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Intelligent control methods of variable speed wind turbine generator

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ABSTRACT

Instability of wind energy generates intermittent electrical energy in wind-turbine electric generators. The sporadic energy pushes researchers to find solutions to provide more consistent electricity. There are many ways to integrate the rotational velocity of the rotor in the generator and make it relatively consistent. One of these ways is the gearbox use to increase the velocity of rotation when the wind speed is low and reduce the speed entering the generator when there is high wind velocity. In this work, the intelligent control of the work of the gearbox is made through an Arduino electronic board to be controlled through the gearbox and thus the speed entering the generator is established. Also, a small wind powered generator is designed to simulate a real wind power generator.

Keywords: Intelligent control, Arduino, Wind turbine, Variable speed.

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1. Introduction

Windmills date back more than 2000 years. They have been used mostly to grind grains and pump water. An important example of modern times is the various forms of Dutch windmills installed in great quantities in the seventeenth and eighteenth centuries in Europe. A century later, the Western Windmill became another great development in the rural areas especially in the United States of America today. In the 1920s, recent wind power construction transformers were developed. However, they were not professional until the 1980s when they experienced an advanced interest to clearly apply them as clean energies. In modern life, wind turbines are fundamentally made from quick start machines with a horizontal shaft, an anchor arrangement and three rotator blades. Machine estimates have increased steadily so the rate built-up power per unit presently exceeds one thousand and seven hundred kilowatts. The marine wind stance with a capacity of six thousand kilowatts is in pilot phase [1, 2].

Today, controlling wind speed in power plants using wind has become a concern of researchers because of the instability of wind energy that leads to the intermittent electric power generation. Some researchers control the wind speed by controlling the angle of the windmill blades. Others depend on the mechanics of working with a gearbox to control wind speed, as it consists of a number of sprockets through which the speed can be reduce and increased [3-5]**.**

This project could be a practical simulation of wind turbines and a control of the velocity of wind speed using the intelligent control to stabilize the generator incoming speed[6, 7]. The design of wind turbines in a simple model presents a simulation of their operation showing their process of intelligent control and continued stability in the wind change. Also, Araduino is used as an intelligent controller for its ease of use and reduced cost.

1.1. Previous study

When wind speed is low, the wind turbine rotation speed could be controlled to find the optimum power. Therefore, by using FC, the wind turbines can generate enough energy. In contrast with low speed wind, power is generated in a given rate by using two NN. This will help the intelligent control limit the disturbance effectively. The generated power and rotation speed of the generator oscillate significantly by the use of PID control. FC can determine the WTGS and the maximum power while NN can limit the power to a specified range. However, manual tuning is negative in big industrial applications. It also consumes time even similar plant applications. Also, the intuitive fuzzy PID such as the design does not clearly work better than the well-tuned traditional controllers [8-11] **.**

When the speed of the wind is high, the wind turbine is controls and maintains the aerodynamic power. Two adjusting methods of the aerodynamic power are investigated in pitch and generator load control. However, the pitch control is relatively quick and can be better utilized for adjusting the flow of power particularly when it is close to the upper speed extreme. When the power oscillation between electrical power and the aerodynamic power and the rotor inertia size, the rotor-speed change smoothly [12, 13].

The development of a proportional-integral controller could avoid the influence of turbulence and generate a maximum wind energy capture without any overload. However, the importance of performance such as transitions among the modes for a switched system is similar to the issue of stability of switching in particular in real-world dynamic applications such wind turbines. For reducing the steep turbine power and torque alteration, an algorithm that regulates the generator torque control law in the low wind speed mode is set. However, there is a disadvantage of controlling the turbine which is its division into two modes. The first is the low wind speed mode while the second is the high wind speed mode. According to the existing speed, the movement of the two modes in the operation of turbine could result in negative consequence such as vibrations in drivetrain, tower and bladefs [14, 15]. A control system is designed for MW variable speed constant frequency wind turbine. This design requires enough experiments and long-time initial operations in a real wind farm. The primary operation could validate the feasibility and the different strategies of speed control on constant frequency wind turbine. This the control system is safe and can ensure turbine reliability and consistency. However, it is more complicated than fixing wind turbine pitch [16].

The study proposes a new form of generator torque control strategy to reduce the mechanical stress in the gearbox of such wind turbine. This strategy is provided with band pass filter (BPF), thus it does not interfere with the generator speed controller operating the turbines at maximum electricity. In this novel strategy, the gearboxes of wind turbines are smaller in size, lower in weight, higher in speed generators, inexpensive and more efficient. However, it is noted that gearboxes are the least reliable wind turbine element although this technique is used for the reduction of the stress in the gearbox and the turbine drivetrain. In addition, the motion sensor mass torsional spring-damper (seismic sensors) does not include all the real gearbox dynamic effects. For more accuracy, modeling higher level is necessary [17-20].

2. Control Strategies of wind turbine

2.1. Fixed-speed fixed-pitch (FS-FP)

FS-FP is a configuration in which no performance with active control could improve. Here, the turbine of the generator is in a direct link to the power grid. This link locks the speed of the generator to the power line frequency and stabilizes the speed of rotation. The use of passive stall methods could control the turbines at high wind speeds. For this passive control, selecting gearbox ratio is important as it ensures that the power remains in the specified range. Only at a single wind speed in locations where the speed is low, the turbines work very efficiently. Similarly, the rated turbine energy could be obtained only at a speed of wind. This entails a weaker power regulation due to the restricted operations [21, 22].

2.2. Fixed-speed variable-pitch (FS-VP)

FS-VP configuration works when there is a stable pitch angle smaller than the the rated wind speed. It also regulates the angle bigger than the rated speed of wind without interruption. This means a maximum energy is generated by a single fixed speed of wind. Two methods can be used to limit power generation: the first is feather and the second is stall pitch control in the configuration. The first method occupies a substantial control design amount while the second increases unwanted thrust force because the stall raises. While exceeding the rated speed, the angles of pitch oscillate and reduce power loss to little or zero [23].

2.3. Variable-speed fixed-pitch (VS-FP)

This type of configuration continuously regulates the rotor speed in proportion to the wind speed by power electronics that regulates the synchronous generator speed. In this kind of control, the generator is of the grid type. Therefore, the rotor of the generator and drive-train is in a free rotation which is frequency free grid. Also, the fixed-pitch depends mainly on the design of the blade restricting power by the use of passive stall. This stall regulation has a key role in the failure of the rated power. This is because of the poor power regulation which is higher than the rated speed. In lower wind speed operations, VS-FP can produce more power and its quality improves [24].

2.4. Variable-speed variable-pitch (VS-VP)

This configuration is derived from VS-FP and FS-VP. It works in a speed lower than the rated. Also, for maximizing the power capture and quality, the variable speed and fixed pitch are utilized. The operation at a high fixed wind speed than the rated speed and at a variable pitch regulates an efficient power at the rated power. This configuration is the only control strategy which has been theoretically in an ideal curved power [24].

3. Methodology

A wind powered generator is designed to simulate the real generator where the wind speed is controlled by controlling a constant D.C Motor with a speed sensor. As a result, the speed of rotation simulates the speed of the wind which the Arduino program controls. This makes the speed almost constant entering into the generator as seen in the chart below:

Figure 1. Flowcharts of Methodology

Step1

In this step, we collect all the tools needed for research Motor and wind speed in real wind turbines is described. Voltage sensor is also used to read the voltage value and the speed sensor helps reading the value of the transfer speed. Bridge DC motor drive unit can measure speed control while Adruino controls all the above tools. All gadgets can be named a gearbox together and represent the control circuit.

Step 2

In this step, each tool is programmed according to how we need (voltage sensor, speed sensor, DC bridge drive) using Arduino.

Step 3
In this step, a box is made to combine the components. It is made from alimuinme.
Step 4
In the last step, all the tools are linked with each other and fixed inside an aluminum box.

3.1. Arduino Mega

<u>Description</u>
Voltage of operation:5v
Inputvoltage (recommended):7-12v
Limits of Input voltage :6-20v
Digital I/O pins:54(of which 15 provide
PWM output
Analog (input) pins:16
DC current per I/O pin :40mA
DC current for 3.3v pin :50mA
Flash memory :256KB
SRAM:8KB
EEPROM:4KB
Clock speed :16MHZ

Figure 2. Arduino Mega

Arduino simplifies the operation by microcontrollers systems. This system gives advantages for teachers, students, and interested inexperienced users over alternative systems. The Arduino Software (IDE) operates on different systems such Windows, Macintosh OSX, and Linux while the majority of the microcontrollers can only operate on Windows. Also, beginners can easily use the easy and clear IDE programming environment which is also flexible for professional users. Furthermore, teachers can conveniently use it on the basis of the processing programming environment. Therefore, students can learn to use IDE in that environment and become familiar with its operation.

There is open access published sources and extendable software tools for professional programmers. Its language is also expandable by C++ libraries. Also, people who aim to understand the technical details can move from IDE to its AVR C programming language.

3.2. L298N dual H-bridge dc motor driver module

The very common L298 Dual H-Bridge Motor Driver Integrated Circuit is the basis of the dual bidirectional motor driver circuit. The circuit helps to simply and freely regulate the two motors up to 2A each in the two directions. For, robotic industries, it is ideal. Also, it is best suited to connect to a microcontroller with only many control lines in a motor. In addition, TTL logic gates, simple manual switches and relays can be connected to circuit. This board is supplied with protection diodes and indicators of power LED on-board +5V controller. H-bridges are mainly utilized to control the speed and direction of motors.

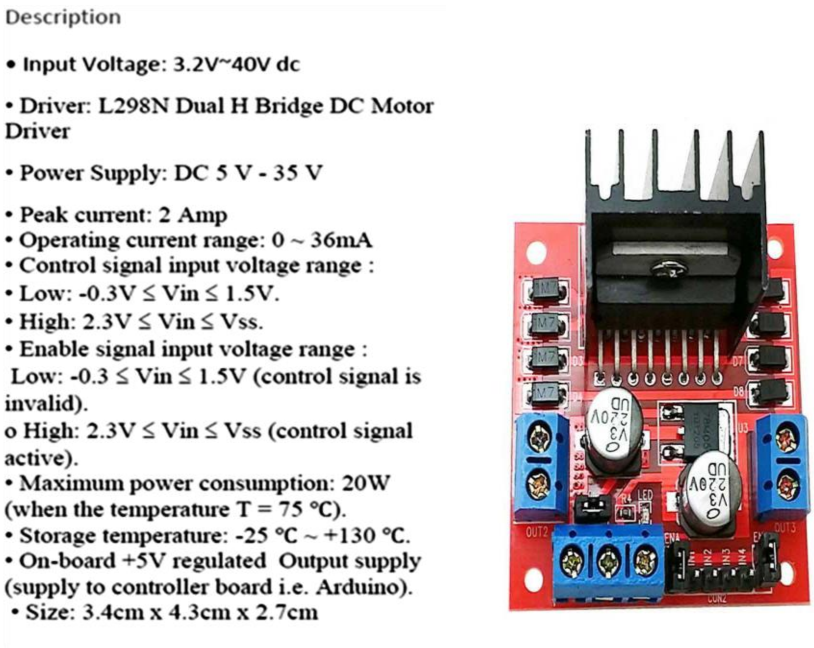

Figure 3. L298N Dual H-Bridge

4. Results

After assembling the parts and inserting them inside the aluminum box, the Arduino is programmed to make the speed always fixed on the rotating part of the generator using a speed sensor that feeds to the feedback information. The decision is made through the Arduino, which in turn gives a signal to the relay to close or open the connection circuit.

Table 1. Results

state	The range of voltage(v)	The range of speed(rpm)
rated	25	1071
Max1	28	1092
Max2	41	1743
Min1	20	840
Min2	14	609

Through practical experience and operation of the simulated model of reality, the results are in the table above. The study finds that the approved voltage rate is 25 volts where the average speed through this value was 1071 rpm. This shows the value of voltages increases with the increase of speed, and decreases when the speed is low, i.e. instability in the voltages is caused by changing the speed. This indicates that unstable winds will influence the generation of electricity. Therefore, when speed increases, it is sensitized by the sensor and sends a signal to IED controls to fix the speed and keep it relatively constant. The same happens with the decrease in speed. In reality, the dominant sends a signal of height and low to relays to push the lever to change the cog wheels in the gearbox to change the speed and make it stable in all circumstances.

5. Discussion

The importance of this work lies in its simplicity in the use of an electronic board that controls the process of setting the speed entering an electric generator. It was also explained in this paper as a simulation process that can be implemented in wind powered generators.

6. Conclusions

In this paper, we designed a simple and easy wind turbine to generate electricity for house appliances by using the control tools such as Arduino (Mega Arduino) and a control circuit called L298NH-Bridge DC Drive Motor Module. This module consists of a gearbox in the actual wind turbine. Its tools are easy and simple compared to the actual wind turbine. For this reason, this wind turbine simulates the actual wind turbine. Thus, this paper is a simulation of the actual wind turbine connecting the control. The wind speed shows the motor speed by this control circuit from the program by using Arduino. Therefore, the required voltage is finally produced by the generator. This procedure can control the motor speed by the above tools.

References

[1] M. Luther, K. Rohrig, and W. Winter, "Wind Power in the German System—Research and Development for the Transition Toward a Sustainable Energy Future," in *Wind Energy Engineering*: Elsevier, 2017, pp. 95-124.

[2] W. Shi, J. Han, C. Kim, D. Lee, H. Shin, and H. J. R. E. Park, "Feasibility study of offshore wind turbine substructures for southwest offshore wind farm project in Korea," vol. 74, pp. 406-413, 2015.

[3] S. Arnaltes, "Comparison of variable speed wind turbine control strategies," in *Proceedings of the International Conference on Renewable Energies and Power Quality*, 2003, pp. 1-6.

[4] F. T. Abed, H. T. S. ALRikabi, and I. A. Ibrahim, "Efficient Energy of Smart Grid Education Models for Modern Electric Power System Engineering in Iraq," in *IOP Conference Series: Materials Science and Engineering*, 2020, vol. 870, no. 1, p. 012049: IOP Publishing.

[5] H. Tuama, H. Abbas, N. S. Alseelawi, H. T. S. J. P. o. E. ALRikabi, and N. Sciences, "Bordering a set of energy criteria for the contributing in the transition level to sustainable energy in electrical Iraqi Projects," vol. 8, no. 1, pp. 516-525, 2020.

[6] W. K. J. I. J. o. R. E. R. Ahmed, "Mechanical modeling of wind turbine comparative study," vol. 3, no. 1, pp. 94-97, 2013.

[7] I. Al Barazanchi, H. R. Abdulshaheed, M. Safiah, and B. Sidek, “Innovative technologies of wireless sensor network : The applications of WBAN system and environment,” *Sustain. Eng. Innov.*, vol. 1, no. 2, pp. 98–105, 2020.

[8] R. M. Llorente, "Electric Machine Control Technics," in *Practical Control of Electric Machines*: Springer, 2020, pp. 27-83.

[9] B. Zhang *et al.*, "Breath-based human–machine interaction system using triboelectric nanogenerator," vol. 64, p. 103953, 2019.

[10] H. R. Abdulshaheed, I. Al Barazanchi, M. Safiah, and B. Sidek, “Survey : Benefits of integrating both wireless sensors networks and cloud computing infrastructure,” *Sustain. Eng. Innov.*, vol. 1, no. 2, pp. 67–83, 2020.

[11] N. S. Alseelawi, E. K. Adnan, H. T. Hazim, H. Alrikabi, and K. Nasser, "Design and Implementation of an E-learning Platform Using N-Tier Architecture," 2020.

[12] V. Kostjukov, M. Medvedev, N. Poluyanovich, M. Dubyago, D. Bulanovich, and D. J. E. E. T. o. E. W. Pavlenko, "Control law synthesis of the wind-driven power-plant with variable geometry," vol. 6, no. 23, 2019.

[13] A. Fernández-Guillamón, E. Gómez-Lázaro, E. Muljadi, Á. J. R. Molina-García, and S. E. Reviews, "Power systems with high renewable energy sources: A review of inertia and frequency control strategies over time," vol. 115, p. 109369, 2019.

[14] H. Wang, S. Ke, T. Wang, and S. J. R. E. Zhu, "Typhoon-induced vibration response and the working mechanism of large wind turbine considering multi-stage effects," vol. 153, pp. 740-758, 2020.

[15] H. Alrikabi, A. H. Alaidi, and K. J. I. J. o. I. M. T. Nasser, "The Application of Wireless Communication in IOT for Saving Electrical Energy," vol. 14, no. 01, pp. 152-160, 2020.

[16] C. Karunanayake, J. Ravishankar, and Z. Y. Dong, "A Novel Torsional Vibration Mitigation Strategy for DFIG Based Wind Turbines," in *2019 7th International Conference on Smart Grid (icSmartGrid)*, 2019, pp. 27-32: IEEE.

[17] Z. Li, S. Tian, Y. Zhang, H. Li, and M. J. E. Lu, "Active Control of Drive Chain Torsional Vibration for DFIG-Based Wind Turbine," vol. 12, no. 9, p. 1744, 2019.

[18] W. Tian *et al.*, "Individual pitch control strategy for reducing aerodynamic loads and torque ripples," vol. 14, no. 11, pp. 1624-1632, 2019.

[19] I. A. Aljazaery, H. T. S. Alrikabi, and M. R. J. i. Aziz, "Combination of Hiding and Encryption for Data Security," vol. 14, no. 9, p. 35, 2020.

[20] H. F. Khazaal, H. T. S. Alrikabi, F. T. Abed, S. I. J. P. o. E. Kadhm, and N. Sciences, "Water desalination and purification using desalination units powered by solar panels," vol. 7, no. 3, pp. 1373-1382, 2019.

[21] E. Mangwende, "Modelling and Grid impact of Slip Synchronous Generator (SSG) on weak distribution grids," 2019.

[22] K. Rao, "Wind Energy: Technical Considerations–Contents," in *Wind Energy for Power Generation*: Springer, 2019, pp. 1-426.

[23] Á. Olcoz Alonso, "Computer assisted aerodynamic design of a 10 kW HAWT blade," 2019.

[24] C. Sompracha, D. Jayaweera, and P. J. T. J. o. E. Tricoli, "Particle swarm optimisation technique to improve energy efficiency of doubly-fed induction generators for wind turbines," vol. 2019, no. 18, pp. 4890-4895, 2019.