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Multifunctional control design for voltage control, frequency and active microgrid power

Hossein Ravangard[a], Mohammad Mehdi Ghanbarian[a,*], Mohammad Hossein Fatehi Dinarlo[a]

[a]*Department of Electrical Engineering, Kazerun Branch, Islamic Azad University, Kazerun, Iran*

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Abstract

Increasing the number of microgrids will challenge centralized control and telecommunications control structures. Multifunctional systems are a good alternative to decentralized control and management structures. The focus of this article is on designing multifactorial control for voltage, frequency and active power control. Past studies have spent their ability to stabilize the voltage at different terminals of a microgrid on a value. This can be technically and economically criticized. Different terminal voltages can be set to different values. It is not necessary to set the voltage of each terminal to the value of the apex. Economically, given the optimal load distribution, it may be possible to stabilize all terminals on an unjustified value. In this study, a protocol has been proposed by which the voltage at different terminals of a microgrid is able to stabilize at different values. In this paper, due to the stabilization of the voltage of different terminals on different values, the optimal distribution of reactive power is created. To regulate the voltage at the terminals where the voltage control devices are not available, the voltage corresponding to these terminals can be considered as one of the optimal reactive power dissipation constraints; in this case, the improvement of the voltage profile in critical terminals is facilitated. The article has tested the comparative method of fixed time and the postmodern method on a similar system. And it has been shown that the time-constant adaptive method has a better convergence time than the regression method. But the simplicity of the backlog method is significant in some applications (where there are no power-sensitive loads).

Keywords: design, multifunction control, voltage control, frequency, active power, microgrid

*Corresponding author

Email addresses: Hossein13.6872@gmail.com (Hossein Ravangard), Ghanbarian@kau.ac.ir (Mohammad Mehdi Ghanbarian), Mh_Fatehi@kau.ac.ir (Mohammad Hossein Fatehi Dinarlo)

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1. Introduction

The integration of scattered production resources with loads and storage devices creates the concept of microgrid. It is applicable to the microgrid in work mode connected to the network and independent of the network. In network-connected mode, the frequency is applied to the microgrid from the network, but since the voltage is a local quantity, the microgrid can help regulate the voltage in the local area network. Frequency and voltage control is one of the major challenges of microgrid in island mode. For hierarchical control, a hierarchical structure has been proposed [9]. The primary control loop will help the stability of the system by injecting artificial inertia, and sometimes it will be responsible for the correct division of power and harmonic division between converters. Due to the presence of the primary control loop, a constant error in the voltage and frequency value is created, which will be compensated by the secondary control of this error. Finally, tertiary control is responsible for the optimal operation of the microgrid in both operating modes. The methods proposed for secondary control are divided into two categories: centralized and distributed [6]. Distributed methods have been considered in recent research due to the lack of need for a central controller, fewer telecommunication links, and higher reliability [10, 4, 3, 5, 14, 2, 8, 7, 11, 16, 19, 18]. In distributed participatory control, each distributed generation source acts as a factor and exchanges information with neighboring agents in order to achieve the control objectives of the microgrid, including frequency control, voltage, and proper power distribution (to prevent rotation). There are a number of factors involved in controlling multi-factor systems: 1) agreement without a leader, 2) tracking the leader, for example, controlling the frequency, and recovering it from the leader tracking type, and the problem of correctly dividing the active power by the leader-type agreement. In [10, 4] the distributed control is used for the mentioned control purposes. [10] The first-order agreement protocol is used to control the voltage, frequency, and distribution of the system, while the agreement protocol for the voltage control problem is of the second-order agreement protocol type. In [4], linear feedback is used to linearize nonlinear relationships of system dynamics, and the problem of voltage control is of the type of the second-order agreement protocol. In [3, 5], instead of modeling the internal dynamics of voltage and current control circuits, a neural network was used to estimate the dynamics of the internal voltage and current control circuits in order to distribute the distributed voltage.

The proposed method in the above reference is not resistant to parametric uncertainties and external disturbances. The protocols provided in [10, 4, 3, 5] have unlimited time to reach the final value. In [14], after presenting the microgrid small signal model, the stability of the small signal was investigated and finally the distributed averaging method was proposed in order to control the voltage, frequency and division of active and reactive power. [2] The time limit agreement protocol is designed to solve the time convergence problem. References [8, 7] examine the resistance of the agreement protocol to parametric uncertainties and external disturbances. In [11] the distributed mode viewer and the limited time control are used to adjust the voltage and frequency. A secondary distributed design with a terminal slider mode controller is proposed to improve the convergence of the voltage-frequency control agreement protocol and the sharing of active storage capacity [16]. The points that have received less attention in the proposed methods along with the innovations and specifications of this research can be expressed as follows:

Some of the proposed methods have an indefinite convergence time [10, 5] and [14]. Rapid convergence time is one of the important factors in the study of distributed controllers and in microgrid due to the presence of load-sensitive loads, the speed of return of voltage and frequency to nominal values is necessary. The time constraints presented in [2, 8, 19] and [18] depend on the initial value, and their convergence time is limited but uncertain. To overcome this problem, this article uses a fixed-time protocol in which the overlap of the convergence time is independent of the initial state of the system.

The protocols provided in [8, 15] and [16] have a nonlinear slip level of fraction and less than one. Although the use of these slip surfaces will reduce the convergence time, these slip levels will lead to uniformity when converging near the origin. In order to prevent the singularity of the proposed slip surface, a sliding surface consisting of two parts will be used in this study, in order to prevent singularity when the slip surface is close to zero.

External disturbances in microgrid voltage control in [4] and [5] have been eliminated by linear feedback. If external disturbances are not measurable, it will be difficult to eliminate them in linear feedback. To solve this problem, a comparative control method has been used to estimate external disturbances.

Sliding fashion-based methods, despite their acceptable resistance to external disturbances, have a complex control structure and often have discontinuous protocols [2]. To simplify the control structure in the research, in addition to providing a fixed time structure, a regression controller is designed for voltage control.

Due to the use of agreement with the leader in the proposed protocols [10, 4, 3, 5, 14, 2, 8, 7, 11, 16, 19, 18, 15, 12], the voltage of all microgrid terminals is set to the same value. This is sometimes technically and economically unjustified. Due to technical or economic issues, microgrid terminals will be stabilized at different voltages. In addition, if the factor related to the leader is lost, the voltage regulation throughout the system will be compromised. To solve this problem, the agreement of several leaders is used, in which the conditions for stabilizing the terminals on different values of voltage are provided.

[10, 4, 3, 5, 14, 2, 8, 7, 11, 16, 19, 18, 15, 12] and less attention has been paid to tertiary control and some of its functions in island mode such as optimal distribution of reactive power and reduction of voltage deviations of microgrid terminals. In this study, in the third voltage control, the NLP method has been used in order to optimally distribute the reactive power and reduce the voltage deviations, in which the optimal reference value for the voltages of the controllable terminals is provided.

Voltage stabilization is of particular importance in critical terminals (terminals where voltage control devices are not available) and has been noted in [1] and [17]. However, since the proposed methods are one-way, they have considered the leader factor as the input to stabilize the voltage at the critical terminal of the voltage reference. In this case, the voltage of all controllable terminals is set to one value (and in such a way that the voltage stabilization at the critical terminal is achieved). This method can be considered economically or technically unjustified. To address this challenge in this study, the value of the critical terminal voltage is stabilized according to the constraints related to the optimal distribution of reactive power (which occurs in tertiary control).

Most of the distributed methods [10, 17] have abandoned the initial source modeling of distributed generation generators. If the primary source is not modeled, the secondary voltage and frequency control tracks any imposed power (even higher than the nominal values) to the distributed generation source. In this study, fuel cells have been used to model the primary source of scattered generators. The use of fuel cells in the direct current link causes problems such as changes in the voltage of the direct current link and delays in tracking power changes. To prevent these problems, the fuel cell with a storage device is operated in parallel at the direct current link. The limited power of the fuel cells will make it difficult to operate them in the event of a sudden increase in load. To solve this problem, load response is used in this study. The DLC load response program has the ability to remove loads in an emergency.

The dynamic models presented in References [4, 19] and [13] do not take into account the effect of the virtual impedance loop on the dynamic modeling of distributed generation generators. In this research, a complete model of scattered production materials is presented by considering the virtual impedance ring.

2. Materials and Methods

2.1. Agreed control of limited time distributed frequency and active power

In this section, the agreed control method is distributed for 1) recovery of frequency $\omega_i \rightarrow \omega_{ref}, \forall i \in v$ and 2) division of active power $k_{pi}P_i = k_{pj}P_j, \forall i, j \in v$ (in order to prevent the flow of rotation between converters) presented. By deriving the control of voltage and frequency drop and assuming that the internal dynamics are stable [4], the input of the control can be calculated to control the frequency and active power. The issue of frequency control is in line with the leader and the issue of active power control is in the form of agreement without a leader. Distributed methods are the time constraints provided in references [18, 17] or in two ways: 1) discrete 2) continuous. Discrete methods have a smoother transient state and continuous methods have a faster convergent time. In this research, a hybrid method has been used, which is a combination of transient mode smoothness of discrete method and continuous convergence time of continuous method.

$$\dot{\omega}_i = \dot{\omega}_{ni} - K_{pi}\dot{P}_i \rightarrow \dot{\omega}_{ni} = \dot{\omega}_i + K_{pi}\dot{P}_i = \dot{v}_{\omega i} \tag{2.1}$$

In relation (2.1) $\dot{v}_{\omega i}$, the control input is for controlling the frequency and active power of the i factor, which according to Protocol (2) and (3) in the limited frequency time, all units reach the reference value and then the correct division of active power takes place.

$$\begin{cases} \dot{e}_{\omega i1} = \sum_{j\in v} sig(\omega_i - \omega_j)^{a_\omega} + sig(\omega_i - \omega_{ref})^{a_\omega} \\ \dot{e}_{\omega i2} = \sum_{j\in v} sign(\omega_i - \omega_j) + sign(\omega_i - \omega_{ref}) \\ v_{\omega i} = -\int c_{\omega 1}(\dot{e}_{\omega i1}) + c_{\omega 2}(\dot{e}_{\omega i2}) \end{cases} \tag{2.2}$$

$$\begin{cases} \dot{e}_{pi1} = \sum_{j\in v} sig(k_{pi}P_i - k_{pj}P_j)^{a_p} \\ \dot{e}_{pi2} = \sum_{j\in v} sign(k_{pi}P_i - k_{pj}P_j) \\ v_{pi} = -\int c_{p1}(\dot{e}_{pi1}) + c_{p2}(\dot{e}_{pi2}) \end{cases} \tag{2.3}$$

According to the above protocol, the frequencies of the units will be equal to $\omega_i = \omega_j \ \forall i, j \in v$ and each of them will reach the reference value of $\omega_i = \omega_{ref} \ \forall i \in v$. Correct deactivation of the active power of $k_{pi}P_i = k_{pj}P_j, \forall i, j \in v$ will also be performed.

2.2. Distributed frequency control using load management

In the references [10, 4, 3, 5, 14, 2, 8, 7] and [16, 19, 18, 15, 12, 1, 17] that used the distributed control for the secondary frequency control, the effect of the dynamics of the primary direct current source is not considered. Modeling of these sources causes problems that threaten the stability of the voltage and frequency of the microgrid. 1) The output voltage of primary sources (due to the presence of internal resistance changes with the change of output power. Changing the output voltage of primary source disturbs the conversion of direct voltage to alternating current. Direct voltage is referred to as the required alternating voltage. Some studies have used DC / DC boost converters to stabilize the voltage at the DC link.

2) The primary sources of converters due to electrodynamic cycles (such as microturbines) or electrochemicals (such as fuel cells) are unable to instantly detect changes in load capacity. That's why some research on the DC link, along with the fuel cell (or microturbine), has used storage devices such as batteries or supercapacitors to quickly track the load.

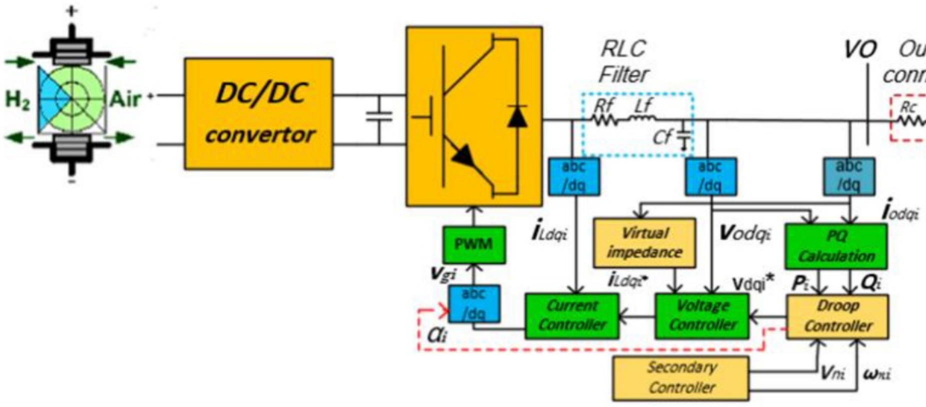

Figure 1: Primary source modeling

3) If the primary source of the microgrid converters is ideally modeled, it is able to restore the frequency and voltage even under a sharp increase in the secondary load control voltage and frequency. If the initial source capacity of the microgrid converters is limited, and there is no ability to restore voltage and frequency under load above the nominal values.

In this study, DC / DC converter is used to solve the problem of load tracking and voltage drop in DC link. And to solve the problem of transient loads above the nominal limits, load management is used. Load management is a set of programs that facilitate economic control and exploitation of power systems by applying incentive or punitive policies to subscribers. Various programs are provided to respond to the load. Compatibility of the load response program with the aim of secondary frequency control is one of the important goals of this research. Time-based applications such as CPP. Because TOU and RTP are optional, they do not have the ability to accurately stabilize the frequency. Market-oriented applications such as DB or A / S are not feasible due to the lack of market formation in a single microgrid. The DLC direct load control program is applicable to the microgrid structure. The direct load control program is activated when the apparent output power of the converters exceeds the nominal limit. Figure 1 shows the control input of controllable loads.

$$if \quad p_i > p_{max} \qquad e_{pi} = k_L sig(p_i - p_{max})^{a_l} \tag{2.4}$$

In order to prevent the momentary oscillations of the load from affecting the performance of the controller (2.4), the output power of the converters is passed through a low-pass filter before entering the comparator.

3. Systems Studied

To evaluate the efficiency of the proposed method, its performance in island microgrids with different specifications and with different scenarios in MATLAB / simulink environment is investigated. The value of the frequency reference in microgrids below 50 Hz and the reference value of the voltage is 380. The switches used in both microgrids are IGBT / Diode with a frequency of 10 kHz.

1. Test system with two DGs
   Figure 2 shows a microgrid containing two DGs and a telecommunication structure between agents. Table 1 shows the information repeatedly displayed in Terminals 2 and 3, the coefficients of deflection, the coefficients of the controllers of the internal circuits and the virtual impedance voltage, the output filter parameters, the connecting impedance and the line impedance.

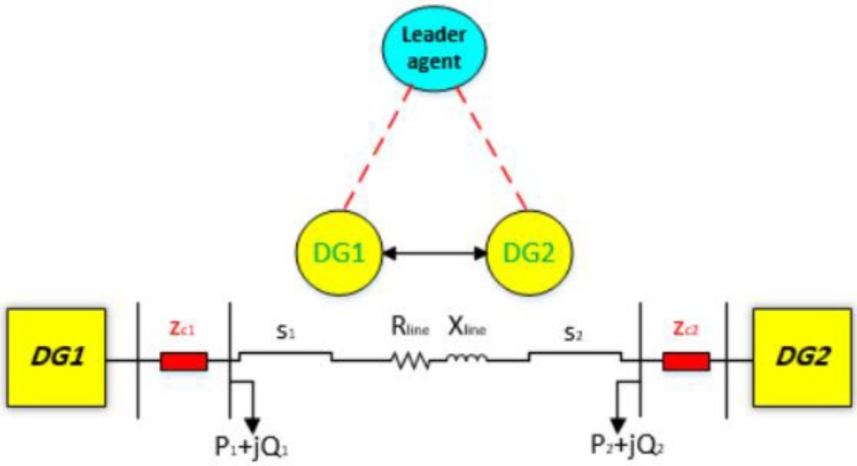

Figure 2: Microprocessor (1) Test system with two DGs

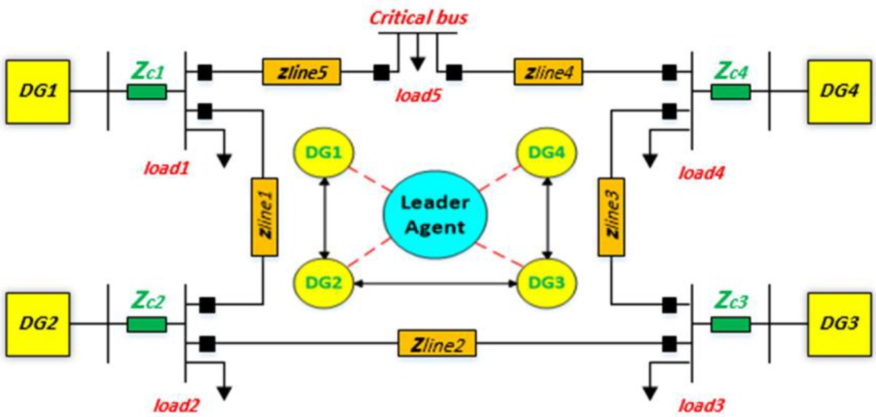

Figure 3: Microprocessor frequency changes (2)

2. Test system with four DG
   Figure 3 shows the microgrid (2) with four DGs. This microgrid has a different structure from the microgrid (1). For example, the loads of this microgrid are fixed impedance and the ring structure of this microgrid can be converted into a radial structure. In microgrids (2) there are terminals, in which there are no voltage control devices. Therefore, studies on the critical terminal can be done on this microgrid. The voltage and frequency controller coefficients of active and frequency power are shown in Table 1. The effect of virtual impedance is considered through linear feedback. The following steps are performed in order to check the method presented in the microgrid with two DGs.

4. Results and Discussions

4.1. Testing the fast limit time resistive method and the fixed time adaptation method on the microgrid (1)

Steps 1-5 in the microgrid (1) are performed to evaluate the efficiency of the resistive fast time limit method and the fixed time adaptive method provided for frequency and voltage control, respectively. The parameters of the controllers in this case are shown in Table 1. In this microgrid, both factors have access to the frequency control reference.

Table 1: Voltage and frequency control parameters

Voltage Controller	
Sliding surface	m_1=0.4 , n_1=1.5 ,k_1=1.5 σ_1=10 , σ_2=5 , ϕ=0.2
Control law	m_2 =0.8 , n_2 =1.2 φ = 5 , τ = 10
Adaptation law	κ =1 , ρ = 1 , ε = 0.2
Frequency & Active power Controller	
Frequency controller	α_ω = 0.75 , $C_{\omega 1}$=80 $C_{\omega 2}$=60
Active power Controller	α_p =0.6 ,C_{p1}=60C_{p2}=30

Step 1 At time t = 0, the microgrid (1) is disconnected from the network and enters island mode. In this case, only the primary control (drop control) is active. Due to the presence of active power loss control, it is divided correctly between units. But a permanent error occurs in the reference value of the frequency and the magnitude of the voltage.

Step 2 At moment t = 1, the secondary control of voltage, frequency and active power is activated. At this point, the error due to the initial control function in the voltage and frequency reference value is compensated. In order to maintain the correct division of active power, the correct division between units is done while controlling the frequency.

Step 3 At the moment t = 2, in order to check the efficiency of the proposed method, it is connected to terminal 1 with an active power of 3 kW and a reactive power of 3 kV.

Step 4 At the moment t = 3, the third control is activated with the aim of optimal control of the reactive power. By increasing the voltage at terminal 4, it leads to a reduction in losses in the microgrid (1).

Step 5 At time t = 4, the S1 and S2 keys are opened due to an error in the line between terminals 2 and 3. In this case, the connection between the two DGs is disconnected and each DG stabilizes the voltage and frequency on its reference value. Because in this case there is no need to divide the active power between the units; each unit provides only the active and reactive power of the loads connected to it. After disconnecting the line, the communication link between the two DGs is disconnected, and each DG is required to provide its own connected loads.

Frequency changes, active power, and two DG active power ratios in steps 1 to 5 can be seen in Figures 4 to 6. Changes in voltage and active power can be seen in Figures 3 and 4. Changes in microgrid losses during testing can be seen in Figure 5. As can be seen from the moment $t > 3$, due to the presence of tertiary control, the losses in the microgrid (1) have decreased. Accessing both DGs to the frequency reference value is the reason for recovering the frequency after the line is interrupted.

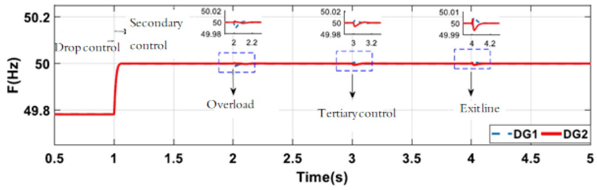

Figure 4: Microgrid frequency changes (1)

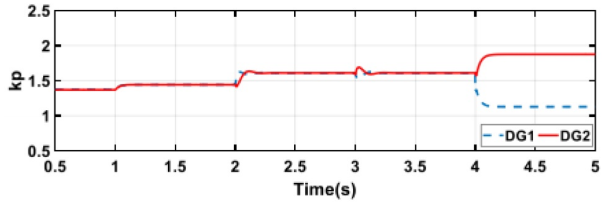

Figure 5: Changes in the active power ratio of the microgrid (1)

4.2. Testing the fast limited time-resistant method and the fixed-time comparative method on the microgrid (2)

Various scenarios are created to evaluate the effectiveness of the proposed method in microgrid (2). At time $t = 0$, the microgrid is disconnected from the network. In $0 < t < 1$ only the primary control is active. In $t = 1$ the secondary control is activated. From $t > 2$ the secondary control compensates for any frequency and voltage deviation from the reference value. To check the resistance and repel external disturbances in $t = 3$ and $t = 4$, respectively, the load is added to the terminal and the load is cut off from the terminal. In $t = 5$, the third control is performed with the aim of reducing losses. There is no voltage control at the critical terminal. In order to stabilize the desired terminal voltage, its voltage is placed in addition to the optimal distribution of reactive power and is fixed at 1 pu. In $t = 5$, lines 2 and 5 are opened and the connection between agent 2 and agent 3 is disconnected. This condition can be seen in Figure 7. In this case, due to the use of multi-leader protocol, there is the ability to stabilize voltage and frequency. Frequency changes, active output power, active power ratio are shown in Figures 8 to 10. Figures 11 and 12 show the voltage of the converters and their reactive output power, respectively. As can be seen in $t > 4$, due to the presence of tertiary control, the values of the reactive output power change significantly. This change is due to the conflict between the objectives of controlling the correct distribution of reactive power and voltage control, which is fully stated in the reference. Figures 13 and 14 show voltage changes at the critical terminal and total network losses, respectively.

4.3. Retrograde test on microgrid (1)

The adaptive method has a complex structure despite a fast convergence time and good resistance. The retrograde method is easier to implement due to the simplicity of the control structure. Since the

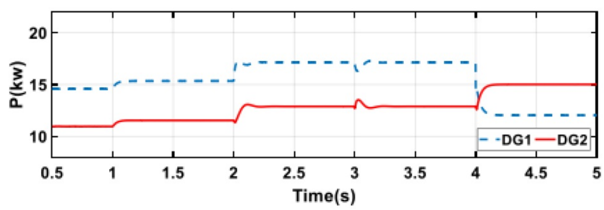

Figure 6: Changes in the active power of the microgrid (1)

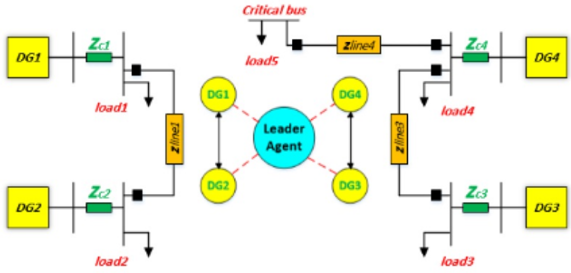

Figure 7: Micropropagation arrangement (2) after cutting lines 2 and 5

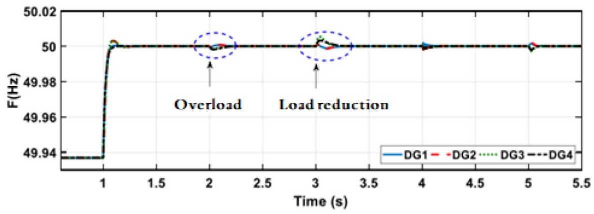

Figure 8: Frequency output changes of microgrid converters (2)

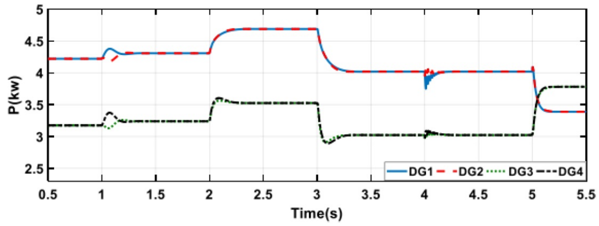

Figure 9: Changes in the active output power of microgrid converters (2)

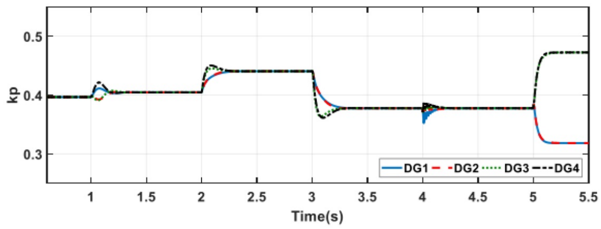

Figure 10: Changes in the ratio of active power of microgrid converters (2)

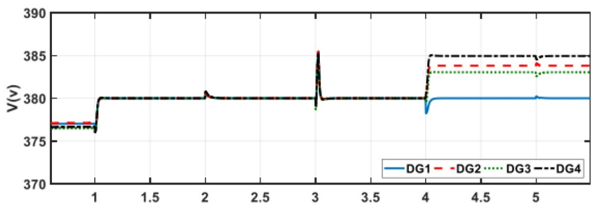

Figure 11: Changes in the output voltage of microgrid converters (2)

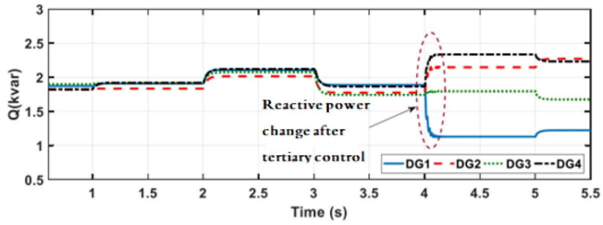

Figure 12: Reactive power output changes of microgrid converters (2)

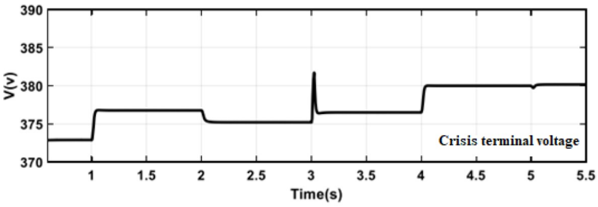

Figure 13: Microcircuit critical terminal voltage changes (2)

coupling between frequency and voltage control is minor in this paper, and the step-by-step method is provided only for voltage control, the results of frequency control and active power division in this structure are similar to the previous structure. So here we only look at the backward method in voltage control. Figure 15 shows the changes in microgrid voltage (1) during the five steps mentioned above.

Figure 15 shows that the regression method has an acceptable ability to control the microgrid voltage (2). One of the weaknesses of this method is the slower time convergence of this method than the limited time and constant time methods. Figure 16 shows that this method is not capable of controlling voltage if external disturbances cannot be eliminated by linear feedback. If the external disturbances are not removed, the input signal to the voltage control authority will reduce the voltage instead of increasing the voltage. In Figure 16, the reason for the non-collapse of the voltage is the presence of a PWM reference voltage limiter. The PWM reference voltage limiter does not allow the reference voltage to increase by more than 10%. If the reference voltage limiter is not present, the voltage is reduced more than shown in Figure 16.

4.4. Effect of Virtual Impedance Ring on Secondary Microwave Voltage Control (1)

In this section, the presence of virtual impedance and its non-modeling in voltage control is discussed. The first method is chosen because of its simplicity between the time-consuming and time-constant methods. Figure 17 shows the output voltage of microgrid converters (1). As can be seen in this figure, the lack of modeling of the virtual impedance ring causes incorrect voltage adjustment. The virtual impedance enters the voltage control loop after controlling the drop, and affects the voltage setting.

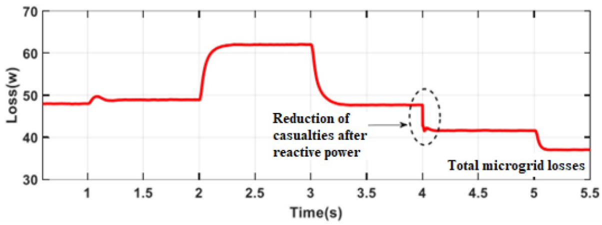

Figure 14: Loss of microgrid losses (2)

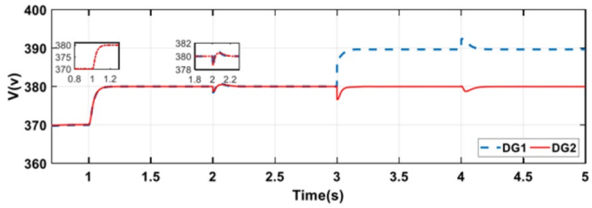

Figure 15: Changes in the output voltage of microgrid converters (1) by the backward method

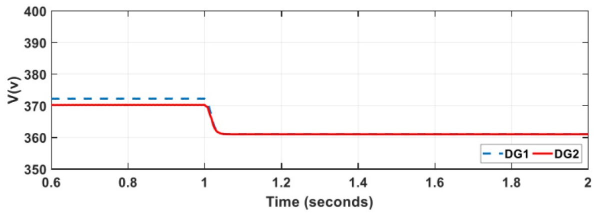

Figure 16: Backward method for adjusting the output voltage of microgrid converters (1) with the presence of external disturbances

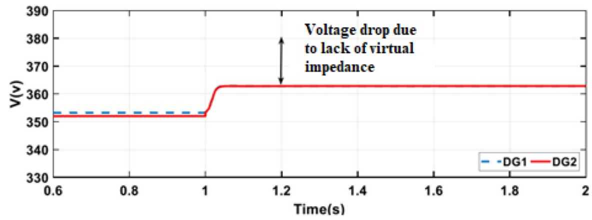

Figure 17: The effect of non-modeling of virtual impedance on microgrid voltage regulation (2)

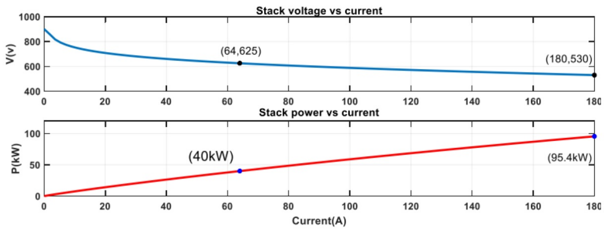

Figure 18: Characteristic of DG1 fuel cell from microgrid

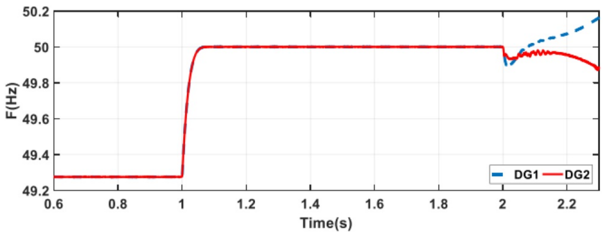

Figure 19: Change the output frequency of microgrid converters (1) without the presence of controllable loads

4.5. Utilizing load response to control power in the microgrid (1)

In this section, it is assumed that the primary source of the converters in the microgrid (1) is the fuel cell type and the characteristic of DG is in the form of 18. The characteristic of each fuel cell can be plotted with the input of the values of voltage and rated current and the maximum voltage and current in the MATLAB / Simulink environment. The fuel cell parameters are provided in the appendix. An incremental DC / DC converter is used to stabilize the voltage and track the load on the DC link.

Two similar operating modes are considered to investigate the effect of direct load control. A) First, without the presence of direct controllable loads, the fuel cells connected to converters 1 and 2 are operated. At moment $t = 1$ the secondary frequency control is activated. And at $t = 2$ times 40 kW is added to terminal 2. Figures 19 to 22 show the changes in the output frequency of the converters, the output power of the converters, the output voltage of the DC link after passing the DC / DC increment converter, and the output power of the fuel cell in the DC link, respectively. The reason for the frequency instability from the second onwards is the sudden increase in load at the second terminal.This increase in load leads to a sharp drop in voltage on the DC link. Exit voltage is one of the important parameters of the fuel cell. If the increase in load leads to a decrease in the fuel cell voltage to the output voltage, the protective structures of the fuel cell will operate and its output current will be cut off.

B) In this case, all the steps of mode A are performed, with the difference that the controllable loads of 30 kW are present in terminals 2 and 3.

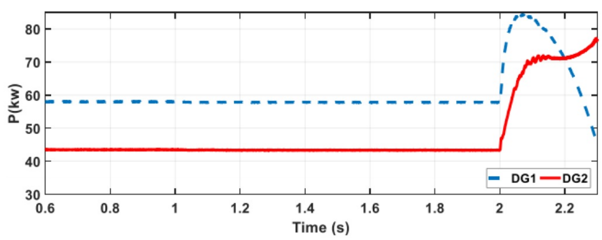

Figure 20: Changing the output power of microgrid converters (1) without the presence of controllable loads

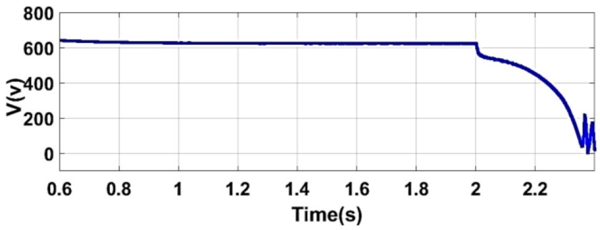

Figure 21: Change the output voltage of the boost converter connected to DG1 without the presence of controllable loads

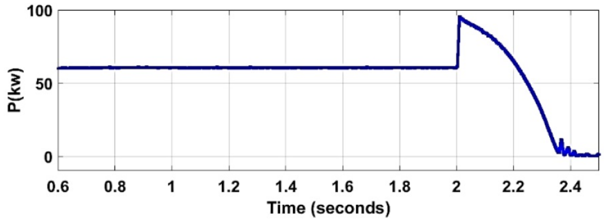

Figure 22: Changing the output power of the fuel cell connected to DG1 without the presence of controllable loads

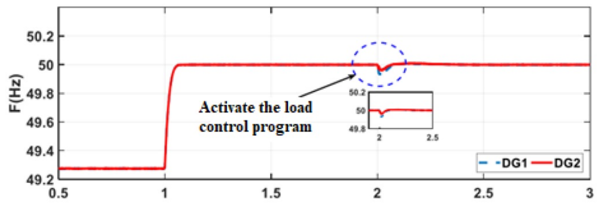

Figure 23: Change the output frequency of microgrid converters (1) with the presence of controllable loads

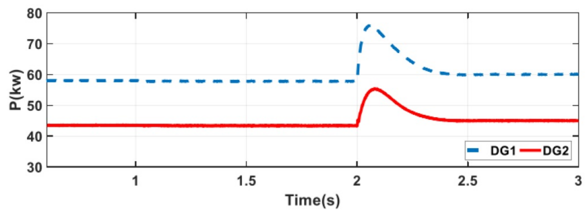

Figure 24: Changing the output power of microgrid converters (1) with the presence of controllable loads

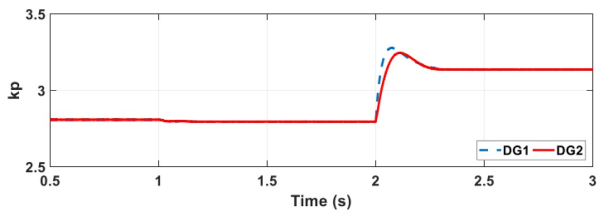

Figure 25: Changing the output power ratio of microgrid converters (1) with the presence of controllable loads

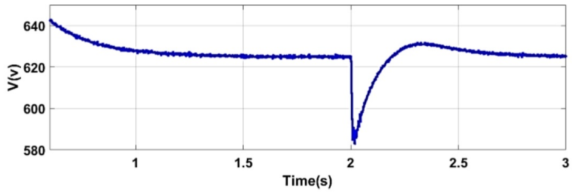

Figure 26: Change the output voltage of the boost converter with the presence of controllable loads

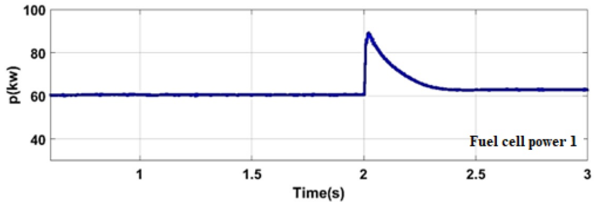

Figure 27: Changing the output power of fuel cell 1 with the presence of controllable loads

4.6. Comparison of performance of fixed time adaptive method with limited and common time methods

The frequency control method presented in this study has been compared with the conventional and time-limited methods presented in [2] and [8], respectively, and the voltage control method presented in this study has been compared with the conventional and time-limited methods used to The sequences presented in [4] and [8] are compared, the test system (1) is selected for ease of implementation. Figure 28 shows the frequency changes of DG2 during steps 1 to 5 of Subsection 4.1. Figure 29 shows that the proposed method has a higher convergence rate than conventional and time-limited methods. Although limited time and conventional methods are able to eliminate external disturbances, at the moment when the line between terminal 2 and terminal 3 is cut off, due to lack of access to the reference value and the presence of pest control, they do not have the necessary ability to stabilize frequency in DG2. Figure 30 shows this.

Figure 31 shows the DG2 voltage changes in steps 1 to 5 of Subsection 4.1. Figure 32 shows the faster convergence of the proposed protocol than the limited and common time protocols. Figure 33 shows that in the event of an error between terminals 2 and 3, limited and common time methods cannot adjust the voltage. There are two reasons for the increase in partial voltage after the line is drawn between terminals 2 and 3: 1) the presence of voltage drop control-reactive power) in the primary control structure 2) the activation of linear feedback after disconnection between DG1 and DG2.

5. Conclusion

In this section, according to what was presented in the simulation and analysis section, the general conclusion is summarized as follows:

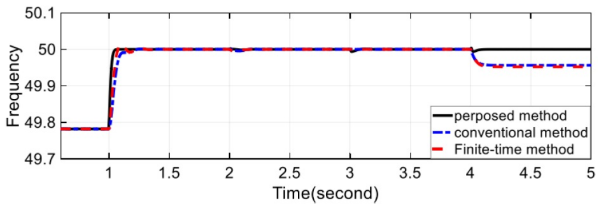

Figure 28: Comparison of the efficiency of the proposed frequency control method with time-limited and common methods

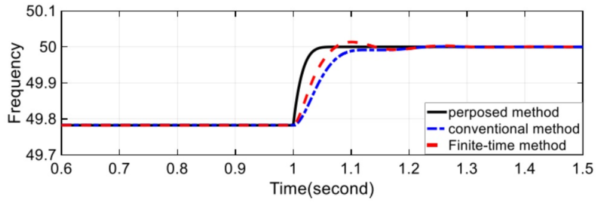

Figure 29: Comparison of convergence time of the proposed control method with time-limited and common methods

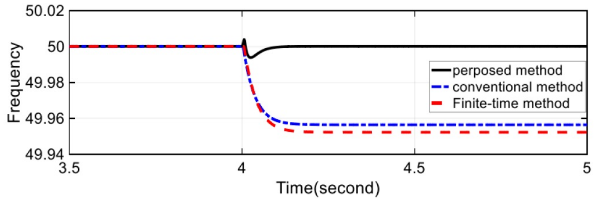

Figure 30: Comparison of performance of the proposed control method with time-limited and common methods against line exit

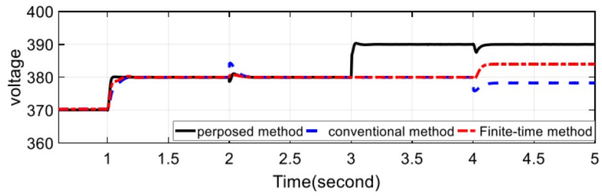

Figure 31: Comparison of performance of the proposed voltage control method with time-limited and common methods

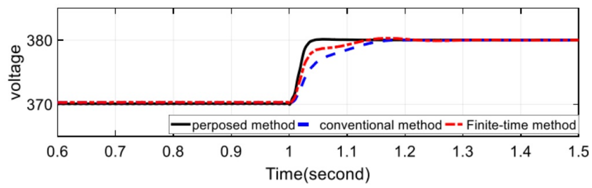

Figure 32: Comparison of convergence time of the proposed voltage control method with time-limited and common methods

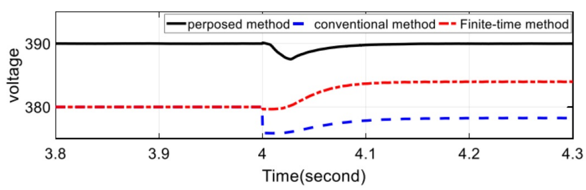

Figure 33: Comparison of the performance of the proposed voltage control method with time-limited and common methods against line output

1. Increasing the number of microgrids will challenge centralized control and telecommunications structures. Multifunctional systems are a good alternative to decentralized control and management structures. The focus of this paper is on multifactorial control design for voltage, frequency and active power control.
2. Past studies have spent their ability to stabilize the voltage across different microgrid terminals at a value. This can be technically and economically criticized. Different terminal voltages can be set to different values. It is not necessary to set the voltage of each terminal to the value of the apex. Economically, given the optimal load distribution, it may be possible to stabilize all terminals on an unjustified value. In this study, a protocol has been proposed by which the voltage at different terminals of a microgrid is able to stabilize at different values.
3. In this paper, due to the stabilization of the voltage of different terminals on different values, the optimal distribution of reactive power is created. To adjust the voltage of the terminals where the voltage control devices are not available, the voltage corresponding to these terminals can be considered as one of the optimal reactive power dissipation constraints, in which case the improvement of the voltage profile in critical terminals is facilitated.
4. In this paper, the comparative method of time constant and the regression method are tested on a similar system. And it has been shown that the time-constant adaptive method has a better convergence time than the regression method. But the simplicity of the backlog method is significant in some applications (where there are no power-sensitive loads).
5. In the presence of linear feedback and its non-modeling in secondary voltage and frequency control, disturbances will occur.
6. If the primary source of the converters is not modeled, the secondary control has the ability to return the voltage and frequency under load conditions above the nominal values. This assumption is incorrect and in this study, this problem is prevented by modeling the primary source and using load response.

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