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Stabilizing Micro grid Frequency by Linear Controller Design to Increase dynamic response of Diesel Generator frequency Control Loop

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Abstract- *In this paper, a distributed generation including diesel generators, wind turbines, and microturbines are introduced, and their mathematical model is described using the Taylor expansion method. With the goal of computational complexity eliminating, the reduced order model (ROM) of microgrid components is considered. The results of the studies indicate that the microgrid frequency is unstable. The main purpose of this paper is stabilizing the frequency of the microgrid by design modified linear controller. It is shown that the using proposed linear controller increases the dynamic response of the diesel generator and therefore can be constituted stable microgrid. The results show that the diesel generator can control the frequency of the microgrid in unwanted islanding and load change conditions. To verify the validity and feasibility of the proposed controller, several simulations results have been presented on MATLAB/Simulink software. The simulation results show the appropriate performance of the proposed controller for example in islanding mode, frequency restoration time is less than 1 (s) by using the proposed controller, as a result, the microgrid can be exploited in island mode.*

Keyword: Microgrid, PID, Islanding, Linearization, Phase margin .

1. INTRODUCTION

According to the expansion of greenhouse gas emissions and the gradual increase in earth temperature, researchers are investigating solutions to limit the greenhouse gas emissions. An appropriate solution to reduce the production of these gases is using distributed generation [1]. Renewable energy sources have some merit such as environmental friendly effects and low price which is discussed in reliability [2-3].

According to the merits, wind energy is considered as the most affordable and cheapest renewable energy source, and the use of natural gas as the cleanest fossil fuel can be complemented by wind energy application. In recent decades, due to the development of semiconductor technology, the use of power electronics switch has become cheaper, so that ability to control and manage the renewable energy sources has been provided [4].

Combined Heat and Power Generation (CHP) system has high electrical efficiency and can be complemented by the renewable energy sources usage [5]. It is obvious that most renewable energy sources are uncontrollable and their generation power is in most cases randomly, so the researchers are searching for solutions to reduce this defect [6-7].

Distributed generation connection to each other and constitute of microgrid can be an appropriate way to meet the consumers demands growing [8], but there are limitations and problems with connecting these resources with together such as increasing the power electronic converters cost, requires the high-speed processors usage as well as the load optimization and load management method in the microgrid [9].

As a result, to access the stable and high reliability microgrid, several criteria should be considered which have been discussed in Ref. [10]. In this paper, the proposed microgrid components are included diesel generators, wind turbines, and microturbines [10-11]. The wind turbines operation and control have been discussed in Refs. [12-13]. The wind turbine generator is a squirrel cage and the power generated by the turbine is not controllable [14]. Advantages of using microturbines in microgrid and its power control methods are discussed in Refs. [15-16]. The diesel generators role in the microgrid voltage and frequency control has been studied in Refs. [17-18]. The distributed generation operating characteristics show that these sources are stable alone, but when they

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connect to each other and constitute a microgrid, the operation of the microgrid will be unstable, and its components will not be synchronized with each other. The microgrid frequency control strategies have been discussed [19-20]. Though that provides an efficient method for control of microgrid but they neglect form islanding occurred in microgrid or nonlinear behaver in microgrid components.

The suggested scheme is using energy storage system, but it have main disadvantage such as with using energy storage cost of system is increased and it is not economically feasible. Another proposed method is the load shedding techniques that have been discussed in [21-22] the main drawback of this method is its low reliability because the use of this method has important limitations in the sensitive and vital load applications.

For design linear the controller, the microgrid components are modeled and the obtained models are linearized around the operation point. Then, the designed controller is implemented on the diesel generator speed control system.

This paper develops a modified controller structure for improved control of the diesel generator system under an island mode control configuration. Then, based on the proposed control structure, the integrated microgrid system is developed, including wind turbine, microturbine and diesel generator and performa nce of the proposed controller in unwanted islanding mode and load increase are investigated.

The rest of this paper is organized as follows: In section2, the microgrid components are introduced. In section3, the microgrid component is modeled in detail. In section 4, the microgrid simulation results are given. In section 5, the controller is designed to stabilize the frequency of the microgrid.

2. Micro grid Components

The purpose of using the microgrid is to achieve proper performance with the least cost and maximum efficiency. Therefore, the microgrid components should be selected in such a way that they can act independently from the power grid. Over the past two decades, the wind energy and CHP systems have used in microgrids, because of their great merits .

The natural gas as a microturbine fuel is one of the cleanest and cheapest fossil fuel which connects the microturbine to the microgrid. But, the output power of the wind turbines and microturbines is variable [23].

Furthermore, other sources with the voltage and frequency control ability are necessary to connect to the microgrid. Diesel generators can control the frequency and voltage of the microgrid at high capacity and appropriate price. Diesel generator frequency is controlled by the governor system and voltage is controlled by the Automatic Voltage Regulator (AVR) system. Therefore, the microgrid is consist of some diesel generators, microturbines, and wind turbines.

3. Micro grid Mathematical Modeling

For analyses and design linear control, microgrid components should be modeled. After modeling, by linearization method such as Taylor expansion, linear models are calculated. In following microgrid components are modeled respectively.

1.1. Wind Turbine Modeling

P_m is wind turbine output power which is calculated using the following equations [14].

$$p_w = 1/2\rho A v^3 c_p(\lambda,\beta) \tag{1}$$

$$c_p(\lambda,\beta) = .22\left(\frac{116}{\lambda_i} - .4\beta - 5\right)e^{\frac{-12.5}{\lambda_i}} \tag{2}$$

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.35}{\beta^3 + 1} \tag{3}$$

where, ρ is the air density, A is area swept by blades , v is wind speed, β is the pitch angle of blade, R is blade length and λ is tip speed ratio which represents ratio of tip speed $(\omega_r R)$ to wind speed. The squirrel cage generator is used in this case study and it dynamic equation is presented as follows [24]:

$$\frac{di_{qs}}{dt} = \frac{1}{L_{qs}}\left(v_{qs} - R_s i_{qs} + \omega_s L_{ds} i_{ds}\right) \tag{4}$$

$$\frac{di_{qs}}{dt} = \frac{1}{L_{qs}}\left(v_{qs} - R_s i_{qs} + \omega_s L_{ds} i_{ds}\right) \tag{5}$$

$$\frac{di_{qr}}{dt} = \frac{1}{L_{qr}}\left(v_{qr} - R_r i_{qr} + \omega_r L_{dr} i_{dr}\right) \tag{6}$$

$$\frac{di_{dr}}{dt} = \frac{1}{L_{dr}}\left(v_{dr} - R_r i_{dr} - \omega_r L_{qr} i_{qr}\right) \tag{7}$$

$$p_w = T_w \omega_r \tag{8}$$

$$T_e = \frac{3}{2}\frac{p}{2} L_m\left(i_{dr} i_{qs} - i_{qr} i_{ds}\right) \tag{9}$$

$$\frac{d\omega_r}{dt} = \frac{1}{j}\left(T_w - T_e - T_f\right) \tag{10}$$

Where L_m is stator magnetization inductance, v_{ds} ,v_{qs} are stator voltage, v_{dr} , v_{qr} are rotor voltage on the rotating reference frame, i_{ds} , i_{qs} are stator current, i_{dr} , i_{qr} are rotor current on the rotating reference frame, L_{qs} , L_{ds} are stator inductance in rotating reference frame, L_{qr} , L_{dr} are rotor inductance in rotating reference frame, R_r , R_s are stator and rotor resistant, j is inertia of the turbine and generator set and T_f is mechanical loss model which relate to rotor speed. In this case, system state variables are extracted as given in the following.

$$x = \left[i_{qs}, i_{ds}, i_{qr}, i_{dr}, \omega_r \right] \tag{11}$$

The input vector is also defined as follows:

$$u = \left[V_{qs}, V_{ds}, V_{qr}, V_{dr}, V \right] \tag{12}$$

Wind turbine system equation have some nonlinear term such as p_w because it depend on wind speed exponent of three therefore this equation must be linearization around specified operating point.

Nominal operating point is define as: ($\beta = 0\,deg, v = 12\frac{m}{s}, \lambda = 4.91, i_{qs0} = 455.6\,A, i_{ds0} = 607.6A, i_{qr0} = 4550.6\,A, i_{dr0} = 6070.6\,A, \omega_{r0} = 1575\,rpm$) .with using the Taylor series expansion, the system equations are rewritten as follows Eq. (8).

Wind turbine system is the causal system, therefore, D matrix is zero. The transfer function is defined in the SISO system while the wind turbine is MIMO system, therefore, it is requested to be defined the specified input and output with the goal of transfer function creation so below vector is used for this purpose

$$G^T = \left[0,0,0,0,1 \right] \tag{15}$$

In wind turbine output power is selected as an output and wind speed is selected as an input, the system Transfer function is written as follows [24]:

$$\frac{P_e}{V} = C(SI - A)^{-1} BG + D \tag{16}$$

$$\frac{.94(s+210)(s-40.1)(s+6.78)(s+3.98)}{(s+3.84)\left(s^2+112.5s+4772\right)\left(s^2+315.7s+65210\right)} \tag{17}$$

The above transfer function is very complex and therefore its implementation on the microprocessor such as DSP-AVR-FPGA request high computational burden. In order to reduce this challenge, the order of transfer function is reduced with using of MATLAB software. In this approximation, high order system convert to first zero and two pole system. System bode diagram after model reduction is shown in below.

With using model order reduction method [25], Eq. (17) is written as follow:

$$\frac{P_e}{V} = \frac{3.4(s-13.3)}{(s+15.5)(s+28.6)} \tag{17}$$

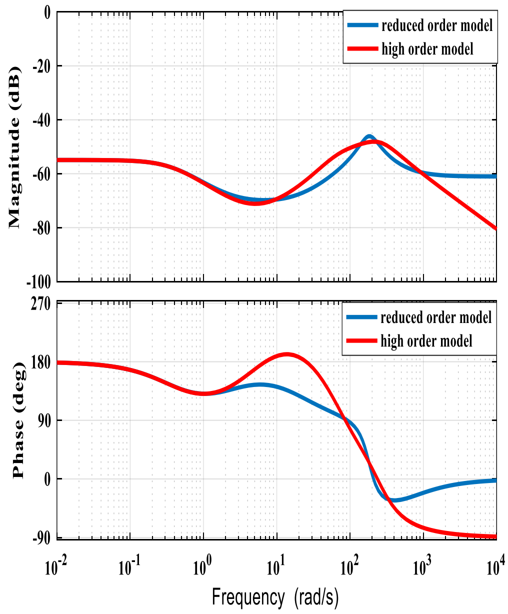

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Table 1. Wind Turbine Parameters value

Parameters	Unit	Value
L_m	Mh	8.35
L_{qs}	mh	.15
L_{ds}	mh	.15
L_{qr}	mh	.12
L_{dr}	mh	.12
R_s	Ω	.012
R_r	Ω	.0034
v	m/s	12
J	Kg.m^2	3.4
Nominal power	kw	400
A	m^2	883.6
ρ	kg/m^3	1.15

1.2. Micro Turbine Model

Microturbine system usually is consist of a permanent magnet synchronous generator and a gas turbine as a prime mover. The rotational speed of these generators is usually high and their speed range is about 10,000 rounds to 200,000 (rpm). As a result, their frequency should be converted to microgrid frequency [16]. The Permanent magnet synchronous generator modeling is given as follows [26]:

$$\begin{pmatrix} \frac{di_{qs}}{dt} \\ \frac{di_{ds}}{dt} \\ \frac{di_{qr}}{dt} \\ \frac{di_{ds}}{dt} \\ \frac{d\omega_r}{dt} \end{pmatrix} = \begin{pmatrix} \frac{-R_s}{L_{qs}} & \frac{\omega_s L_{ds}}{L_{qs}} & 0 & 0 & 0 \\ \frac{-\omega_s L_{ds}}{L_{ds}} & \frac{-R_s}{L_{ds}} & 0 & 0 & 0 \\ 0 & 0 & \frac{-R_r}{L_{qr}} & \frac{\omega_{r0} L_{dr}}{L_{qr}} & \frac{i_{dr0} L_{dr}}{L_{qr}} \\ 0 & 0 & \frac{\omega_{r0} L_{dr}}{L_{dr}} & \frac{-R_r}{L_{dr}} & \frac{i_{dr0} L_{dr}}{L_{dr}} \\ \frac{-1}{j}\frac{3}{2}\frac{p}{2} L_m i_{dr0} & \frac{1}{j}\frac{3}{2}\frac{p}{2} L_m i_{qr0} & \frac{1}{j}\frac{3}{2}\frac{p}{2} L_m i_{ds0} & \frac{-1}{j}\frac{3}{2}\frac{p}{2} L_m i_{qs0} & \frac{P_{w0}}{\omega_{r0}^2} \end{pmatrix} \begin{pmatrix} i_{qs} \\ i_{ds} \\ i_{qr} \\ i_{dr} \\ \omega_r \end{pmatrix} + \begin{pmatrix} \frac{1}{L_{qs}} & 0 & 0 & 0 & 0 \\ 0 & \frac{1}{L_{ds}} & 0 & 0 & 0 \\ 0 & 0 & \frac{1}{L_{qr}} & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{L_{dr}} & 0 \\ 0 & 0 & 0 & 0 & \frac{.49\rho A}{\omega_{r0}} \end{pmatrix} \begin{pmatrix} v_{qs} \\ v_{ds} \\ v_{qr} \\ v_{dr} \\ V \end{pmatrix} \quad (18)$$

$$y = [i_{qs0}, i_{ds0}, i_{qr0}, i_{qs0}, 1] \quad (19)$$

$$\frac{di_{qs}}{dt} = \frac{1}{L_{qs}}\left(v_q - R_s i_{qs} - \omega_r L_{ds} i_d\right) \quad (20)$$

$$\frac{di_{ds}}{dt} = \frac{1}{L_{ds}}\left(v_d - R_s i_{ds} + \omega_r L_{qs} i_{qs}\right) \quad (21)$$

$$T_e = \frac{3}{2}\frac{p}{2}\left(\lambda i_{qs} + \left(L_d - L_{q)}\right) i_{ds} i_{qs}\right) \quad (22)$$

$$\mathrm{j}\frac{d\omega}{dt} = T_m - T_e \quad (23)$$

The permanent magnet machine equations should be presented in the state spaces. In this case, the generator speed and stator d,q currents are selected as the state variables and v_q, v_d are selected as an input variable. Gas turbine dynamic for simplification is approximated by delayed model [26]. The generator power and fuel mass are considered as the output and input of system respectively. Micro turbine model can be defined with using of Taylor expansion methods around operation point. Generally, micro turbine is operated on nominal rate therefore operating point is consider as ($\omega_{r0} = 20000\, rpm$, $i_{qs0} = 151.5, i_{ds0} = 0$). Transfer function is described as follows:

$$\frac{P_g}{fuel\ mass} = \frac{e^{-ST_g}\left(s+6.3\right)\left(s+14.7\right)}{\left(s+15.2\right)\left(s+33.5\right)\left(s+48.8\right)} \quad (23)$$

Micro turbine transfer function is simplified and therefore model order reduction is performed using the Hankel singular values of the system is calculated as follow [27]:

$$\frac{P_g}{fuel\ mass} = \frac{e^{-.003s}}{1+.02s} \quad (24)$$

Micro turbine system is controlled by FOC (Field oriented control) method and more discussion is beyond the scope of this paper.

1.3. Diesel Generator Model

The diesel generator should be equipped with a voltage and frequency control system. Voltage and frequency control system model considering IEEE 421.5 standard is shown in Figs. 2 and 3 [28].In the speed control system, a PI controller is used to eliminated steady state error and improve dynamic response of speed control loop so its appropriate design depends on modeling procedure accuracy .we try to consider the speed sensor and actuator model with the goal of accurate system modeling. For practical implementation, stabilizer model is considered with the causal model in the voltage control loop. More discussion is beyond the scope of this paper.

Table 2. Micro turbine Parameters values

ParameterS	Unit	Value
Nominal power	kW	100
voltage	volt	380
Rotor speed	rpm	20000
Rotor flux	wb	0.901
p	-	4
Rs	Ω	0.01
Ld	mh	7.5
Lq	mh	7.5
j	Kg.m^2	0.04
T_g	s	0.003
fuel	-	Nature gas

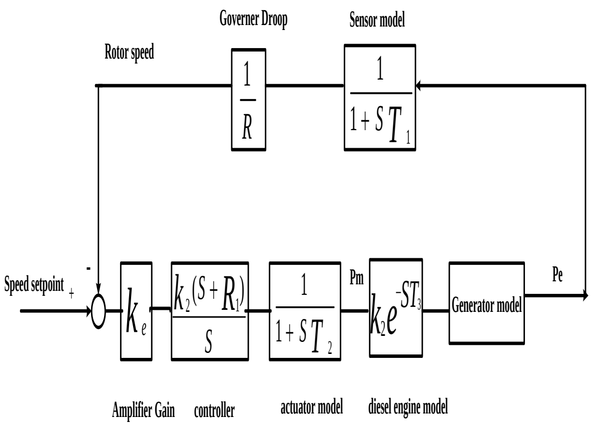

Fig. 2. Diesel generator speed control system

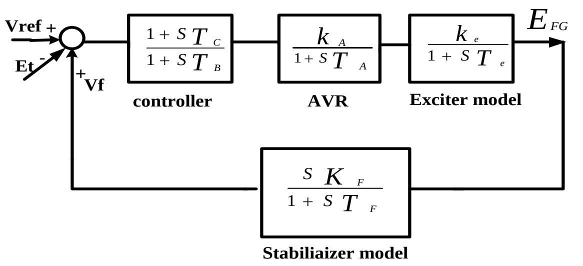

Fig. 3. Diesel generator voltage control system

The synchronous generator stator equation is described as follows:

$$\frac{di_{qs}}{dt}=\frac{1}{L_{qs}}\left(v_q-R_s i_{qs}-\omega_r L_{ds} i_{ds}\right) \tag{25}$$

$$\frac{di_{ds}}{dt}=\frac{1}{L_{ds}}\left(v_d-R_s i_{ds}+\omega_r L_{ds} i_{qs}\right) \tag{26}$$

$$T_e=\frac{P_G}{\omega_r} \tag{27}$$

$$j\left(\frac{d\omega_r}{dt}\right)=T_m-T_e \tag{28}$$

In this microgrid, diesel generator and capacitor bank are supplying reactive power consumption of wind turbine, therefore, the diesel generator is operated on overexcited mode and its nominal power factor is considered -0.9. With the assumption, the operating point for linearization is considered as: ($\omega_{r0}=1500\,rpm,\ i_{d0}=2051,\ i_{q0}=993$).

i_{qs}, i_{ds}, ω_r Are considered as state variables. v_q, v_d, T_m , are considered as input variables and electrical power is defined as system output. In state equations of synchronous generator, $\omega_r L_{ds} i_{ds}$, $\omega_r L_{ds} i_{qs}$ and $\frac{P_G}{\omega_r}$ are intrinsic nonlinear terms therefore for linear controller design and using of linear stability analysis methods such as bode and root locus, using the Taylor expansion method is proposed. The synchronous generator model after linearization around operation point is defined as following:

$$\frac{P_e}{P_m}=\frac{1}{1+.1s} \tag{29}$$

Where, P_e is diesel generator output power and P_m is primary mover mechanical power.

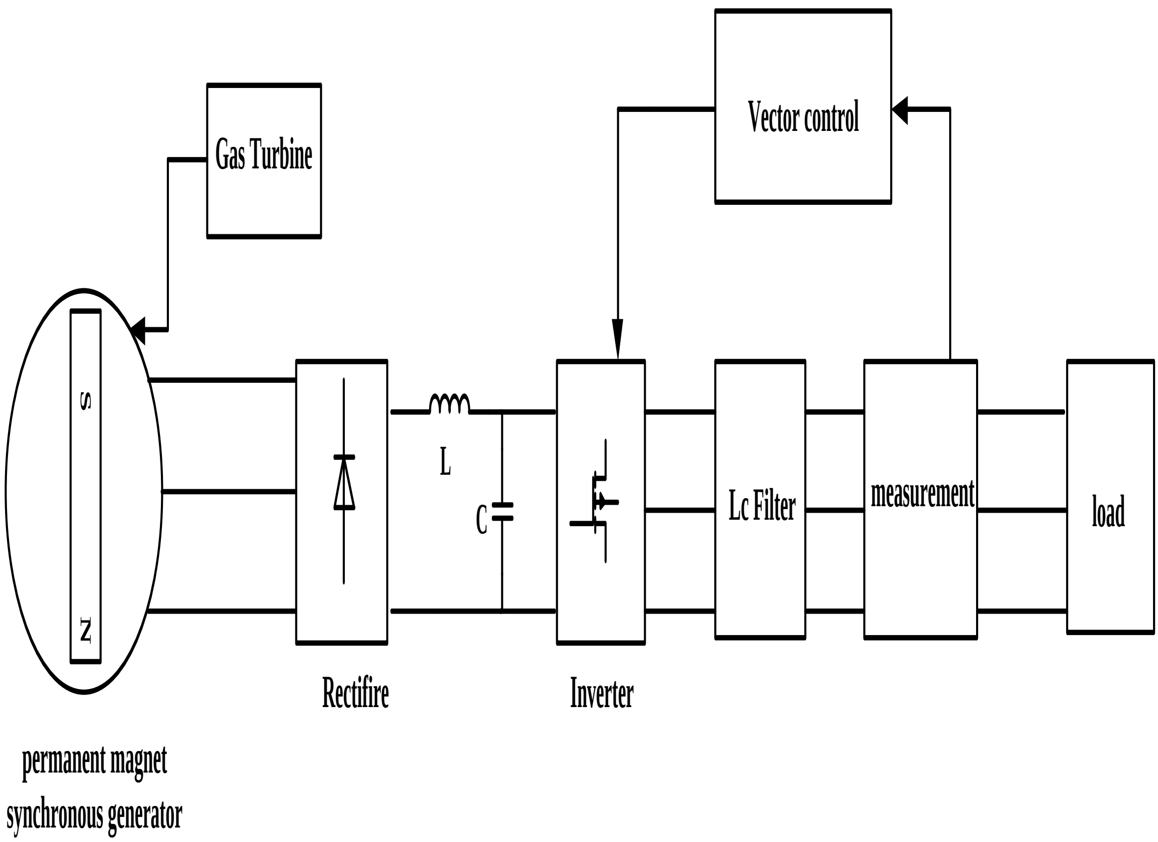

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Table 3. Diesel generator voltage control system parameter

Parameter	unit	Value
K_A	_	300
T_A	s	.01
T_B	s	0
T_C	s	0
T_E	s	1.33
K_E	_	1
K_F	_	.01
T_F	s	.0675
E_{FD2}	pu	2.25
E_{FD1}	pu	3.05
V_{Rmax}	Pu	1
V_{Rmin}	pu	-.9

Table 4. Diesel generator frequency control system parameter

Parameter	unit	value
T1	s	.009
K2	_	23
R1	_	.25
T3	s	.0385
K_{SG}	_	.02
K1	_	1
Kw	_	1
Droop	_	4%
Pmax	pu	1
T_{SG}	s	.04

Table 5. Diesel generator parameter

Parameter	unit	value
Nominal rate	MVA	1.5
frequency	hz	50
pole	_	4
Rs	pu	.0202
H	s	.09
Lds	pu	.0059
Lqs	pu	.0059
Qmax	MVR	.4
v_f	pu	1
R_f	pu	.0031
L_f	pu	.423

4. Micro grid Simulation

Considering IEEE-1547 standard, microgrid initial load should be less than 20% of the nominal capacity of the microgrid [29]. According to the characteristics of the distributed generation sources, the microgrid initial load should be selected less than 400 K.V.A and its power factor is considered 0/8. Based on, the load value in this study is considered 200kW. Simulation results are shown in Fig 5.

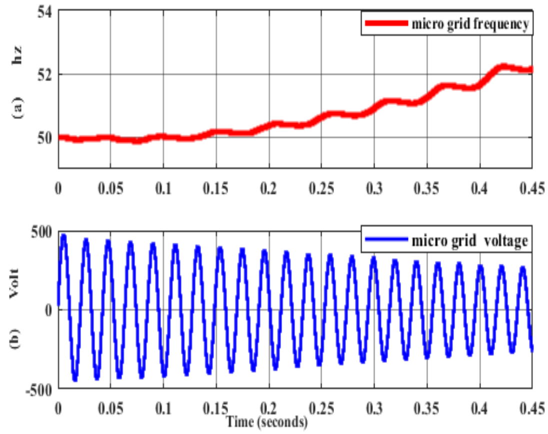

Fig5 .Micro grid simulation results, (a) - micro grid frequency, (b)-micro grid voltage

As shown in Fig. 5, the microgrid is not stable and, as a result, the protection system will be operated to control the system behavior [30]. The main cause of microgrid instability is related to its components dynamic behavior therefore if microgrid main component (in this studied diesel generator) dynamic response is slow, properly lead to the undesirable response. Fig.6 shows the microgrid block diagram which is used in the simulation study.

Table 6. Rotating mass model parameter

Parameter	Unit	Value
D	pu	1
H	pu	.1

In this paper, using of the modified proportional – integral –divertive (PID) controller for using in the diesel generator speed control loop is introduced, which can synchronize microgrid Components and makes its operation condition stable. In traditional PID structure, the divertive term is placed in feedback path which is its main contribution is system performance stabilization and oscillation reduction in system output. Traditional PID structure is showing in Fig (7).

One of the standard controller design methods is using the bode diagram. Phase and gain margin definition in the bode diagram is used to design a desired linear controller. Bode diagram of the G (s) transfer function is shown in the following:

$$G(s) = \frac{\Delta f}{Speed\ setpoint} \tag{30}$$

An induction wind turbine requires reactive power for power generation and their required reactive power should be provided by capacitor bank which is installed in the microgrid but this capacitor is sensitive to microgrid harmonic and overvoltage phenomena therefore in practical implementation, capacitors compensate party of requirement reactive power and other part is provided by other sources.

In this microgrid, the diesel generator is the only compensator of system reactive power.

Active power generation in induction wind turbine generator is depended to voltage and frequency of microgrid so if voltage have fluctuated therefore wind turbine active power is fluctuating and in this state, diesel generator governor system should regulate microgrid generation power with load consumer.

According to the bode diagram shown in Fig. 9, the system phase margin is 91.7 degrees, which is not suitable for industrial systems because the large phase margin will slow down the system performance and therefore the system cannot able to respond to disturbance and microgrid load and power generation variation [31].

This effect should be considered in the design of the proposed controller to prevent an impulse effect on mechanical devices. To use the advantages of the PID controller and prevent generation of impulse signal, the proposed structure is showed in Fig 8.

$$PID\,controller=\left[(k_p+\frac{k_i}{s})+\left(\frac{sk_d}{1+s\tau_d}\right)\right]e(s) \tag{31}$$

In the controller design, a closed loop compensated transfer function is obtained using the Mason method as following [32]:

$$T(s)=\frac{speed\ setpoint}{rotor\ speed}=\frac{\sum \Delta_k p_k}{\Delta} \tag{32}$$

In (32) Δ is system characteristic equation, P_K is route gain and Δ_k is system characteristic equation cofactor.

$$T(s)=\frac{(k_p s+k_I)G(s)}{s\left[\tau_d s^2+s+G(s)+\{k_p\tau_d s^2+k_d s^2+k_p s+\tau_d k_I s+k_I\}\right]} \tag{33}$$

With using equation (33), the open loop transfer function is calculated as given in (34).

$$h(s)=\frac{T(s)}{1-T(s)} \tag{34}$$

$$phase\,margine=\phi+180 \tag{35}$$

$$\phi=tg^{-1}(\omega_c) \tag{36}$$

$$|h|(j\omega)\|_{\omega_c}=1 \tag{37}$$

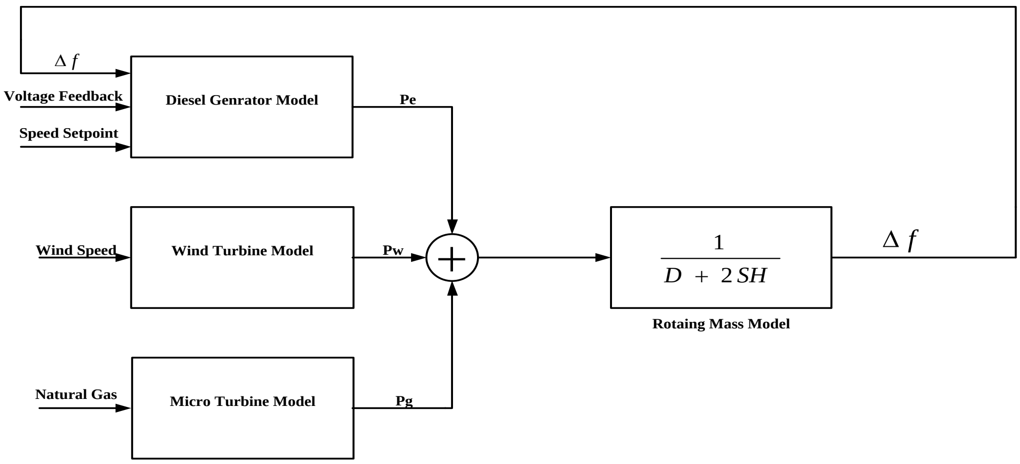

Fig. 6. Micro grid simulated block diagram

MATLAB/Simulink PID tuning toolbox is used to design the Controller and its parameters are given as follows:

$$PI=1.12+\frac{./15}{s} \tag{38}$$

$$D=\frac{./98}{./01s+1} \tag{39}$$

In controller parameter tuning, steady state error reeducation and robustness to model parameter variation is very important because the final purpose of this distributed generation is constitution of stable and island able microgrid so system frequency and voltage should be followed IEEE_1547 Standard.

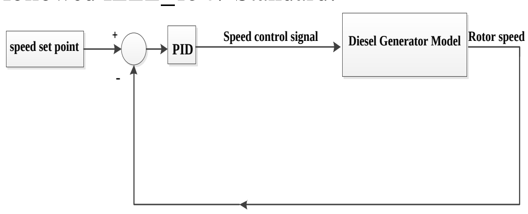

Fig. 7. Traditional controller structure

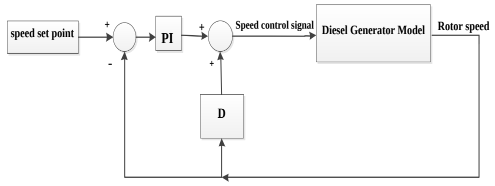

Fig. 8. Proposed controller structure

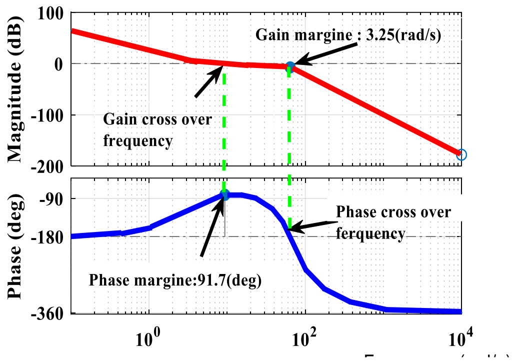

Fig. 9. Transfer function bode diagram

Applying the designed controller decreases the system phase margin to 43.2 degrees and the response speed of the diesel generator speed control system increases as well. As a result, the ability to synchronize the microgrid components with together is increased and finally, microgrid becomes stable. Fig. 10 shows the microgrid voltage and frequency simulation result after using the proposed controller.it is clear that the microgrid voltage and frequency are stable so can be independent exploitation of power system.

To confirm the new controller performance, the microgrid is operated during the unwanted islanding. For investigating microgrid performance in islanding mode the unwanted islanding is occured in t=1.5 (s) and utility grid is disconnect form microgrid, in this case, study microgrid performance is evaluated when its load is 400 KVA and power factor is consider 0/8. In this case studies, 3 different controllers are implemented in diesel generator speed control loop and their results are compere with together.

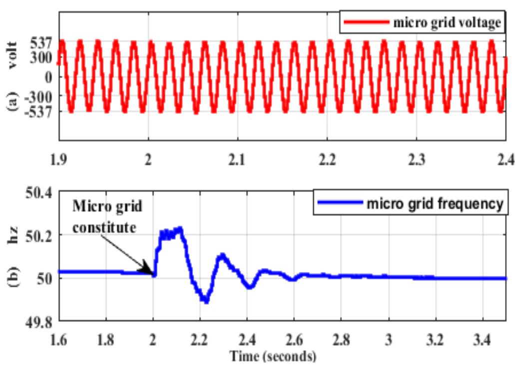

Fig. 10. Micro grid simulation after use of new controller, (a) micro grid voltage, (b) - micro grid frequency

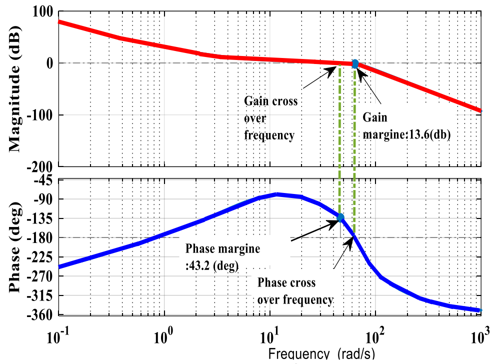

Fig. 11. Bode diagram of compensated system

As shown in Figures 12, 13, 14, when unwanted islanding occurs, the microgrid frequency is drooped suddenly and frequency restoration time depends to diesel generator speed control loop. This simulation are showed using of proposed modified PID controller can prevent the sever microgrid frequency variation and makes it stable less than 500msec.

Proposed PID controller have better performance than other two controller in unwanted islanding event the main benefit of this proposed structure is robustness against external disturbance because divertive term generate signal relate to system output and inject this signal to diesel generator governor system but if PID controller is implemented by traditional form, divertive signal is related to error between set point and output (e(s)) therefore this signal have not impressive influence in frequency droop compensation only improved steady state response and reduce its oscillation.

In this simulation can be supposed that islanding is a great disturbance which is occurred in microgrid so divertive term in proposed PID controller generate appropriate control effort to compensated frequency droop.

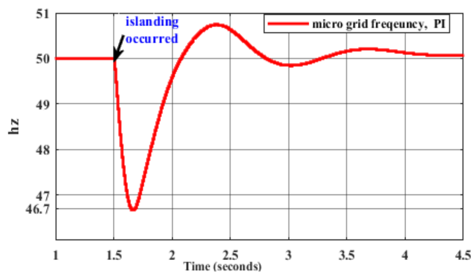

Fig. 12. Micro grid frequency after islanding with using PI controller

In order to illustrate the importance of the proposed controller, below Figures shows simulation results obtained with three different controllers. In this case study, the load is increased about 10 % because in this paper we present a logical procedure to obtain liner model of microgrid components as result for doing accurate studied, load variation in microgrid should be near its operating point.

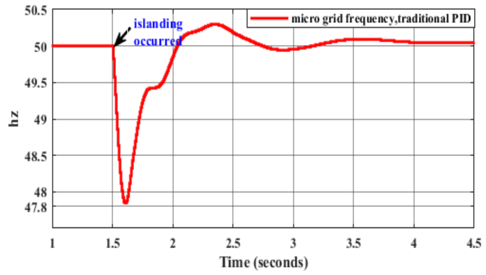

Fig. 13. Micro grid frequency after islanding with using traditional PID controller

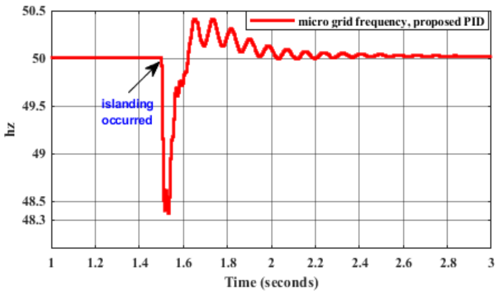

Fig. 14. Micro grid frequency after islanding

As can be seen, with using the PI controller, the microgrid frequency drop value is acceptable but its restoration time is very slow therefore for eliminated this weekend point, using of PID controller are proposed, in this paper the 2 different implementation structure of PID controller is used.

Using traditional PID can prevent the Too much frequency drop and improve frequency restoration time but yet microgrid frequency response should be improved to in controller structure do not use of the divertive term, therefore, to increase operate satisfactorily.

Fig 17 showing proposed PID performance in this Fig it is clear that microgrid frequency in load variation have satisfactory response, for example, microgrid frequency in most drop is near 49.96 Hz that is approximately equal with 50 Hz and another main strong point of proposed controller is its frequency restoration time so that in less than 1 (s) microgrid frequency is regulated in nominal frequency. As can be seen, using of the proposed controller with compression of other controllers have very fast response and low-frequency drop, therefore, it can to be introduced as a suitable choice for using in diesel control system.

One of the most possible events in this studied microgrid is wind speed variation, therefore, wind turbine power changed and therefore affected the microgrid performance. In this event also wind turbine reactive power is variable and influence active power control system therefore microgrid frequency control is also severe problem because in microgrids active deviations and reactive deviations are dependent on each other so when wind speed is change, its reactive power consumption is changing therefore Cannot be ignored this effect in frequency control . The more discussion is beyond the scope of this article.

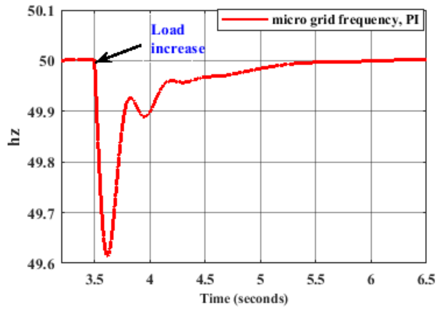

Fig. 15. Micro grid frequency after load variation (10%) with using PI controller

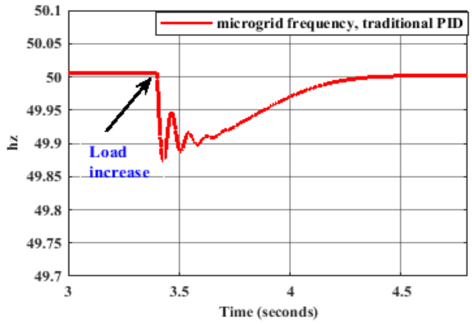

Fig. 16. Micro grid frequency after load variation (10%) with using traditional PID controller.

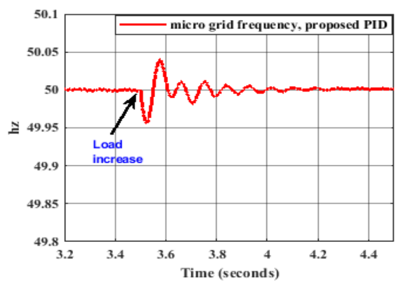

Fig. 17. Micro grid frequency after load variation (10%)

Figure 18 showing wind speed variation profile which is in 8-18 (s) wind speed have oscillated behavior.

From figure 19 and 20 can be deduced that microgrid frequency when using the proposed PID controller. better than two other schemes.

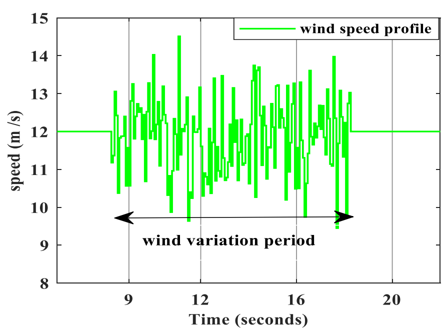

Fig. 18. Wind speed variation period

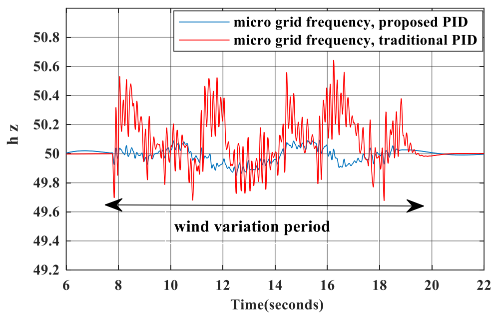

Fig. 19. Micro grid frequency in wind speed variation condition

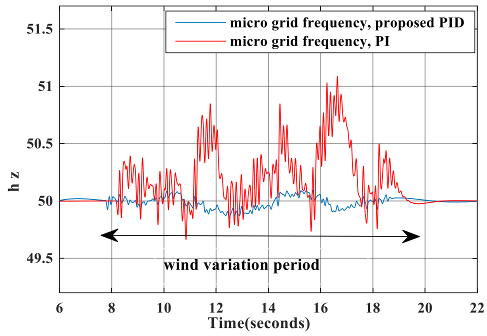

Fig .20. Micro grid frequency in wind speed variation condition

5. CONCLUSION

In this paper, some background of the distributed generations is discussed. As mentioned, to connect the distributed generation sources with together and constitute a stable microgrid, a strong system controller is needed. To stable the proposed microgrid frequency, a new linear controller is designed and it applied to the diesel generator speed control system and is compared with two other traditional linear controllers the proposed controller can successfully prevent the mechanical stresses on the control devices and therefore increase system overhaul period.

The designed controller reduces the system phase margin and therefore increases the response speed of the diesel generator speed control system. With this new controller, it is possible to synchronize the microgrid components together and as a result, the stable microgrid can be constituted .

As shown in Figs such as 14 and 17, the proposed controller can properly control the microgrid during unwanted islanding and load variations. As a result, the proposed controller can be used in microgrid as system stabilize.

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