International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 4 Issue 6, September-October 2020 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Stabilization and Frequency Regulation in Microgrid by Controlling Pitch Angle

Aman Malik[1], Kavita Sharma[2]

[1]M Tech Scholar, [2]Assistant Professor,

[1,2]Electrical Engineering Department, Doon Valley College of Engineering (DVCE), Karnal, Haryana, India

ABSTRACT

PID controller based pitch angle controller for the frequency regulation and active power control in a wind turbine and diesel engine powered hybrid power system, is presented in this paper. For testing the prosed controller, variable wind speed pattern is used for realization of real time wind behavior. Furthermore, the variable load is also connected to the hybrid power system to test the efficacy of the prosed controller. The system is modelled and simulated in MATLAB environment and results obtained are compared with and without pitch angle controller. The frequency deviations in PID based pitch angle controller is less than the without controller.

KEYWORDS: *Pitch angle controller, active power control, variable wind speed, frequency regulation*

How to cite this paper: Aman Malik | Kavita Sharma "Stabilization and Frequency Regulation in Microgrid by Controlling Pitch Angle" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-4 | Issue-6, October 2020, pp.70-77, URL: www.ijtsrd.com/papers/ijtsrd33303.pdf

IJTSRD33303

I. INTRODUCTION

As the power demands in all over the world is increasing exponentially, and increasing environmental pollution due to the fossil fuel burning, led to the attention tilt towards renewable energy resources based electricity generation. Wind and solar power generation are major participants in RERs based power generation. But, increase in RERs in to power system, as these are unpredictable in nature, cause more variations in power and frequency [1].

Therefore, operators of the additional power system review the operating conditions and standards provided by the grid companies and RER based system has to follow those grid codes. [2]. The addition of wind energy into the power system means that wind turbines use conventional power plants that control and strengthen the power system. If the power output of the wind exceeds a certain level, the wind engineers should take care of these problems by designing new control schemes [3]. This is a well-known fact that integration of wind energy conversion system to the grid cause imbalance to the overall system [4]. A stable power system is also very important for wind energy conversion systems, as if there is any difference between the frequency, and the system can get out from synchronism [5]. Short-term temporary fault is the most common disruption. Such a temporary error leads to a sub-synchronous system partition that must be drawn before the system becomes unstable. Usually these type of oscillations are reduced by conventional power plants with compatible generating systems, which are installed by an electric power system. Power system consolidation by synchronization generators is an established technology, used worldwide [6]. If air traffic controllers are to take over power operations they must have effective ways of controlling their power output. A typical type of turbine is a type of high-speed wind energy conversion system, where the output of the wind energy conversion system can be controlled by controlling the pitch angle of the blades of the wind turbines. If a stalling-like turbine can reduce its power, it places its angles at the point where the airflow around the stain converges when caused by spots and becomes turbulent, e.g. Power-efficient turbines have direct squirrel cage generators connected and the active power demand for this type of generator is usually compensated by capacitor banks. Interpretation of the functional concept of stall bona [8]. The operating system for turbines operating has been previously tested and implemented in various energy use scenarios [9]. In this article, a controller is developed that allows the turbine to operate its pump system to make the system robust to the same power plants as conventional power plants. In order to understand the frequency of grid frequency oscillations must be true, a reasonable grid model is required. One approach is to consider the model of the energy system, which can be physically present [10]. One way is to use an actual program model. For this project, the proposed method was chosen to verify the validity of the findings.

Wind-diesel engine model adopted in this paper is an integrated model. Introducing the problem that should be addressed with a brief introduction of event of a power outage and general idea of the strengthening of the power system is given at the beginning of this article. The transfer function of the wind turbine is obtained from the step response of the turbine. For this, a PID control for the normal grid reinforcement was created, using the locus method. The operation of wind turbine with the proposed controller is evaluated by the models and the results are presented.

II. POWER SYSTEM OSCILLATIONS AND STABILISATION

The frequency in the AC power system is stable when the demand for electricity and the electricity loss equals the generation of electricity in the system. The imbalance between generation and demand leads to grid frequency when generation exceeds demand, and a decrease in grid frequency when demand exceeds generation. The grid frequency gets a new equilibrium when there is a load that takes enough frequency from the system, or when the generators are installed by the converters that convert the prime mover power so that the producers pull the frequency back to the rated value. The governor controller, which control the mechanical power supplied by the diesel engine to regulate the frequency at different operating conditions. If the change in generation and demand occurs gradually, the frequency will gradually deviate. When a change occurs, it usually receive temporary oscillations before it can reach its new equilibrium. An unusual short-term error can be considered as a step change, as the shorter cycle now performs the loading step. If a fault happens nearby the generator, the electrical power of the generator stations will be reduced so that the generator can no longer supply running power, which is why changes occur over generations. In any case, the short cycle proposes a balance between load and generation by step change. If, as described above, the associated generator (SG) cannot send electrical power during a short-term fault it must collect the power of the machine, when the main conductor drives the generator. A rotating machine can only accumulate energy faster. The generator is therefore accelerated during the fault, and, after the fault has been removed, tries to extract as much electrical energy as possible to hold it back. Because of this, the rotor speed of the oscillates generates. In AC interconnected network error the fault in one location and the faster speed sequence of SGs in this area resulted in a change of power (local overlap) between different locations throughout the system. Since the rotor in the SG rotates perpendicular to the stator field, the rotor speed is the same as the electric current. Therefore, the rotor speed oscillations are grid oscillations, which must be minimized before the entire system is inactive. In a conventional power plant, SGs equipped with electric power reduce this inefficiency. If future wind farms replace some of the conventional power plants, these wind farms should play a role in reducing grid frequency and spatial distribution. As described above, the frequency oscillations are caused by an imbalance between the energy produced and the energy consumed. Therefore, the regular grid oscillations (and the interarea oscillations) can be solved by a controlled voltage injection into the grid. Since the type of wind turbine considered here is a turbine-powered, squirrel-cage induction generator, the only way to control its output power is a propulsion system that controls the aerodynamic, drive generator.

III. DESCRIPTION OF THE PROPOSED SYSTEM

In this paper a hybrid power system consisting of wind energy conversion system, assisted by diesel engine generator and the pitch angle controller for the purpose of regulating the frequency of the wind generator are presented. The basic block diagram of the proposed system is shown in the figure 1.

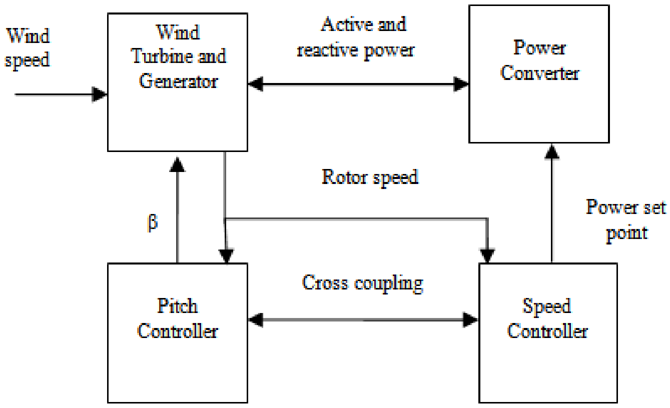

Fig.1 - Hybrid power system diagram

The average electric power is 480 Vrms. Since everything is connected to the same amount of voltage, they do not need to be changed the voltage level by transformers.

3.1. Diesel generator (DG)

The synchronous generator calls for two inputs to generate energy: the mechanical input power and the sector voltage. Mechanical electricity is injected into the generator from the diesel engine with a seize.

Field winding is energized via the excitation system. The energy output of the DG is controlled by means of variants: the engine speed reference and the take hold of condition. The speed reference is used by the diesel engine controller to measure the desired mechanical output. In addition, the grab controls the combination of the diesel engine and the synchronization machine. Engine governor and diesel engine model are described in the following section.

3.1.1. Diesel Engine

The diesel engine presents mechanical power to the synchronous machine. Its version is split in 3 parts: engine, actuator and electronic control container. The electronic manipulate field and actuator represent the engine's speed governor. When operated in isochronous mode, the engine's governor regulates the gasoline consumption in line with the engine's pace; thus keeping the DG pace and device's nominal frequency. Hence, while in isochronous mode, the engine's governor offers frequency regulation.

The diesel engine mathematical model is primarily based on the work in [11]. This model has been extensively use in previous electricity device studies [6]-[11]. The mathematical version is formed by means of separate high order transfer features for the engine, actuator and electronic box, as depicted in Fig. 2.

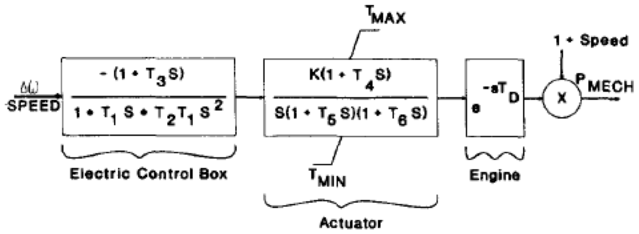

Fig. 2 - Mathematical model of the diesel engine and governor

For including the delay time due to engine mechanics, the use of time delays has been implemented. The engine block can be incorporated from MATLAB Simulink library.

3.1.2. Excitation system

To generate power, the synchronization machine needs a current field. This system is in charge of providing at field current. When operating with automatic control, the system controls the machine and power of the system [9]. When the synchronous generator with the diesel engine is disconnected, the synchronous generator acts as a synchronous condenser [12].

Although the voltage regulation is beyond the scope of the present study, the electrical power of the system must be controlled for it to function properly. In the study below, voltage regulation given by the DG system is quoted. The mathematical model of the excitation system is based on the IEEE Recommended Practice [11]. The arousal program represented by the first order transfer function in Eq as follows:

$$\frac{Vf}{Ef} = \frac{1}{k+sTx} \qquad (1)$$

The excitation system model is depicted in Fig. 3.

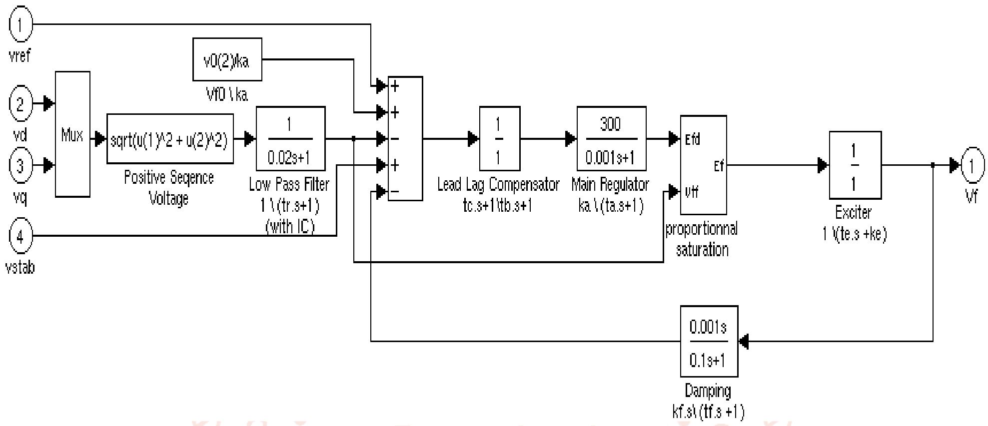

Fig.3- Simulink built in model for the excitation system type DC1A

As the synchronous machine model required here to be in direct and quadrature axis frame so, a d-q transform is introduced.

3.1.3. Synchronous machine

A special synchronous generator was chosen. The synchronization switch is rated at 480 V and 300 kVA. The mathematical model is divided into electrical and mechanical components and is based on [10].

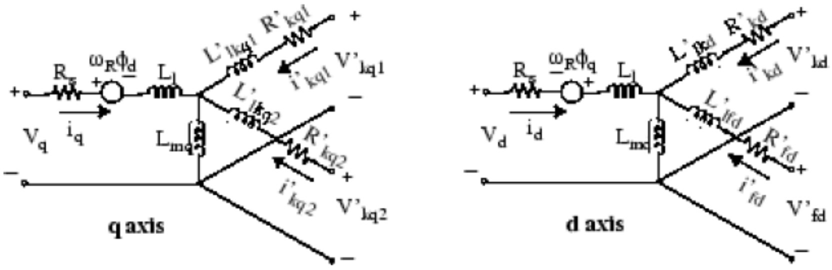

Fig. 4- Wye connected stator winding model

$$v_{qs}= R_s i_{qs}+ \frac{d\lambda_{qs}}{dt} + w\lambda_{ds} \qquad (2)$$

$$v_{ds}= R_s i_{ds}+ \frac{d\lambda_{qs}}{dt} + w\lambda_{ds} \qquad (3)$$

$$0=R'_r i'_{qr} + \frac{d\lambda'_{qr}}{dt} + (w-w_m)\lambda'_{dr} \qquad (4)$$

$$0=R'_r i'_{qr} + \frac{d\lambda'_{dr}}{dt} + (w-w_m)\lambda'_{qr} \qquad (5)$$

And

$\lambda_{qs} = L_s i_{qs} + L_m i'_{qr}$ (6)

$\lambda_{qs} = L_s i_{ds} + L_m i'_{dr}$ (7)

$\lambda'_{qr} = L'_r i'_{qr} + L_m i_{qs}$ (8)

$\lambda'_{dr} = L'_r i'_{dr} + L_m i_{ds}$ (9)

Where:

$L_s = L_{ls} + L_m$

$L'_r = L'_{lr} + L_m$

Where:

*v*dqs, *v*dqr are the stator and rotor voltages in the d-q frame
*i*dqs, *i*dqr are the stator and rotor currents in the d-q frame
λdqs, λdqr are the stator and rotor fluxes in the d-q frame
*R*s, *R*r are the stator and rotor resistances
*L*ls, *L*lr are the stator and rotor leakage inductances
*L*m is the magnetizing inductance
ω is the arbitrary reference frame

3.2. Wind Generator (WG)
The wind turbi provide power to the induction generator which is rated as 275 kW and rms voltage of 480 volts.

3.2.1. Wind Turbine
Wind power generation is divided into two units that generate wind energy i.e. fixed speed generation and variable (VSG) [34]. Fixed speed generators operate at constant rotor speed to obtain maximum power. Deviation from a predetermined speed causes a reduction in efficiency. The VSG at various rates of active rotor speed to keep up with the constant wind of high efficiency. The VSG has a large tracking capacity that emits the available energy from the air at different speeds of air thus leading to better performance. And VSG reduces mechanical pressure on the turbine thereby increasing the turbine time. The VSGs are therefore highly portable. The power of turbine dynamics has been studied extensively. In both forms of generating energy the principle of emission remains the same. The amount of energy produced by the turbine can be related to the torque produced by the wind. The model base equation represents the mechanical force, Pmech, which is bounded by the wind, Eq. 10

$$P_a = \frac{1}{2} \rho \pi r^2 C_p (\lambda, \beta) V^3{}_w \qquad (10)$$

$$\Lambda = \frac{R\Omega}{V_w} \qquad (11)$$

Here P_a is the wind power converted in to electrical power, πr^2 is the rotor swept area, C_p is the power co-efficient, λ is the tip speed ratio, β is the pitch angle and V_w is the wind speed. The tip speed ratio is defined as the ratio between the blade tip speed and the wind speed V_w

Where Ω is the turbine rotor speed and R is the radius of the wind turbine blade.

IV. SIMULATION RESULTS AND DISCUSSION
In this paper a generic model of the High-Penetration, with and without storage, and micro-grid system is presented. The optimal wind penetration (installed wind capacity/peak electrical demand) for this system depends on the site delivery cost of fuel and available wind resource.

When the wind speed is not very high, in that case both the wind energy conversion system and the diesel engine driven synchronous generator provide power to the connected load

In case of wind speed available is high then the diesel engine power is reduced and the whole load is fed by the wind energy conversion system. If the power generated is more than the load requirement then dump load can be utilized to dump this power and frequency is retorted by absorbing the wind power exceeding consumer demand. If the power generated by the wind-diesel system is less than the demand then the diesel engine comes in action and deliver the power to the system to reduce the mismatch between demand and load and also to enable load frequency control of the microgrid.

The Wind Turbine block uses a 2-D Lookup Table to compute the turbine torque output (Tm) as a function of wind speed (w_Wind) and turbine speed (w_Turb).

The DG provides frequency regulation through a speed governor. The speed governor actuates according to the desired speed reference. Hence, the diesel engine state can be controlled through the governor's reference speed. A controller was designed to regulate the governor reference speed according to the system's needs. The DE along with its actuator and speed regulator are included in the Diesel Engine block and their modelling is justified in [13]. This block has the current SM speed (pu) as input and outputs the mechanical power (pu) to take the DG speed to 1 pu speed reference. The DE has been simulated by means of a gain, relating fuelling rate to torque, and a dead time, modelling the firing delay between pistons. The DE torque has 0/1.1 pu as the lower/upper limits respectively and is multiplied by the SM shaft speed to calculate the DE output mechanical power. The actuator has been simulated as a second order system and the speed regulator is a PID control. The inertia constant of the DE+ SM set HDG is 1.75 s.

The SM has a rated power (PSM-NOM) of 300 kVA, it receives as input the DE mechanical output power from the DE block and voltage regulator plus an exciter regulates the voltage in the SM terminals its IEEE type 1 electrical part is represented by a sixth-order model.

The constant speed stall controlled WTG comprises an Induction Generator (IG) of 275kW (WTG rated power PT-NOM = 275kW) directly connected to the autonomous grid and the Wind Turbine (WT) block. The electrical part of the IG is represented by a fourth-order model. The WT block contains the Wind Turbine power curves which define the mechanical power in the WT shaft as a function of the wind speed and the WT shaft speed. The WT mechanical power is divided by the WT shaft speed to calculate the input torque applied to the IG. This WTG has no pitch control, so there is no way to control the power it produces. Normally power system stability studies use reduced order models to increase the maximum integration step size. Apart from faster simulation speed, this results in smothered waveforms when compared to those resulting from full order models. Power system stability studies are primarily interested in the electromechanical dynamics of large electric machines.

The frequency is controlled by the Discrete Frequency Regulator block. This controller uses a standard three-phase Phase Locked Loop (PLL) system to measure the system frequency. The measured frequency is compared to the reference frequency (60 Hz) to obtain the frequency error. This error is integrated to obtain the phase error. The phase error is then used by a Proportional-Differential (PD) controller to produce an output signal representing the required secondary load power. This signal is converted to an 8-bit digital signal controlling switching of the eight three-phase secondary loads. In order to minimize voltage disturbances, switching is performed at zero crossing of voltage.

4.1. Without Pitch Angle Controller

In this case the microgrid system is run for 8 sec. The system contains variable load, which is varied at time interval 1.5 sec. The change in load is 175 kW to 350 kW, which causes frequency deviation can be seen from the respective figures. As the load increases there is a dip in frequency (1 pu to 0.985 pu). To meet the demand the synchronous generator driven by diesel engine increases its power, that can be seen in fig. 4.3. The WT also contributes momentarily, but WT is running at the speed 12 m/s so it can not increase output power over a longer period and can be overloaded for shorter duration.

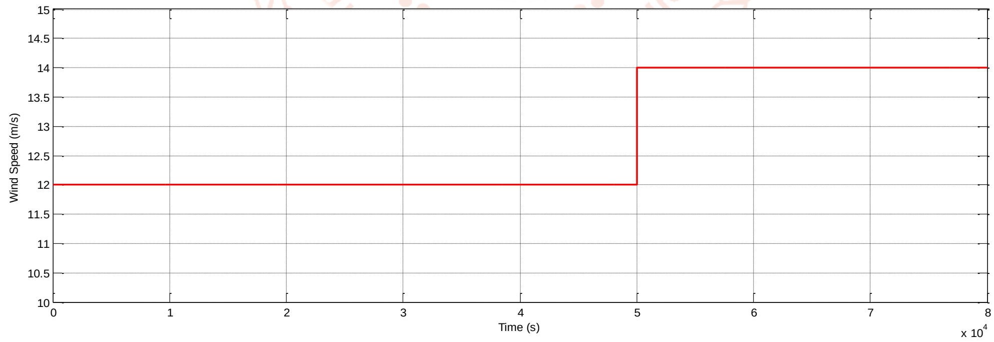

Fig.5 Wind Speed variations (m/s)

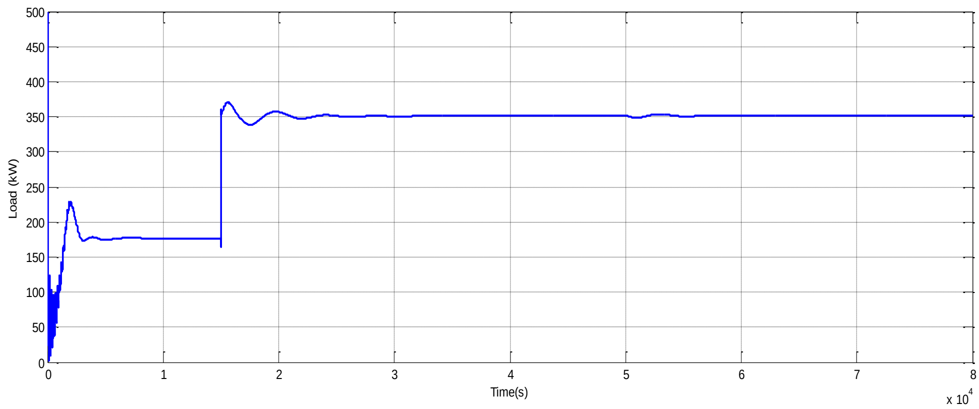

Fig. 6 Variations in Load (kW)

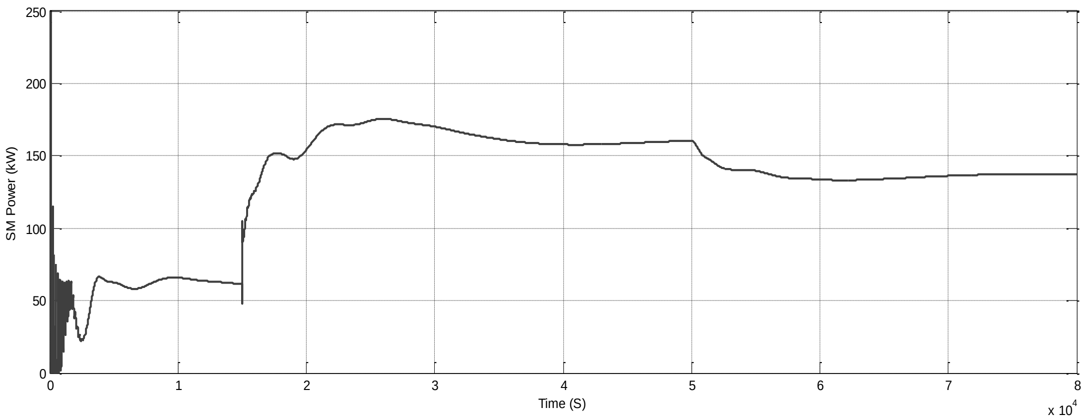

Fig. 7 Synchronous Machine Output Power (kW)

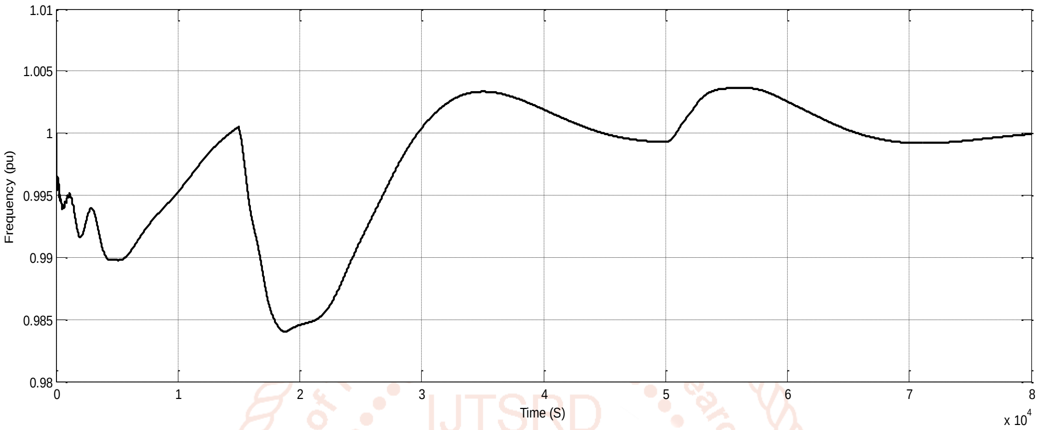

Fig. 8 Frequency variations (pu)

4.2. Simulation with Pitch Angle Controller

In this case of wind-diesel power generator based microgrid system, the microgrid system is connected with pitch angle controller. The function of this is to reduce the mismatch between supply and demand and improve frequency regulation.

The wind speed is varied 12 m/s to 14 m/s at time t=5 sec like the previous case. The load is also varied as it was varied in the previous case when there is no use of pitch angle controller. As the load variations and load change is same as the previous case, so the same waveforms can be used for this case also.

Frequency variations are compared for the both cases and the obvious frequency regulation is found when pitch angle controller are used (Red shows frequency change with pitch angle controller and black without). Here dump load operates when the generated power is more than the demand and the dump load controller commanded by the control circuit to connect the required amount of resistance to be connected to the system.

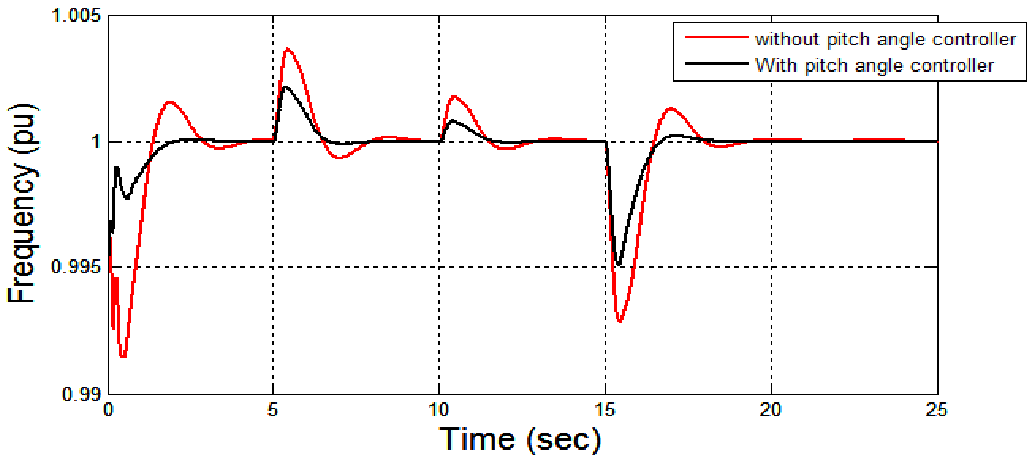

Fig.9 Frequency variations with and without pitch angle controller

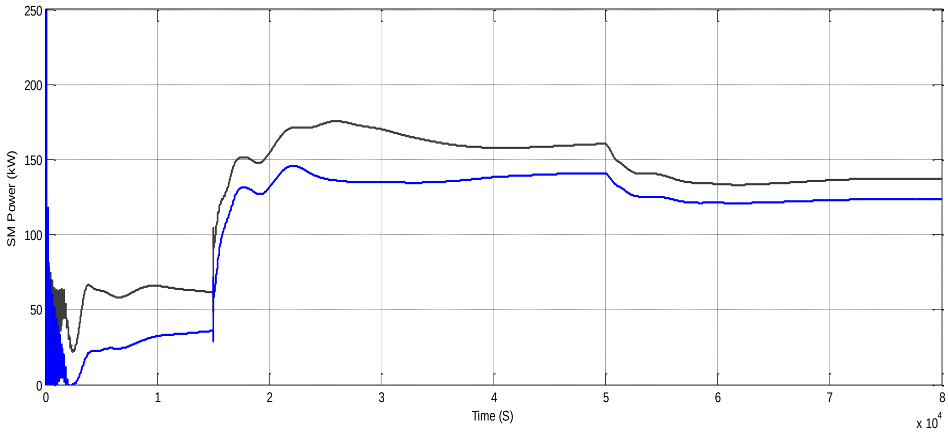

Fig.10 Synchronous Generator output power (With and without pitch angle controller)

V. CONCLUSIONS

In this papera wind-diesel based microgrid system is simulated for the two cases. In first case there is no pitch angle controller is used. The system is subjected to different wind speeds and different load and the waveforms of frequency, synchronous generator power, WT power and the power across load are shown.

In the second case the microgrid system is employed with the pitch angle controller. These balancing mechanisms did their work satisfactorily and help the microgrid system to restore the frequency in better way when the system is subjected to wind variations and the load variations.

REFERENCES

[1] N. Mendis, K. M. Muttaqi and S. Perera, "Active power management of a super capacitor-battery hybrid energy storage system for standalone operation of DFIG based wind turbines," in Industry Applications Society Annual Meeting (IAS), 2012 IEEE, 2012, pp. 1-8.

[2] Chengshan Wang, Mengxuan Liu and Li Guo, "Cooperative operation and optimal design for islanded microgrid," in Innovative Smart Grid Technologies (ISGT), 2012 IEEE PES, 2012, pp. 1-8.

[3] Huang Chao-Hui, Zhang Xiao-Gang and Yao Xin-Li, "A method for micro-gird automatic generation control," in 2011 International Conference on Electronics, Communications and Control (ICECC), 2011, pp. 1224-1227

[4] R. Gagnon, B. Saulnier, G. Sybille, P. Giroux; "Modeling of a Generic High-Penetration No-Storage Wind-Diesel System Using Matlab/Power System Blockset" in 2002 Global Wind power Conference, 2002, pp. 1-6.

[5] G. Mulder et all "Comparison of commercial battery cells in relation to material properties," Electrochimica Acta, vol. 87, 2013, pp. 473-488.

[6] S. Kuehl, P. Landsmann and R. M. Kennel, "Compensating angle estimation errors caused by magnetic saturation in anisotropy-based sensorless control schemes," in Sensorless Control for Electrical Drives (SLED), 2012 IEEE Symposium on, 2012, pp. 1-6.

[7] Seul-Ki Kim, Eung-Sang Kim and Jong-Bo Ahn, "Modeling and control of a grid-connected Wind/PV hybrid generation system," in Transmission and Distribution Conference and Exhibition, 2005/2006 IEEE PES, 2006, pp. 1202-1207.

[8] O. Krishan and S. Suhag, "An updated review of energy storage systems: Classification and applications in distributed generation power systems incorporating renewable energy resources," Int. J. Energy Res., no. October, pp. 1–40, Nov. 2018.

[9] O. Krishan and S. Suhag, "Power management control strategy for hybrid energy storage system in a grid-independent hybrid renewable energy system: a hardware-in-loop real-time verification," IET Renew. Power Gener., vol. 14, no. 3, pp. 454–465, Feb. 2020.

[10] O. Krishan and S. Suhag, "Techno-economic analysis of a hybrid renewable energy system for an energy poor rural community," J. Energy Storage, vol. 23, pp. 305–319, Jun. 2019.

[11] O. Krishan and S. Suhag, "A novel control strategy for a hybrid energy storage system in a grid-independent hybrid renewable energy system," Int. Trans. Electr. Energy Syst., Dec. 2019.

[12] O. Krishan and S. Suhag, "Grid-independent PV system hybridization with fuel cell-battery/supercapacitor: Optimum sizing and comparative techno-economic analysis," Sustain. Energy Technol. Assessments, vol. 37, no. December 2019, p. 100625, Feb. 2020.

[13] O. Krishan and Sathans, "Frequency regulation in a standalone wind-diesel hybrid power system using pitch-angle controller," in 2016 3rd International Conference on Computing for Sustainable Global Development (INDIACom), 2016, pp. 1148–1152.

[14] O. Krishan and Sathans, "Design and Techno-Economic Analysis of a HRES in a Rural Village," Procedia Comput. Sci., vol. 125, pp. 321–328, 2018.

[15] O. Krishan and Sathans, "Optimum sizing and economical assessment of grid integrated hybrid system for a rural village: A case study," in 2016 IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES), 2016, pp. 1–5.

[16] O. Krishan and Sathans, "Optimum sizing and techno-economic analysis of grid-independent PV system under different tracking systems," in 2018 IEEE 8th Power India International Conference (PIICON), 2018, pp. 1–6.

[17] Siegfried Heier, Grid Integration of Wind Energy Conversion Systems, 2nd ed., Wiley, 2006.

[18] L. Y. Pao and K. E. Johnson, "Control of Wind Turbines," Control Systems, IEEE, vol. 31, 2011, pp. 44-62.

[19] G. Mallesham, S. Mishra and A. N. Jha, "Ziegler-Nichols based controller parameters tuning for load frequency control in a microgrid," in Energy, Automation, and Signal (ICEAS), 2011 International Conference on,2011, pp. 1-8.

[20] J. Llanos, D. Saez, R. Palma-Behnke, A. Nunez and G. Jimenez-Estevez, "Load profile generator and load forecasting for a renewable based microgrid using self organizing maps and neural networks," in Neural Networks (IJCNN), the 2012 International Joint Conference on, 2012, pp. 1-8.

[21] P. M. Anderson and A. Bose, "Stability Simulation of Wind Turbine Systems," Power Apparatus and Systems, IEEE Transactions on, vol. PAS-102, 1983, pp. 3791-3795.

[22] R. Rynkiewicz, "Discharge and charge modeling of lead acid batteries," in Applied Power Electronics Conference and Exposition, 1999. APEC '99. Fourteenth Annual, vol.2, 1999, pp. 707-710.

[23] MATHWORKS Inc. Universal Bridge [Online]. Available: http://www.mathworks.com/help/physmod/powersys/ref/universalbridge.html.

[24] N. Mendis, K. M. Muttaqi, S. Sayeef and S. Perera, "Application of a hybrid energy storage in a remote area power supply system," in 2010 IEEE International Energy Conference and Exhibition (EnergyCon), 2010, pp. 576-581.

[25] MATHWORKS Inc. Excitation system [Online]. Available: http://www.mathworks.com/help/physmod/powersys/ref/excitationsystem.html.

[26] Yeager, K. E.; Willis, J. R.; , "Modeling of emergency diesel generators in an 800 megawatt nuclear power plant," IEEE Transactions on Energy Conversion, vol.8, no.3, Sep. 1993, pp.433-441.