International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 04 | April - 2023 Impact Factor: 8.176 ISSN: 2582-3930

DESIGN AND CONTROL OF PID CONTROLLER FOR VARIABLE SPEED WIND TURBINE ENERGY SYSTEM

K. Manasa*, S. V. Govardhini*, K. Chandu Reddy*, M. Dharani Kumar*, M. Bharath Yadav*

*Student, Department of EEE, Srinivasa Ramanujan Institute of Technology, India.

---***---

Abstract - Renewable energy from wind is the safest form of energy. Wind turbine-based energy generators have the potential to generate high amount of electric power if there is a proper wind velocity and control mechanisms. This can certainly reduce the dependency on solar photovoltaic based energy systems, which needs huge space to install the solar photovoltaic panels. However, the output power of wind turbine is affected by the uncertain wind velocity. The output mechanical power has to be properly controlled. Hence, the wind energy system efficacy depends on how well this uncertainty is addressed. The major challenge is to design and control the wind turbine systems that has a suitable mediator between the power generator and the load, which counters the damage to the load due to variable voltages produced by the varying wind velocity. Keeping this in view, this paper implements all-important converter design methods for wind energy application and recommends the most suitable method for its controller design.

***Key Words*:** – PID Controller, Tuning Methods, Permanent Magnet Synchronous Machine, Pulse Width Modulation, Wind Energy Conversion System

1.Introduction

In the world energy point of view, there are two types of energy sources i.e., nonconventional (renewable) energy sources and conventional energy sources. Renewable energy sources are the type of resources which are derived from earth or its ecology, and are plenty in quantity. There are different types of renewable resources in general such as, wind energy, hydro-energy, solar energy, biomass, geothermal energy, etc., which are inexhaustible in nature. Apart from the abundancy, these resources are pollution free in usage when compared to the conventional fossil fuel-based energy systems. So, present day energy sector is depending more and more usage of renewables rather than fast depleting conventional fossil fuels. The main objective is to design a suitable PID controller for wind turbine-based generation system to mitigate the fluctuations in generating power and to reduce the settling time of the PID controller by proper selection of Tuning Method.

2. Literature Review

The constant speed wind turbines allow the use of simple generators whose speed is fixed by the frequency of the electrical system. Although the power electronics needed for variable speed wind turbines are more expensive, this type of turbines can Many researches are on-going in this area to regulate the wind turbine speed, such as, speed control for direct drive permanent magnet wind turbine , non-variable speed control of wind turbine , sensor less control scheme for wind turbine in 1.5 MW doubly-fed induction generator (DFIG) application with maximum power point tracking (MPPT) facility , full range speed control mechanism given for an electromagnetic doubly-salient wind turbine plant , disturbance observer based speed control mechanism for fixed pitch angle based wind turbine , and modern or intelligent speed control novel methods such as wind velocity forecasting concept based predictive control method for wind turbines, adaptive MPPT based rotor speed control of DFIG wind turbine , intelligent speed control integrated with MPPT facility for medium power wind energy systems , protection and control mechanism for full wind speed range of a wind turbine power system, imperialist competitive algorithm based induction motor's speed control provision that was supplied by wind turbine, and model predictive control approach for speed control of a wind turbine energy system.

The constant speed wind turbines allow the use of simple generators whose speed is fixed by the frequency of the electrical system. Although the power electronics needed for variable speed wind turbines are more expensive, this type of turbines can spend more time operating at maximum aerodynamic efficiency than constant speed turbines.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 04 | April - 2023 Impact Factor: 8.176 ISSN: 2582-3930

3.Problem Formulation

All the controllers that are implemented in literature are normally based on Proportional Integral Derivative (PID) controllers. The main fundamental issue of PID controller produce non-linear deviations of the system response that may not be settle down. The generation of harmonics will also increase in greater value. Normally, the tuning PID gain parameters are difficult to specify each and every system of wind turbine energy system and even the generator also produces the abnormal output. In this Project work, Wind energy conversion system is examine with PID controller. The PID controller is further studied for proper tuning. Finally, the best suitable design is recommended to achieve superior performance under uncertainties and implement the PMSG based on WECS that can connect the turbine without using gear box.

4.Wind Energy Conversion System and Pulse Width Modulation

WECS have become increasingly popular in recent years as a source of renewable energy. They offer several advantages over traditional fossil fuel power plants, including reduced greenhouse gas emissions, lower operating costs, and increased energy security. However, they also face several challenges, including the intermittent nature of wind, the need for large land areas to install the turbines, and potential impacts on wildlife and the environment.

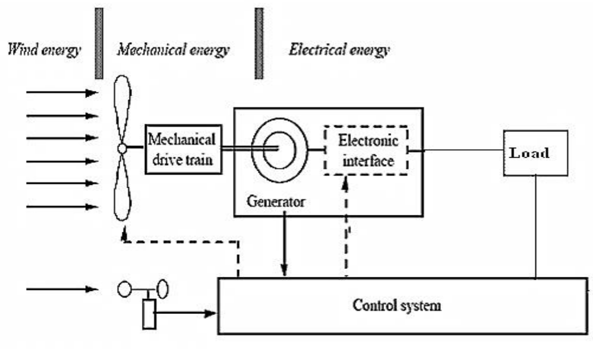

Fig.1: Wind Energy Conversion System

4.1 Sample Block Diagram

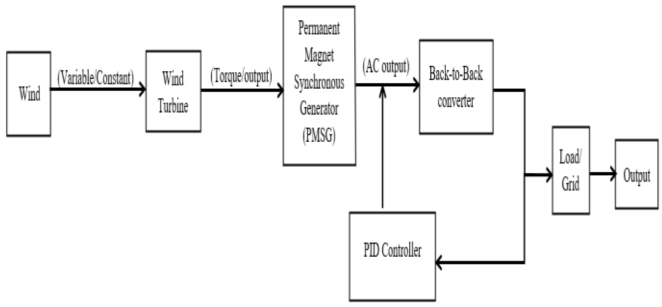

Fig.2: Block Diagram of WECs

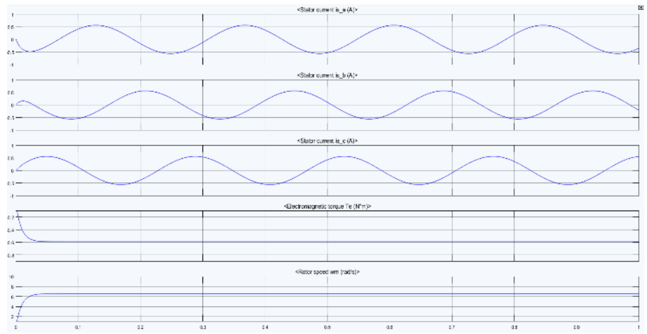

Fig.3: Constant wind speed

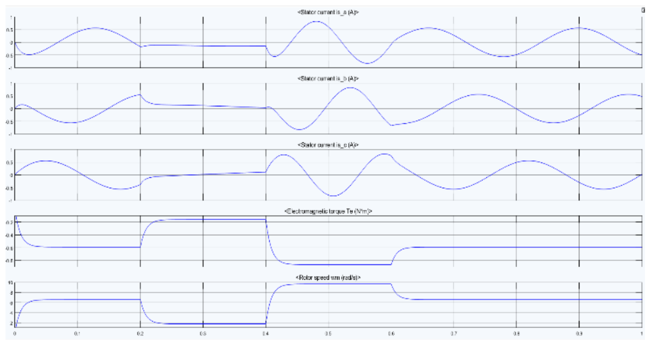

Fig.4: Variable wind speed

Pulse width modulation reduces the average power delivered by an electrical signal by converting the signal into discrete parts. In the PWM technique, the signal's energy is distributed through a series of pulses rather than a continuously varying (analogue) signal. Pulse width modulation or PWM is a commonly used control technique that generates analogue signals from digital devices such as microcontrollers. The signal thus produced will have a train of pulses, and these pulses will be in the form of square waves.

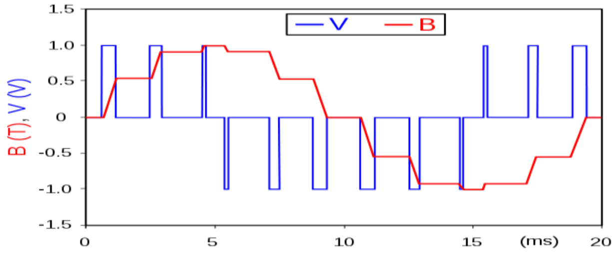

Fig.5: Wave for combined positive and negative pulse

4.2 Principle

Pulse-width modulation uses a rectangular pulse wave whose pulse width is modulated resulting in the variation of the average value of the waveform. If we consider a pulse waveform f(t), with period T, low value Ymin, high value Ymax and a duty cycle D (see figure 1), the average value of the waveform is given by:

$$\bar{y} = \frac{1}{T}\int_0^T f(t)dt. \qquad \ldots (1)$$

Where,

f(t) is a pulse wave,

Ymax ranges from 0 < t < D.

T and Ymin for D, T < t < T

The above expression then becomes:

$$\bar{y} = \frac{1}{T}(\int_0^{DT} Ymaxdt + \int_{DT}^{T} Ymindt) \quad \ldots (2)$$

$$= \frac{D.T.Ymax+T(1-D)Ymin}{T}$$

$$= D.Ymax + (1 - D)Ymin \qquad \ldots (3)$$

5.PID Tuning Methods and its Comparative Analysis

A PID controller is an instrument utilized in modern control applications to direct temperature, stream, tension, speed and other cycle factors. PID (proportional integral derivative) controller utilize a control circle criticism system to control process factors and are the most reliable and stable controller.

5.1 Methods of Tuning:

5.1.1 OLTR (Open Loop Transfer Function): This method is frequently used to obtain the gain parameters of the controllers and this method is limited with respect to adjustment of steady state error.

- **Zigler-Nichols Method (ZN):** This method starts by zeroing the integral and differential gains and then raising the proportional gain until the system is unstable.

Kp=642.882, Ki=1208576.4, Kd=0.8036

5.1.2 Ultimate Cycles (UC): It is an procedure used to tune a controller using PID control with optimum controller settings.

- **Tyreus-Luyben(TL) Method:** This method is based on ultimate gain and ultimate period and it obtains better stability in the control loop.

Kp=482.1615, Ki=21916.43, Kd=0.76519

5.2 Comparative Analysis

Fig.6: Settling time comparison of ZN and TL methods

In comparison with above two methods Zigler-Nichols (ZN) Method gives a best performance when compared to the other method. It gives a better response in Settling Time when compare with Tyreus-Luyben (TL) Method. ZN Method generates less Harmonics when compared with the TL Method. ZN method also provides a good amplitude value.

6.Matlab Results

The output of the system would typically be measured in terms of the power output of the turbine, which should be optimized for maximum efficiency and stability. Overall, a well-designed variable wind turbine energy system using a PID controller is delivered with stable and efficient power output in a range of wind conditions, helping to maximize the value of effectiveness of the renewable energy source.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 04 | April - 2023 Impact Factor: 8.176 ISSN: 2582-3930

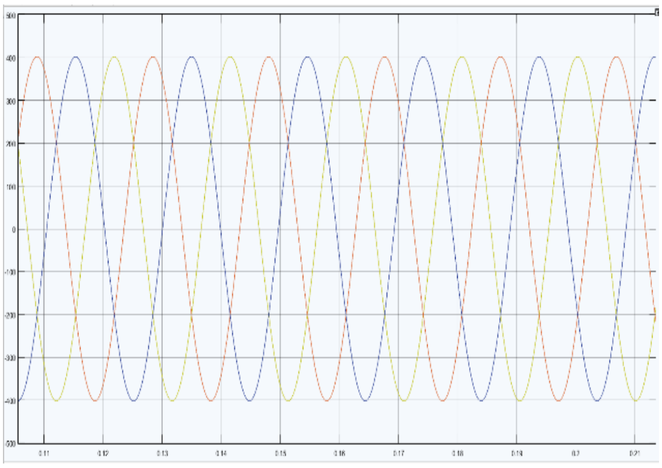

Fig.7: Output Voltage Waveform

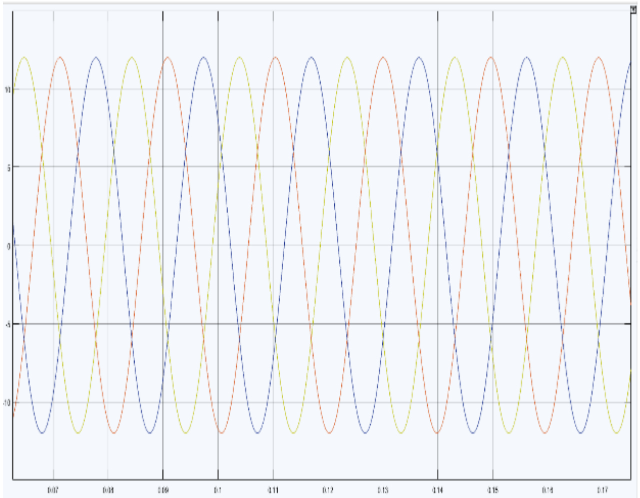

Fig.8: Output Current Waveform

5.1 Harmonic Distortions

Harmonic Distortions are unwanted periodic variations in a system that can be caused by the variety of factors, including electrical noise, mechanical vibrations, and non-linearities in the system. Due to the high Harmonic Distortions the in the PID tuning the high proportional gain can cause many disturbances such as oscillations and instability in the system.

The Total Harmonic Distortion (THD) is a measurement of the harmonic distortion present in a signal and is defined as a ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency**.** To mitigate harmonic distortions in PID Tuning, it is important to choose appropriate tuning method based on the characteristics of the system.

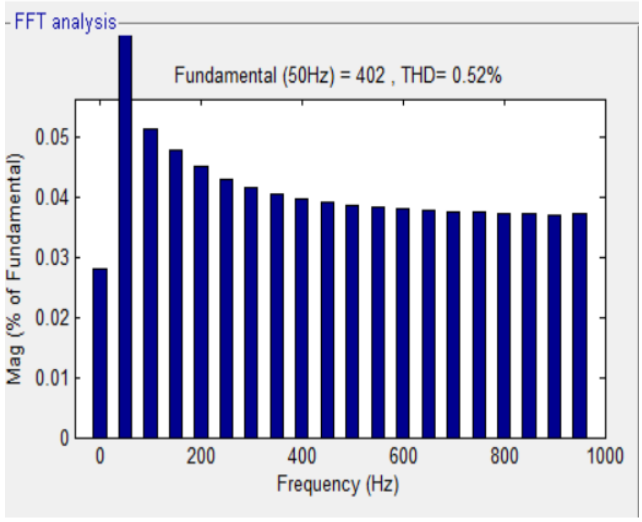

Fig.9: Total Harmonics value of ZN Method

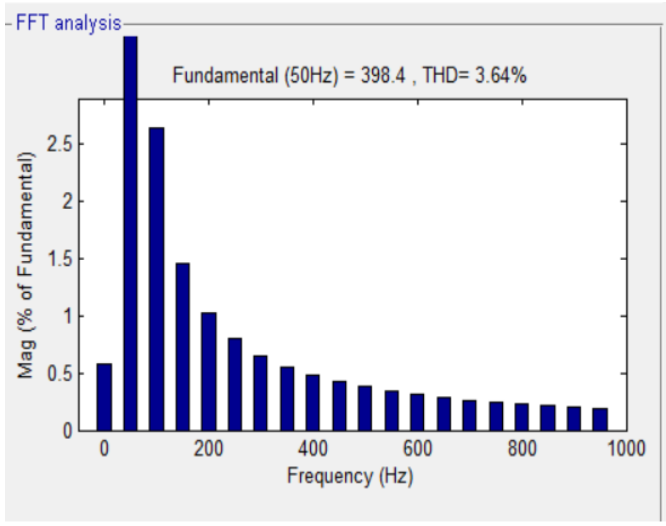

Fig.10: Total Harmonics value of TL Method

7.Conclusion

From the simulation results and the presented analysis on the time domain performance specifications, it is observed that use of Ziegler - Nichols (ZN) method for the design of PID controller gain parameters is leading to best response when compared to all the other important methods. Hence, it is recommended to use for the controller design for wind turbine energy applications. The appropriate energy management processes has been performed in order to maximize the energy production of the wind turbines and transfer the wind-generated energy to the consumer with high efficiency and adequate power quality. Therefore, PMSG provides stable and secure output during operation of wind turbine energy systems. Finally, we conclude that the given variable input of wind energy provides the constant output voltage and output current when given to the grid system.

References

[1] A. J. Mahdi, W. H. Tang, Q. H. Wu, "Derivation of a complete transfer function for a wind turbine generator system by experiments," in Proc. 2011 IEEE Power Engineering and Automation Conference, Vol. 1, pp. 35-38, 2011.

[2] Christian Leisten, Uwe Jassmann, Johannes Balshusemann, Dirk Abel, "Model predictive speed control of a wind turbine system test bench," IFAC Papers Online, Vol. 51, No. 32, pp.349- 354, 2018.

[3] Dinh-Chung Phan, Shigeru Yamamoto, "Rotor speed control of doubly fed induction generator wind turbines using adaptive maximum power point tracking," Elsevier Energy Journal, Vol. 111, pp. 377- 388, Sep. 2016.

[4] Ehab S. Ali, "Speed control of induction motor supplied by wind turbine via imperialist competitive algorithm," Elsevier Energy Journal, Vol. 89, pp. 593- 600, Sep. 2015.

[5] Essam H. Abdou, Abdel-Raheem Youssef, Salah Kamel, Mohamed M. Aly, "Sensorless Wind Speed Control of 1.5 MW DFIG wind turbines for MPPT," in Proc. 2018 Twentieth International Middle East Power Systems Conference (MEPCON), pp. 700-704, 2018.

[6] Mahinsasa Narayana, Ghanim Putrus, Milutin Jovanovic, Pak Sing Leung, "Predictive control of wind turbines by considering wind speed forecasting techniques," in Proc. 2009 44th International Universities Power Engineering Conference (UPEC), Glasgow, UK, pp. 1-4, 2009.

[7] Moein Lak, V. K. Ramachandaramurthy. "Speed control for direct drive permanent magnet wind turbine," in Proc. 2014 International 2020 International Conference on Artificial Intelligence and Signal Processing (AISP) Conference on Renewable Energy Research and Application (ICRERA), Milwaukee, WI, USA, pp. 317-321, 2014.

[8] Vlaho Petrovic, Carlo L. Bottasso, "Wind turbine envelope protectioncontrol over the full wind speed range," *Elsevier Renewable EnergyJournal*, Vol. 111, pp.836-848, Oct. 2017.[10] Ehab S. Ali, "Speed control of induction motor supplied by wind turbine via imperialist competitive algorithm," *Elsevier Energy Journal, Vol.* 89,pp. 593-600, Sep. 2015.

[9] Y. Jaganmohan Reddy, Y. V. Pavan Kumar, K. Padma Raju, Anilkumar Ramsesh, "Retrofitted hybrid power system design with renewable energy sources for buildings," *IEEE Trans. Smart Grid*, Vol. 3, No. 4, pp. 2174 – 2187, Dec. 2012.

[10] Ying Liu, Guofen Tang, Haidong Liu, Bo Zhou, Honghao Guo, Guangjie Zuo. "Speed control method of double salient electro-magnetic wind power generator in full range of wind speed," in Proc. 2010 World Non-Grid-Connected Wind Power and Energy Conference, Nanjing, China, pp. 1-5, 2010.

Acknowledgement

We are sincerely thankful to all our faculty for their guidance for the project work. Without their guidance it was difficult for us to accomplish this task. We are especially very thankful to our guide S. Bhargava Reddy sir for their guidance, support, and encouragement throughout this project. Their valuable insights and expertise have been instrumental in shaping this research paper. We also thankful for their willingness to share their time and knowledge, which has helped me in gaining new perspectives and developing our research skills. Their constant motivation and support have been crucial in completing this project. Thank you for being an exceptional project guide.