{dt} i_{sys}^d = -\frac{R_{sys}}{L_{sys}} i_{sys}^d + w_S.i_{sys}^q + \frac{1}{L_{sys}}(v_{sys}^d - v_{bus}^d)$$

(11)

$$\frac{d}{dt} i_{sys}^q = -\frac{R_{sys}}{L_{sys}} i_{sys}^q - w_S.i_{sys}^d + \frac{1}{L_{sys}}(v_{sys}^q - v_{bus}^q) \tag{12}$$

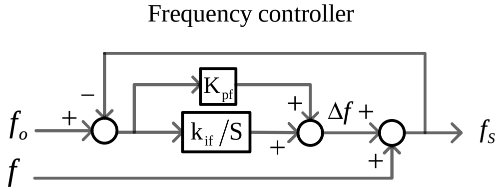

Figure 4. Control block diagram of system frequency

$$\frac{d}{dt} i_L^d = \frac{1}{L_{load}} v_{bus}^d + w_S.i_L^q \tag{13}$$

$$\frac{d}{dt} i_L^q = \frac{1}{L_{load}} v_{bus}^q - w_S.i_L^d \tag{14}$$

When microgrid system changes its status to the island mode, breaker is opened and in this stage, v_{sys} and i_{sys} will be neglected in the equations which are extracted from Figure 3.

The frequency control scheme is exhibited in block diagram form in Figure 4. The islanded microgrid system frequency is highly sensitive and it is fluctuated by each type of disturbances which are occurred in transient states especially. Therefore, the frequency controller task is to generate the desirable signal for PWM to appropriately cover all working modes of microgrid system. A modern application of feedback procedure in PI controller is suggested for creating the proper frequency. The equation of this controller mathematically is written as:

$$f_S = k_{if}\int (f_O - f_S)\,dt + k_{pf}(f_O - f_S) + f \tag{15}$$

Where, f_O, f and f_S are nominal, measured and generated frequency signals, respectively.

4. Optimization Algorithms

First, the relation between inputs and outputs of system as a differential equation must be procured and then with solving this equation, the values of variables are obtained. If no certain relevance exists, the smart mathematical methods must be used to calculate the variables values. These methods are named optimization algorithms which work based on a cost function including system variables. Most of these algorithms use a repeating complex mathematical process to estimate minimum value for cost function. In each step, the values of cost function are compared with each other and which variables are selected that they generate minimum cost function.

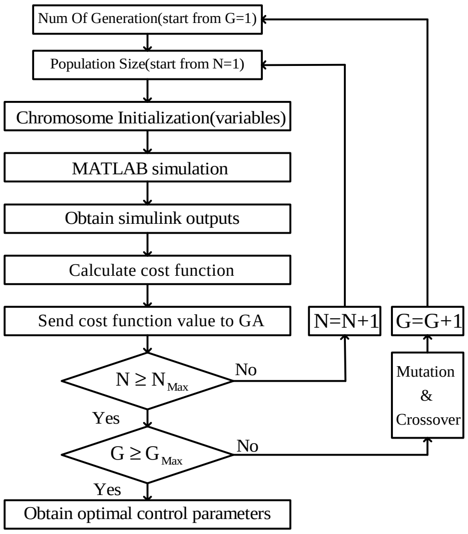

Figure 5. Flowchart of the GA algorithm

A. Genetic Algorithm (GA)

GA is one of the most popular optimization methods for solving the microgrid system nonlinear equations and searching the control parameters using natural selection process. First, a population of chromosome is randomly selected to create individuals. New generations are produced by previous gens as parents in per iteration. Some of the individuals are removed with consideration to the objective function. Other ones which have more fitness use some methods like Selection, Mutation and Crossover to make next generation [26].

The crossover operator generates two strings of children using two strings of parents and it has explorative characteristic to combine the data of parents.

Mutation is one of the most important operators in GA. Mutation operator uses just one parent to generate children and has exploitive characteristic. It provides genetic diversity from parents to the next generation. Diversity is implemented by changing some gens. Therefore, new parents generate new generations with more fitness for objective function. As usual, mutation is applied after crossover [15-21-26].

B. Imperialist Competitive Algorithm (ICA)

This algorithm starts with a numbers of countries as initial population. Imperialism is a competition between countries to dominate each other. Therefore, countries are divided in two groups which form imperialists and colonies. Index for dividing the groups is the minimum cost of each country. Countries with less cost are included in imperialist cluster and the rests form the colonies. Now, each empire tries to possess more colonies to win the competition.

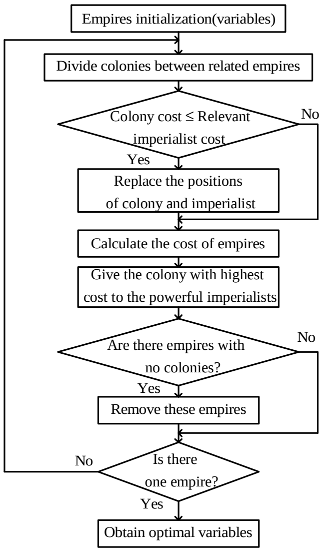

Figure 6. Flowchart of the ICA algorithm

ICA like GA algorithm utilizes some functions to faster convergence to result and so that two main operators which called Assimilation and Revolution are applied in ICA algorithm. ICA using Assimilation operator enables colonies of empires to go to the imperialist state to establish bigger empire.

The placement of colonies can be suddenly changed by revolution which acts same as mutation to make variations in position of some colonies. In this way, one country might have the dominance of entire empire and win the competition. This procedure repeats over and over until the target of optimization will be satisfied [19].

5. Controllers Optimization

In this research, Droop, inverter and frequency control parameters are optimized by one cost function and two optimization algorithms just for comparison between the performances of GA & ICA. In previous studies, these two groups of parameters are separately optimized with two cost function [18]. This solution disturbs the overall stability of microgrid because of two cost functions utilization. It is no guaranty that the best optimized droop parameters are obtained at the same time with the best ones of inverter and frequency controllers.

When the optimal control parameters are set to studied microgrid system, some criteria must be checked to ensure the correct performance of applied optimization method.

This paper follows optimization aims such as:

1) The bus voltages and microgrid system frequency should be close to nominal values. This means that $q-$axis, $d-$axis bus voltages and system frequency be environs zero, $380V$ and $50Hz$, respectively.

2) Microgrid should have so much reliability to response load demand.

3) The control system should have enough flexibility to rapidly damp the transient modes.

The microgrid system is simulated using the control block diagram and power electronic equipment of MATLAB.

For surveying the transient and steady states, control parameters must be available in each mode. This case makes complexity of controlling hence for solving this problem, it is tried to propose one pack of parameters for all working modes. A cost function appropriate with the control goals is applied for acquiring optimal control parameters based on the minimum value of cost function.

The purpose of determining optimal parameters is to decline deviations of system outputs from nominal values and faster stabilization of system. Therefore, one cost function is utilized for all parameters and the system is configured with a set of parameters to cover all modes. The integrated time-weighted error (ITAE) cost function is described in each period of simulation as [17]:

$$ITAE \rightarrow \sum_{k} k \, . \, W \, . \left| E\,(\mathrm{k}) \right| \qquad (16)$$

Where, k is the simulation time for computing the control parameters; W is weighting matrix for showing the importance of each element of $E(\mathrm{k})$ and it is fixed to $[3,3,1,1]$; $E(\mathrm{k})$ is the error matrix which includes the electrical characteristics of microgrid and here it is described as [18]:

$$E\,(\mathrm{k}) = [\Delta V\,(\mathrm{k}), \Delta freq\,(\mathrm{k}), \Delta P\,(\mathrm{k}), \Delta Q\,(\mathrm{k})]^T \qquad (17)$$

The errors as shown by Δ are the difference between nominal and measurement values in $E(\mathrm{k})$. $\Delta V\,(\mathrm{k})$, $\Delta freq(\mathrm{k})$, $\Delta P(\mathrm{k})$, and $\Delta Q(\mathrm{k})$ are the voltage, frequency, active power and reactive power errors, respectively.

k_p and k_i are the PI control parameters for all PI controllers which applied in studied microgrid system. In each step of optimization procedure, these parameters are variable to change the error values of $E(\mathrm{k})$.

First, the optimization algorithms produce a set of values for control parameters with considering the cost function and the number of variables. MATLAB simulation uses these values to compute the needed outputs for $E(\mathrm{k})$. Now, the cost function can be obtained for removing a number of produced variables in previous level of optimization and generating new variables in the next level. This function so continues that the total value of errors becomes minimum and the proper condition of microgrid system is satisfied.

6. The Proposed Algorithms

Figure 5 shows the flowchart of proposed GA algorithm. In this process, GA generates a random population as binary strings which called chromosome. Each chromosome is a possible solution for optimization problem and it is evaluated by cost function.

The GA flowchart has two inner and outer parts. The inner part performs based on the population size and produces a random primitive population for control parameters as chromosome, firstly. The outer layer has the task of creating a new generation and for this purpose, algorithm uses mutation and crossover operators. Each new generation makes new population and this scenario is repeated until all assigned generations.

Figure 6 displays the general operation of ICA algorithm. In the real world, the increased costs of countries make them go weaker and removed from world. This reality is precisely simulated in ICA algorithm for obtaining the powerful countries. Control parameters as variables have the role of countries to organize the imperialists and colonies. The cost function is defined based on the cost of empires and algorithm moves the colonies from the empires with highest cost to the authoritative empires. Algorithm iterates this exchanging until one empire possesses all colonies.

In the ICA flowchart, the countries comprise droop, inverter and frequency control parameters which initialized in a matrix as:

$$X = \left[k_p \;\, k_i \right]$$

Then, these parameters are sent to the simulation to create the required outputs for calculating the cost of each country. In this way, countries with high cost are removed and optimal control parameters (countries with low cost) are acquired.

7. Case Studies

In this paper, a small-scale microgrid system is studied without the presence of general grid. This system includes two DGs with enough capability for supplying the local demands. The objective of this study is to closely analyze the controlability and reliability of microgrid system in different modes. This work developes the proposed control method which is applied in [18]. Here, all microgrid network is locally controlled without any central controller. Two optimization algorithms using ITAE cost function have the task of microgrid stability. Which algoritm take into account appropriate that it can achieve the system to stable state.

Table 1. Microgrid system parameters by GA

	Mode I	Mode II	Mode III	Mode IV	Mode V	Mode VI	Mode VII	Mode VIII
time	0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1	1-1.2	1.2-1.4	1.4-1.6
R_{inv}, L_{inv}	0.08,0.002	0.08,0.002	0.08,0.002	0.08,0.002	0.08,0.002	0.08,0.002	0.08,0.002	0.08,0.002
k_{p1}, k_{i1}	4.55,80.3	4.55,80.3	4.55,80.3	4.55,80.3	4.55,80.3	4.55,80.3	4.55,80.3	4.55,80.3
k_{p2}, k_{i2}	3.15,41	3.15,41	3.15,41	3.15,41	3.15,41	3.15,41	3.15,41	3.15,41
k_{p3}, k_{i3}	6.7,11.5	6.7,11.5	6.7,11.5	6.7,11.5	6.7,11.5	6.7,11.5	6.7,11.5	6.7,11.5
k_{p4}, k_{i4}	12.3,16.66	12.3,16.66	12.3,16.66	12.3,16.66	12.3,16.66	12.3,16.66	12.3,16.66	12.3,16.66
k_{pf}, k_{if}	10.25,16.2	10.25,16.2	10.25,16.2	10.25,16.2	10.25,16.2	10.25,16.2	10.25,16.2	10.25,16.2
P_{DG1}, Q_{DG1}	0.6,0.033	0.73,0.046	0.63,0.023	0.55,0.027	0.7,0.04	0.6,0.033	0.57,0	0.77,0.023
P_{DG2}, Q_{DG2}	0.6,0.033	0.73,0.046	0.63,0.023	0.55,0.027	0.7,0.04	0.6,0.033	0.57,0	0.77,0.023
P_{load}, Q_{load}	1.2,0.066	1.46,0.094	1.26,0.046	1.1,0.054	1.4,0.08	1.2,0.066	1.14,0	1.54,0.046

($P_{rated} = 30KW, V_{rated} = 380V$ & $f_{rated} = 50Hz$, parameters are in p.u.)

The overall system is put into island mode and there are eight operating modes with load changing for searching the performance of control parameters. In this section, the outcomes of GA & ICA are surveyed and then with considering the results, it is proved the GA satisfies determined control objectives. Based on the single-line diagram of microgrid model presented here, the system parameters which are derived from GA optimization are shown into the Table 1.

Table 1 shows circuit fixed parameters and obtained control parameters by GA analysis. The bus voltages and system frequency are quickly set to system nominal values, powers and currents are stably set to new level based on local load demand.

In order to the precise performance of GA algorithm, population size and generation numbers are 500. The control parameters defined in ITAE cost function are k_p & k_i of PI controllers for following the reference values. The calculated results for cost function are:

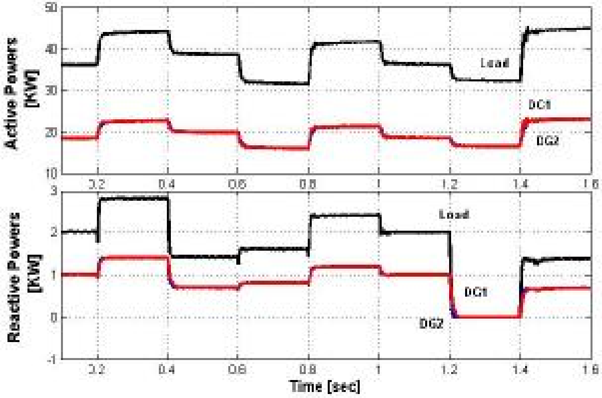

Figure 7. Active and reactive powers of inverter and load

Minimum Cost = 1.462 Iteration Number = 91

The obtained control parameters by ICA are as matrix X:

$$X=[k_{p1}\ k_{i1}\ k_{p2}\ k_{i2}\ k_{p3}\ k_{i3}\ k_{p4}\ k_{i4}\ k_{pf}\ k_{if}]=$$

$$[15\ 25.5\ 70\ 4.3\ 115.5\ 2.16\ 1.2\ 0.55\ 202.8\ 77.3]$$

Figure 7 shows the produced and demanded active and reactive powers variations by DGs and load, respectively. The total simulation time is considered in $1.6\,s$ for eight load changes. Two DGs have the same operation by nominal power $30\,KVA$ and the values of all powers of transient states are represented in Table 1.

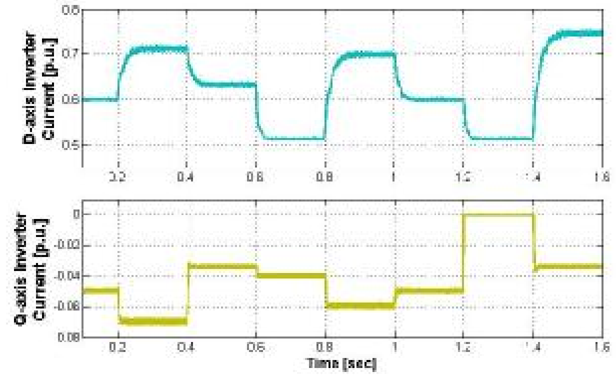

Figure 8. D- and q-axis inverter output currents

In Figure 7, both DGs supply the load in equal active and reactive powers which demonstrates the correct power sharing between DGs.

Figure 8 shows the inverter current which are achieved by GA parameters. The currents of $d-$ and $q-$axis quite invariable and set to the fixed values. Also, the values of currents exactly follow the power flow. This proof explains the accurate operation of PI controllers and exact selection of control parameters. The negative sign of $q-$axis current is adverse with the system analysis because of the $d\text{–}q$ transformation.

Figure 9 shows the system frequency deviations with considering the island modes without power grid attendance. After the removing transient states, system frequency is strictly preserved within $50\,Hz$ by GA optimized parameters.

In the first island mode, the local load is stable between $0-0.2\,s$ and the control parameters are capable to regulate the system frequency on $50\,Hz$. In the $0.2\,s$, local load suddenly increases and causes frequency falling down. This disturbance is quickly eliminated and frequency backs to it's nominal value. This behavior is repeated in toatal simulation time. Really, the system frequency fluctions are exactly matched to power system studies. On the other hand, the frequency deviations based on ICA are an major sign of an unstable system which is displayed in (b).

Figure 10 depicts the comparison between two bus RMS voltage (a) and (b) curves which are obtained from GA & ICA, respectively. As shown in (a), v_{bus}^{rms} precisely reaches to the nominal value $1\,p.u.$ in different load changes based on GA analysis.

The scenario for voltage regulations is in this way: the overload causes the voltage reduction and when the load decreases; the bus voltage rises and all these occurrences are verified by losses. The resultant bus voltage from ICA proves the inappropriate performance of control parameters in (b).

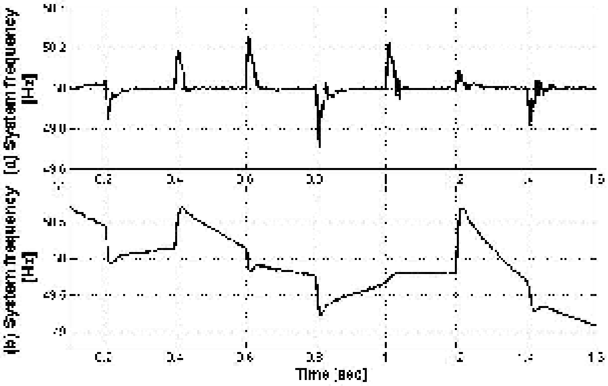

Figure 9. System frequency fluctuations for two (a) GA and (b) ICA solutions

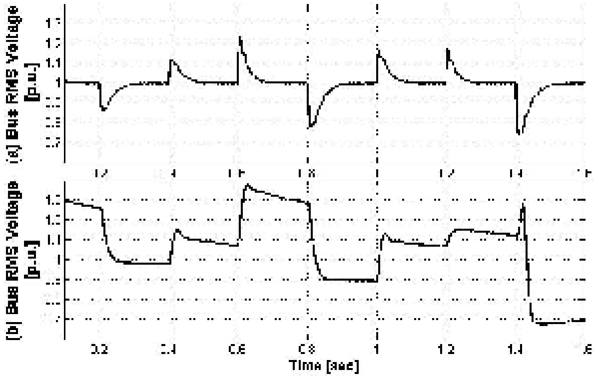

Figure 10. Bus RMS voltage profile based on (a) GA and (b) ICA

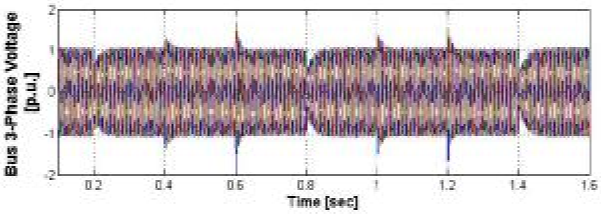

Figure 11. Overview of Bus voltage waveform

For having the complete view of microgrid system operation, the 3-phase bus voltage is represented in Figure 11. This waveform lets to closely study bus voltage amplitude and harmonics.

The important indicator for choosing an optimization method is to quickly damp the transient states and maintain the system stability. The implementation of two optimization method proves that each method does not fit with each system. Because of the wide uses of these algorithms in the power system analysis, this matter must be highlighted.

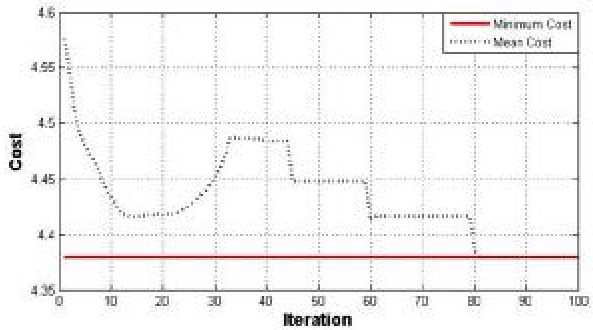

Figure 12. The ICA mean and minimum cost of imperialists

The ICA algorithm optimizes the control parameters in an equal condition with GA algorithm. For this reason, countries in ICA have the same role of chromosome in GA.

Figure 12 shows the mean and minimum values of ITAE cost function and the procedure of variations. It is obvious the minimum cost of ICA is bigger than of GA. This value for ICA is 4.38. ICA will have good performance when, these two values quickly close to each other in primitive iterations. As shown in Figure 12, the ICA algorithm could not meet the control objective in the total simulation time.

As mentioned, two layers PSO which was used in [18] could not satisfy the control objectives. Each layer generates another layer initial conditions and cause a limitation and disturbance in the selection procedure and algorithm calculations out of normal optimization method. Therefore, it is suggested to allow the optimization algorithm to compute the variables for one working operation without any forces of initial conditions of some obtained variables in previous layer.

On the other hand, all algorithms are not designed for all problems and each one is suitable for some similar issues however; it may be not an appropriate solution for some different problems. This subject has been studied by GA & ICA in a new control configuration of droop and frequency controllers in the absence of supervisory controller in this research.

8. Conclusion

This paper proposed a modular and practical control method in microgrid system. The microgrid system was simulated in island mode so that major control problems appear in this mode. The concentration of this paper was on the coordination between two droop and inverter controllers. In addition, an operative frequency controller was applied to guaranty the system reliability. In this paper opinion, all control parameters must be optimized in one point and they do not be separated in the optimization process.

The microgrid nonlinear equations were solved by mathematical intelligent algorithms to compute the control parameters. Two ICA & GA algorithms were used with ITAE cost function and the system outputs were represented for identifying the more suitable algorithm.

The results of both GA and ICA algorithms were compared with considering to the system reliability and stability. The results confirmed the GA algorithm had more effective performance.

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