An Optimal Controlling Approach for Voltage Regulation and Frequency Stabilization in Islanded Microgrid System

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Abstract: The control of distributed generations (DGs) with renewable resources is an important endeavor in modern power systems due to the fact that the system frequency and voltages are highly variable in these kinds of networks especially in the island mode. This paper introduces a new combination of conventional controllers for solving the critical problems in islanded microgrid systems. With considering the 3-phase operation of power networks and comfort controllability of the d-q system, the general controller is designed based on two mentioned techniques. The indicator of proper performance of studied microgrid controller is to provide reliable electric power in the presence of the transmission line impact and abnormal conditions. The control system parameters are optimized by Imperialist competitive algorithm (ICA) for enhancing the power quality. The effectiveness of recommended method is contrasted with other controllers and studies. The simulation results show the truth behavior of suggested controller for stabilizing the possible transient states.

Keywords: Droop control, microgrid control system (MGCS), optimization algorithm, imperialist competitive algorithm (ICA).

1. INTRODUCTION

The microgrid concept provides the integration of various kinds of distributed renewable energy resources (DRERs) that most of them are DC sources. In the connected mode, the duty of supporting the frequency and voltages of unbalanced, nonlinear, or sensitive microgrid loads is the responsibility of the main grid, (Liu et al., 2013; Chung et al., 2010). In the island mode, an unstable condition governs on microgrid system because of the absence of the main grid, (Chowdhury and Crossley, 2009). The frequency and voltages disturbances have severe negative impacts on load requirement. Thus, the island mode control (IMC) debate is highlighted for eliminating these undesired effects, (Savaghebi et al., 2013).

Despite of diverse control methods for IMC in previous studies, Some of these researches just used the 3-phase models, (Bevrani and Shokoohi, 2013; Vandoorn et al., 2011) whereas, others only applied 2-phase strategies based on d-q technique, (Liu et al., 2013; Chung et al., 2010; Savaghebi et al., 2013). In this paper, a combinatorial control scheme is represented to comprehensively control the islanded microgrid system. The implemented control method is modeled in the space of both 3-phase and d-q systems for flexible controllability of microgrid system. Also using the benefit of d-q transformation, the q-axis voltage (V^q) is considered zero for decreasing the system variables, (Chung et al., 2010). Several transient states are simulated to test the proper operation of recommended novel IMC method.

In (Bevrani and Shokoohi, 2013), presented control method has the 3-phase structure, which it just follows the load variations and the system stability was satisfied by adaptive neuro-fuzzy inference system (ANFIS). This work introduces a new controller based on the droop control concept with a PI controller as a supplement for the output voltage amplitude rectification. Droop control is an effective way for regulating the active and reactive power flow based on the load demand and source limitations. However, this simple application can cover all stable and transient working modes but it's qualified performance has high dependency on PI control parameters and transmission line impedance in this scheme.

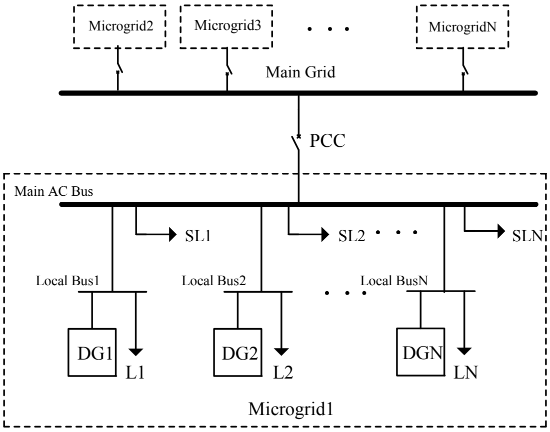


Fig. 1. A typical model of the main grid with AC microgrids.

The optimal parameters cause the improved overall system response and somewhat remove the line impedance effect. In (Ghosh and Banerjee, 2015), two optimization techniques particle swarm optimization (PSO) and gravitational search algorithm (GSA) were used. The proposed intelligent strategy for computing the optimal parameters is the ICA. It was first proposed by Atashpaz-Gargari and Lucas in 2007, (Atashpaz-Gargari and Lucas, 2007) as an evolutionary algorithm based on humans socio-political evolution for searching problem space with an initial random population called country, (Lucas et al., 2010). Like other evolutionary algorithms, ICA simulates a natural behavior using the approach based on the imperialistic competition between countries to dominate other ones which have higher cost, (Soroudi and Ehsan, 2012; Yang et al., 2013; Safari and Sarvi, 2014).

The remainder of this paper is organized as follows. The challenges of microgrid control and the configuration of the island mode controller are represented in section 2. Section 3 involves the mathematical formulation for microgrid system analysis. In Section 4, the microgrid control system (MGCS) structure is discussed using new techniques. Section 5 gives the ICA optimal parameters results for droop and PI controllers. Section 6 shows the results of this useful method to prove the correct controlling of the system frequency and voltages. In Section 7, a synopsis argument is presented on the microgrid control methods.

2. PROBLEM STATEMENT

The focus of the current study is on the planning a simple and practical controller for various working modes of islanded microgrid system. Some critical control problems are the results of microgrid networks' complexity especially in island mode (with so many uncertainties). Therefore, there is a powerful link between controller configuration and system topology.

The important characteristics of microgrid controllers are their fast reaction and accurate response to any change in system condition or sudden disturbances in system outputs. References (Liu et al., 2013) and (Chung et al., 2010) show the application of the d-q technique. This framework requires several PI controllers with optimized parameters in each mode. Because of the several integrator operators, the general controller has too inertia to quickly response to various modes and stabilize the system states. On the other hand, control parameters must be calculated again for any load or mode change. This issue adds to the complexity and nonlinearity of microgrid system with line impact.

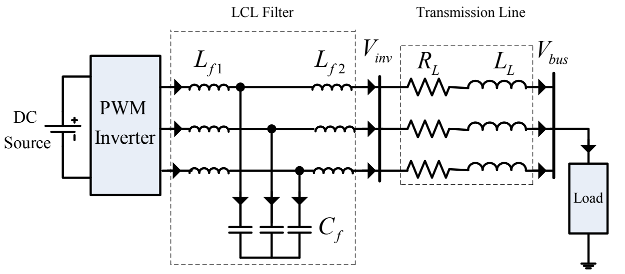


Fig. 2. Studied microgrid schematic diagram.

In recent researches, different controllers are proposed in order to cover different control goals. Always, a trade off exists between control target and controller scheme. Therefore, a desirable controller must satisfy the control goals with feasible structure. (Bevrani and Shokoohi, 2013) uses a 3-phase based approach to control an islanded microgrid system. With respect to the quick response of this model to changes, which are occurred in loads or system conditions; it just follows the states without balancing the system outputs.

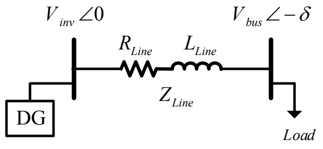


Fig. 3. Single-line diagram of islanded microgrid system.

In order to make a stable microgrid system, an extra methodology with high computational volume is applied. Also, the transmission line impact has not been truly removed from system frequency and voltage.

3. MATHEMATICAL FORMULATION

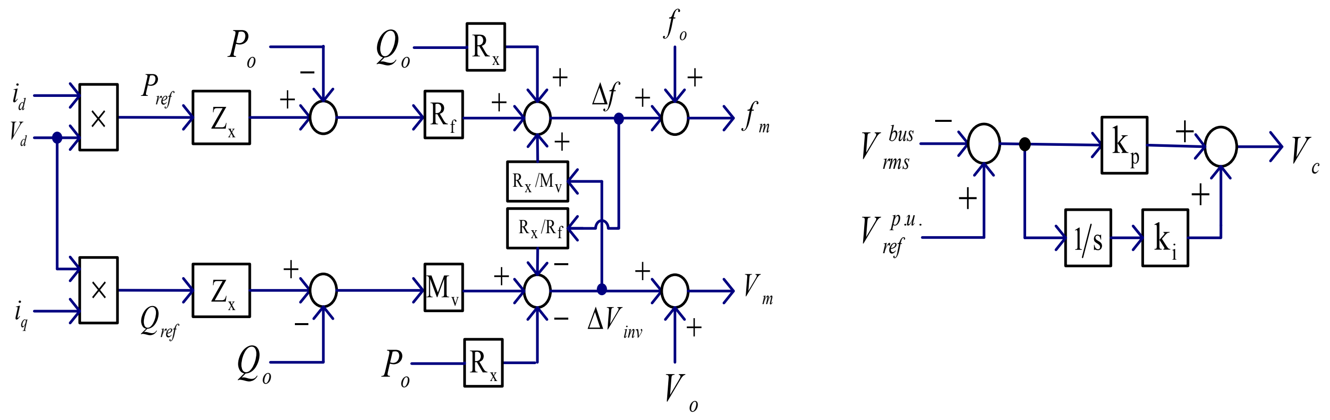
The proper performance of a microgrid system is strongly related to the operation of it's DGs. This paper studies an islanded microgrid network with one DG resource. This model can be expanded if the proposed control method supplies the overall system stability and reliability. In this part, the mathematical formulations of the power system are introduced. These equations represent the power system operation in stable mode without any prediction of transient modes behavior. Also, the droop control relations are used for assigning the active and reactive power for the load demand based on the system conditions.

Fig. 1 shows a main power grid with the branches of local networks as microgrids. The point of common coupling (PCC) is a switch between connected and islanded mode of microgrids. The detailed structure of sampled microgrid1 is given in this figure for precise analysis of inner operation of DGs. As shown, the sensitive loads (SLs) are supplied by the main bus, which has the powered up capability from other local buses, and the other less important loads are connected with the local bus. Here, the total microgrid1 is simplified with one DG; therefore, the local and main buses could be considered in a format of the common bus. Normally, the microgrid is parallel with the main grid and the system frequency and voltages are guaranteed by the main grid. When a fault occurs in the main grid, the microgrid can disconnect in order to locally support the local loads. In this case, the major control problems are appeared.

An electrical diagram of a simple microgrid system is shown in Fig. 2. This model includes general parts such as DC source, PWM inverters, LCL filter, transmission line, and the local load. All parts are fixed except transmission line parameters because of the significant impact on system frequency and voltages. In this paper, three common transmission line characteristics are studied and also, it is tried to damp the line influence. The single-line diagram of Fig. 2 is shown in Fig. 3 to obtain the mathematical relations. Fig. 3 can be described in following equations as:

$$P = \frac{V_{inv}^2}{Z} cos\theta - \frac{V_{inv}V_{bus}}{Z} \cos{(\theta+\delta)} \tag{1}$$

$$Q = \frac{V_{inv}^2}{Z} sin\theta - \frac{V_{inv}V_{bus}}{Z} \sin{(\theta+\delta)} \tag{2}$$



(a) (b)

Fig. 4. Control block diagram for island microgrid system. (a) Droop based controller. (b) Simple supplementary controller.

Where, V_{inv} and V_{bus}, P and Q, θ and δ are the inverter and bus voltages, active and reactive exchanged powers, line impedance and power angles respectively. The expanded equations (3) and (4) are obtained by assuming the line impedance $Z = R + jX$ as:

$$P = \frac{V_{inv}}{R^2 + X^2}[R(V_{inv} - V_{bus}cos\delta) + XV_{bus}sin\delta] \tag{3}$$

$$Q = \frac{V_{inv}}{R^2 + X^2}[-RV_{bus}sin\delta + X(V_{inv} - V_{bus}cos\delta)] \tag{4}$$

Also by considering the two inductive $(X \gg R)$ and resistive $(X \ll R)$ characteristics for transmission line, following equations can be resultant, (Bevrani and Shokoohi, 2013):

$$if\ X \gg R\ \rightarrow\ \delta = \frac{XP}{V_{inv}V_{bus}};\ V_{inv} - V_{bus} = \frac{XQ}{V_{inv}} \tag{5}$$

$$if\ X \ll R\ \rightarrow\ \delta = \frac{RQ}{V_{inv}V_{bus}};\ V_{inv} - V_{bus} = \frac{PR}{V_{inv}} \tag{6}$$

Droop control equations provide P/f and Q/V relations as:

$$P = P_0 + (f_0 - f)/R_f \tag{7}$$

$$Q = Q_0 + (V_0 - V)/M_v \tag{8}$$

P_0, Q_0, f_0 and V_0 are nominal values of the active and reactive powers, the system frequency and the bus root-mean-square voltage respectively. R_f and M_v are droop characteristics.

4. MICROGRID CONTROL SYSTEM (MGCS)

The $(X \gg R)$ and $(X \ll R)$ cases are the two assumptions of all probable states. The designed controller must cover all states of system. For this reason, the power equations can be written as, (Bevrani and Shokoohi, 2013):

$$P_{ref} = \frac{X}{Z}P - \frac{R}{Z}Q \tag{9}$$

$$Q_{ref} = \frac{R}{Z}P + \frac{X}{Z}Q \tag{10}$$

Where, P_{ref} and Q_{ref} are the system power references.

By defining $Z_x = \frac{Z}{X}$, $R_x = \frac{R}{X}$ and with using the droop control equations, the following equations are obtained from (9) and (10) as:

$$\Delta f = R_f[Z_xP_{ref} - P_0] + \frac{R_xR_f\Delta V_{inv}}{M_v} + R_xR_fQ_0 \tag{11}$$

$$\Delta V_{inv} = M_v[Z_xQ_{ref} - Q_0] - \frac{R_xM_v\Delta f}{R_f}R_xM_vP_0 \tag{12}$$

R_f and M_v are supposed unit in the second and third expression of (11) and (12) respectively. In droop controller, R_f has an effect on P/f characteristic whereas, other effects on ΔV_{inv} and Q_0 are unwanted. The reason for M_v in (12) is like R_f in (11) .

By applying statement above, the final equations are derived as:

$$\Delta f = R_f[Z_xP_{ref} - P_0] + \frac{R_x\Delta V_{inv}}{M_v} + R_xQ_0 \tag{13}$$

$$\Delta V_{inv} = M_v[Z_xQ_{ref} - Q_0] - \frac{R_x\Delta f}{R_f}R_xP_0 \tag{14}$$

In previous studies, the active and reactive powers are calculated in 3-phase system. For eliminating the destructive harmonics and fluctuations, these parameters require low-pass-filter (LPF). The d-q transformation provides the clean and stable powers without LFP as:

$$P \cong V_{inv}^{d}i_{inv}^{d} \tag{15}$$

$$Q \cong V_{inv}^{q}i_{inv}^{q} \tag{16}$$

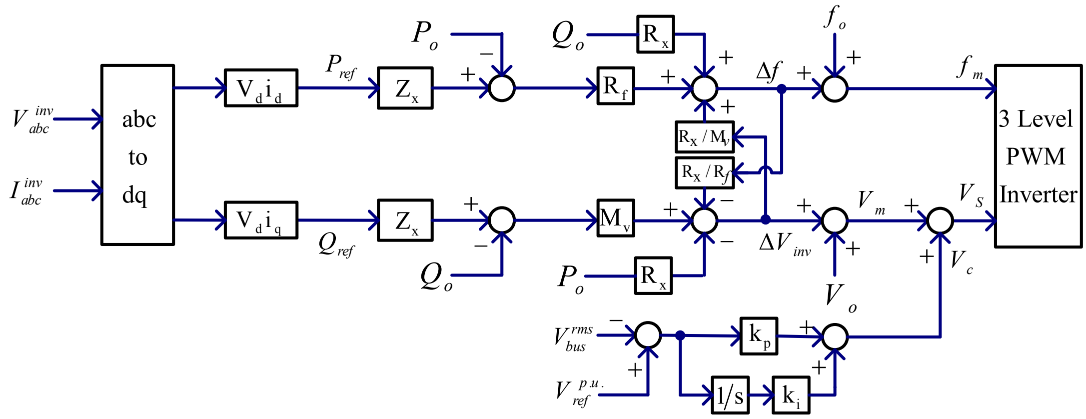


Fig. 5. Block diagram based on d-q technique for microgrid control system.

When, V_{inv}^{q} be equal zero, the above equations are resultant. This case creates the comfortable analysis between demanded powers and voltages of inverter. The inverter voltages and currents have high frequency harmonics in 3-phase form. The d-q transformation clears these harmonics instead of LPF. Moreover, this technique significantly enhances the results for system frequency and output voltages.

Fig. 4a shows the final control block diagram that provides the signals for triggering the PWM inverter in a sin wave form. These signals are made as:

$$f_m = \Delta f + f_0 \quad , \qquad V_m = \Delta V_{inv} + V_0 \tag{17}$$

The system and controller equations until (17) are a basic part of the proposed scheme. This controller does not merely satisfy the microgrid system normal conditions. In Fig. 4b, a supplementary controller is introduced to correct the main controller operation. It includes a PI controller for stabilizing the system output voltage profile.

In Fig. 4a, V_m is not a desirable signal; therefore, for covering this defect, the extra control path of Fig. 4b adds to the V_m path for producing the V_c as a compensational signal which is obtained as:

$$V_c = k_p\left(V_{ref}^{p.u.} - V_{bus}^{rms}\right) + k_i \int (V_{ref}^{p.u.} - V_{bus}^{rms})dt \tag{18}$$

Where, k_p and k_i are the PI control parameters. V_{bus}^{rms} and $V_{ref}^{p.u.}$ are the measured and nominal values for the bus voltage respectively.

Fig. 5 shows the final MCGS that is a mixture of two control part in Fig. 4. When V_{bus}^{rms} is equal $V_{ref}^{p.u.}$, the PI output is stable and V_s is the eligible triggering signal to guaranty the controllability of probable states. V_s is compensated as follow:

$$V_s = V_m + V_c \tag{19}$$

5. PROPOSED OPTIMIZATION ALGORITHM

5.1 Imperialist competitive algorithm (ICA)

Imperialist competitive algorithm (ICA) is a powerful evolutionary intelligent method based on the socio-political competition among empires. ICA has proved it's flexible and prominent ability for solving the different optimization problem, (Jain and Nigam, 2010; Duan et al., 2010; Lucas et al., 2010). This algorithm starts with a number of initial populations as countries. The imperialism competition divides the countries in two groups that form the imperialists and colonies. The index for classifying these groups is the cost of each country. Countries with less cost are included in imperialist cluster and the rest figures the colonies. Now, each empire tries to possess more colonies to win the competition. In addition, there is another kind of competition between empires; the high-powered empires eradicate weak empires to possess the weak ones' colonies.

ICA simulates the system variables such as control parameters in the term of country. The dimension of the country array is depending on the N_{var} (variable number) as:

$$if \qquad N_{var}\!: 1, 2, \dots, j$$

$$country = [k_1, k_2, \dots, k_j]_{1\times j} \tag{20}$$

For computing the country cost, a cost function $f(x)$ is defined by considering the control goals. In each iteration, the cost value is updated by new selected variables as follow:

$$cost = f([k_1, k_2, \dots, k_j]_{1\times j}) \tag{21}$$

ICA needs an initial value to start the optimization process. N_p is the initial countries number based on the population size. It is divided in two parts N_{imp} and N_{col}, they are the number of imperialists and colonies respectively. ICA divides colonies between empires using the power of each empire. This matter is defined mathematically in the normalized power word as:

$$P_n = \left|\frac{C_n}{\sum_{i=1}^{N_{imp}} C_i}\right| \tag{22}$$

Where, P_n is the normalized power and C_n is the normalized cost that is calculated as:

$$C_n = c_n - \max\,(c_i) \tag{23}$$

Where, c_n is the n^{th}imperialist cost.

The initial colonies number for each imperialist has direct relation with its normalized power. To assign the initial colonies to each empire, the $round$ function is defined as:

$$N.C_n = round\{p_n.N_{col}\} \tag{24}$$

Where, $N.C_n$ is the required initial colonies number for n^{th} empire.

5.2 Control parameters optimization

In each system, the relation between inputs and outputs as a differential equation of the system must be procured. By solving this equation, the values of variables are obtained. If no certain relevance exists, the smart mathematical algorithms must be used for calculating the variables values. A cost function, including system variables, is defined using control objectives, which it has interface role between algorithm and system. Most of these algorithms apply a repeating complex mathematical process to estimate minimum value for the cost function. In each step, the cost function values are compared with each other and those variables will be selected, which they generate the minimum value of cost function.

The optimization process is summarized into finding the minimum cost for an argument. In this study, this argument includes the droop parameters R_f & M_v and PI parameters k_p & k_i in the matrix form $X = [R_f, M_v, k_p, k_i]$.

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

This paper follows optimization aims such as:

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

2) The microgrid should have high reliability to response to the local load requirement.

3) The control system should have enough flexibility to rapidly damp the transient modes and cope with load changes.

The microgrid system is simulated using the control block diagram and the power electronic equipment of MATLAB. This software is a powerful toll for control analysis and also it has the most adjustment with optimization algorithms and complex mathematical computations.

For analyzing the transient and steady states, the control parameters must be available in each mode. In other words, the microgrid system needs the online parameters due to proper performance. To fix this problem, it is tried to propose one pack of parameters for all working modes. To this end, an appropriate cost function is used for acquiring the optimal control parameters. Normally, four types of cost function are defined in power system studies including integrated absolute error (IAE), integrated squared error (ISE), integrated time-weighted squared error (ITSE), and integrated time-weighted absolute error (ITAE). The ITAE is a proper selection for optimization process in this research based on the similar results of (Chung et al., 2010). Also, an implementation of ISE, IAE and ITAE was represented by (Kaliappan, 2016).

The purpose of determining the optimal parameters is to decline deviations of system outputs from nominal values and faster stabilization the states of system. Therefore, one cost function is utilized for all parameters and the system is configured with a set of parameters for covering all modes. The ITAE cost function is described in each period of simulation as:

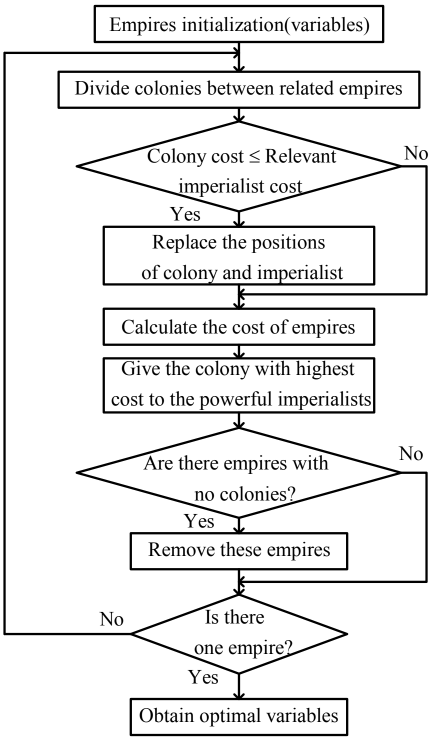


Fig. 6. Flowchart of the ICA.

$$ITAE \to \sum_{k} k.W.|E(k)|$$

$$f = \sum_{k=k_0}^{k_n} (k - k_0).W.|E(k)| \tag{25}$$

Where, k is the simulation time, W is weighting matrix for showing the importance of each element of $E(k)$ and W matrix is fixed to [1,3,1,1], $E(k)$ is the error matrix that includes the electrical characteristics of the microgrid and here it is described as:

$$E(k) = [\Delta V(k), \Delta f_{req}(k), \Delta P(k), \Delta Q(k)]^T \tag{26}$$

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

First, a set of control parameters are randomly produced by optimization algorithms. MATLAB simulation uses these values to compute the needed outputs for $E(k)$. Now, the algorithm, by considering the cost function value, removes a number of produced variables in previous level of optimization process and generates new variables in the next level. This procedure will continue till the total value of errors keep to minimum and the proper condition of the microgrid system will be satisfied. The mentioned operations are time-wasting processes, but one of the significant properties of ICA is it's high convergence speed, which provides the faster optimization procedure, (Duan et al., 2010).

Fig. 6 displays detailed steps of the ICA method in flowchart form. First, the control parameters of droop and inverter form the ICA countries. Then, these parameters are sent to the simulation in order to creation of required outputs for calculating the cost of each country. In this way, countries with high costs are removed and optimal control parameters (countries with low costs) are acquired.

6. CASE STUDIES

This paper works on control system of a small scale microgrid network in the absence of main power grid. It is assumed that this system has enough capability to supply the local loads by one DG. The aim of the present study is to closely analyze the controllability and stability of a microgrid system in different modes. These subjects are tested with several operating modes using rapid change in local load for searching the performance quality of the control system. Therefore, the overall system is put into the island mode with five working parts. There are several applications of MGCS block diagram in previous studies. This paper improves the MGCS without any complexity in the control system. This fact has been proved by system output results in suggested states.

In (Bevrani and Shokoohi, 2013), the speed and voltage parameters of the droop controller are fixed but in this study, they are considered as a variable with a limitation based on the source capability. The line resistance and inductance are set in three conventional models, whereas PI and droop control parameters are changeable in each models. The system can become stable with a certain set of control parameters but they might not be the optimal parameters. Hence, ICA is coordinated with simulated model to determine the optimal parameters.

Table 1. shows fixed power system parameters based on proposed single-line diagram in section 3 and acquired optimal control parameters from ICA. As mentioned earlier, the system stability is examined by five load changes in three line types which are introduced by R_x with 0.1, 1, and 10 values. Although, the control parameters may stable the system states, the optimal parameters remove the unwanted deviations and provide the faster system stability. k_p and k_i are the optimal proportional and integral PI coefficient and R_f and M_v are the optimal speed and voltage factors of droop control. Also, all parameters are in per unit.

In this section, the analysis of system outputs is discussed between [0,1] in five sectors. Also, a simulation comparison is performed between system outputs by non-optimal and optimal control parameters. The simulation results verify the correct operation of the controller and the effective performance of obtained optimal parameters.

Table 1. Microgrid system parameters.

	Mode I	Mode II	Mode III
R *L*	0.003, 0.03, 0.03 0.03, 0.03, 0.003	0.003, 0.03, 0.03 0.03, 0.03, 0.003	0.003, 0.03, 0.03 0.03, 0.03, 0.003
	-0.945, -0.01	-0.945, -0.01	-0.945, -0.01
(general)	1.6, 21	1.6, 21	1.6, 21
(optimal)	2, 38	2, 38	2, 38
P	0.3, 0	0.45, 0	0.17, 0.5

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

In this case study, the load variations are considered over the power networks working modes. The protection systems do not withstand the applied variations and quickly isolate the network from these critical transient states which occurs upper the permitted protection ranges. To examine the operation of proposed control system in such condition that the protection system fails, these load variations are simulated to prove the correct performance of control system in abnormal conditions. Fig. 7 shows the mean and minimum values of ITAE cost function and the procedure of variations. When it can be declared the ICA has a good performance that these two values of cost function be close to each other in some primitive iterations and do not diverge in following iterations. The mean and minimum costs are coincident with each other after about 20 iterations. Although, the total iteration is 100 the process of calculated costs are shown for 40 iterations in Fig. 7.

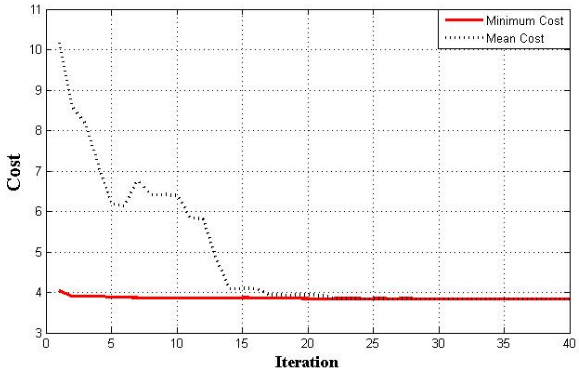


Fig. 7. Mean and minimum cost of imperialists.

According to this argument, ICA can meet the objectives of suggested control scheme in total simulation time. Actually, the optimal control parameters achieved by ICA satisfy the power system standards and also load requirement.

Fig. 8 shows produced active and reactive powers by inverter in 1 second. First between 0-0.2, all demanded power is active, whereas reactive power is zero. Between 0.2-0.4, active and reactive powers are about 0.3 and 0.04 respectively. In 0.4-0.6, the maximum value of both powers is about 0.75 and 0.09. Between 0.6-0.8, active power decreases to 0.7 and reactive power is near 0.06. In final part, between 0.8-1, the total power again is active with the value of 0.5.

To study the line impedance impact on the system frequency and voltages fluctuations, the system output diagrams are considered in three line types.

Fig. 9 depicts the regulation of the bus RMS voltage as one of the important control targets. As shown, V_{bus}^{rms} quickly attains to rated voltage of (equals to) $1\ p.u.$ When the load increases, V_{bus}^{rms} declines. Thus, the total loss grows up and vice versa. When the load reduces, V_{bus}^{rms} rises in transient states. The bus voltages' variations are exactly matched to the power system studies.

Fig. 10 shows the system frequency deviations with considering the island mode without the power grid attendance. After removing transient states, the system frequency is strictly preserved within nominal frequency of $50Hz$.

When starting the simulation between 0-0.1, the local load is fixed and control parameters are capable to regulate the system frequency on $50\ Hz$ until 0.2. In 0.2 s and 0.4 s, the local load suddenly climbs and causes the frequency falling down. These disturbances are eliminated instantly and the frequency backs to it's nominal value. In 0.6 s and 0.8 s, the load reduces and the frequency again settles to the nominal value. The behavior of the system frequency is like the bus voltage.

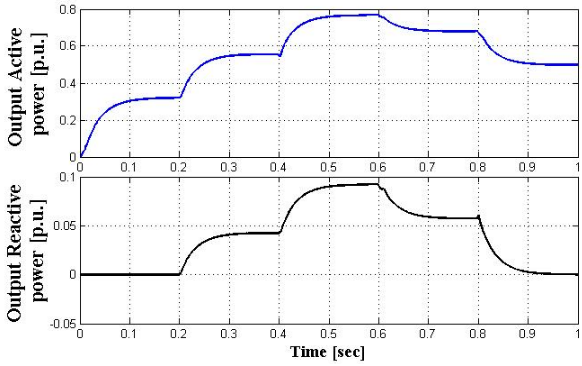


Fig. 8. Inverter output active and reactive powers.

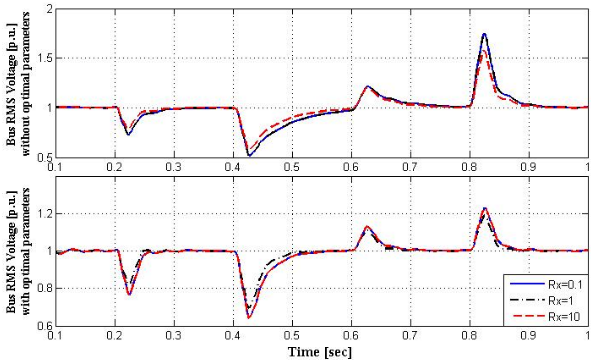


Fig. 9. Obtained bus RMS voltage with & without optimal control parameters.

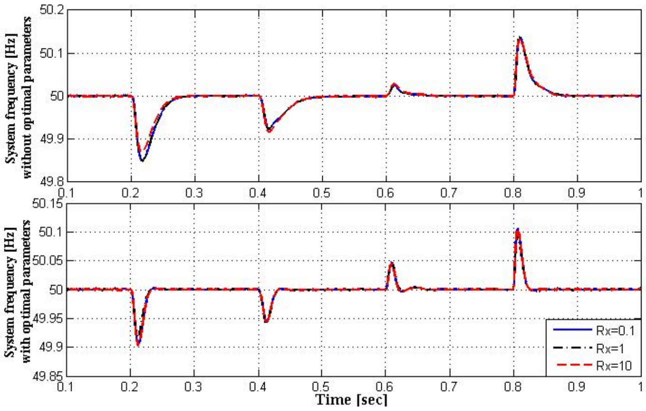


Fig. 10. System frequency response based on two sets of control parameters .

In Fig. 11, the impact of optimal control on frequency and voltage is completely obvious in the bus voltage waveform. Also, the zoomed voltage is represented for closely focusing on harmonics, frequency, and amplitude. The other control goal is to keep the bus q-axis voltage near zero.

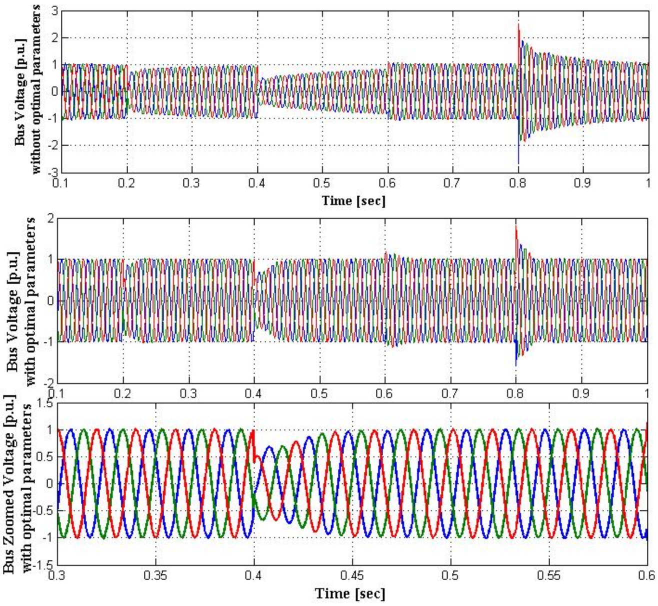


Fig. 11. Bus voltage waveform based on control parameters given in Table 1.

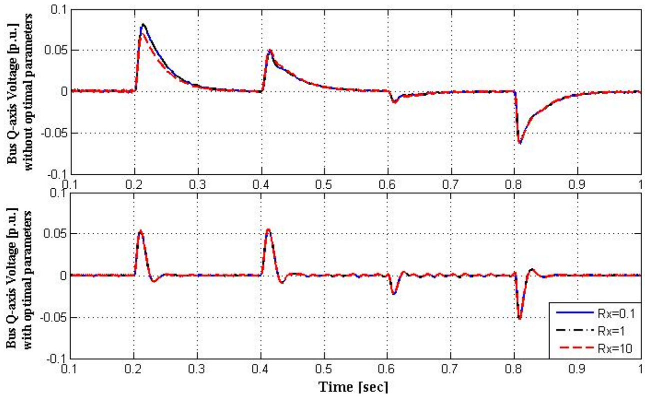


Fig. 12. Obtained bus q-axis voltage profiles under control parameters of Table 1.

Fig. 12 shows the phase-locked loop (PLL) parallel operation with the main controller. With removing the V^q, one of the system variables decreases and V_{bus}^{rms} only has d-axis voltage factor. In Fig. 12, V^q is exactly on zero and it has small deviation in transient times.

7. CONCLUSION

This paper proposed a new control method with a combination of d-q and 3-phase techniques in the microgrid system includes one DG. The microgrid system is simulated in the island mode so that the major control problems appear in this case. The correct performance of this controller was surveyed in three specific line types because of the significant impact of the line characteristic variations on the system outputs. Also, five transient states were considered to test the control system flexibility. The mentioned controller took advantage of a supplement controller in voltage control path. This simple combinatorial idea showed the great improved impacts in simulation results. This extra controller concept can be used by storage systems in practical operations.

In order to acquire a better response of the system operation, both control parameters of the droop and PI controllers were optimized by ICA. The ITAE cost function was implemented to connect the simulation results with the ICA.

The purpose of the current study was to provide the stability for probable states, which was occurred in islanded microgrid systems. This stability was evaluated by system outputs measurement such as the frequency and voltage. Furthermore, the results showed the suggested controller flexibility in adaptation with different conditions.

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