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Development and analysis of vawt offgrid in ducting system

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ABSTRACT

Horizontal Axis Wind Turbine (HAWT) had been widely used in Malaysia, however, research concluded that the power produced is still low which approximately 0.02% from the wind turbine input is. The average wind speed in Penang, Malaysia, is recorded between 1.0 m/s to 2.5 m/s whereby to produce 2.7 kW of power by HAWT, 12.0 m/s of average wind speed is needed. Therefore, the main objective in this project is to develop and analyse the suitability on the Vertical Axis Wind Turbine (VAWT) to be used for power generation with the wind speed in between 0.5 m/s to 3.0 m/s. Ducting system is chosen rather than the open air since commercial buildings used Heat Ventilation Air Conditioning (HVAC) system. Arduino microcontroller and LabVIEW is used as interfaced to setup two types of sensors that is temperature sensor and anemometer.

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1. INTRODUCTION

Renewable energy accumulated from renewable sources such as daylight, wind, rain, tides, waves, and geothermal heat. Renewable energy is converting natural phenomenon into electrical energy [1]. There are many types of renewable energy around the earth such as from sun [2], wind [3], biomass [4] and biogas [5]. Renewable energy often provides power in 4 essential regions: energy generation, air and water heating/cooling, transportation, and rural (off-grid) energy services [6]. Wind power has become one of the fastest emerging renewable energy technologies for electricity generation, and the total installed capacity has reached 487 GW (about 4% of the global electricity) by the end of 2016 [7]. In Malaysia, horizontal axis wind turbine is widely implemented in Malaysia but Sustainable Energy Development Authority (SEDA) still not declare wind as renewable energy [8]. Wind energy is still not practical because based on previous study by A.R.N. Razliana in 2012 [9], the power harvested using wind energy is around in 50W which is low and the power produced was not constant in time. Then, from previous research by J. Ahmadian et al. [10] which was carried out in Kuala Terengganu Horizontal Axis Wind Turbine (HAWT) of the input power 2MW only able to produce 3.5 kW output power. Hence, this proved that HAWT is not practical and the best solution to be implemented in Malaysia. Therefore, further study needs to be done to find the best method to be implemented in Malaysia.

Wind energy is of the best renewable energy due to cost reduction of wind power generation, improvement of the used technology and equipment reliability [11]. Two types of the most popular wind turbines are Fixed Speed Wind Turbine (FSWT) and Variable Speed Wind Turbine (VSWT) [12]. Basically, FSWT in wind turbine consists of 2 types that are Horizontal Axis Wind Turbine (HAWT) and Vertical Axis

Wind Turbine (VAWT) [13]. Vertical Axis Wind Turbine (VAWT) is operating in perpendicular to the directions of wind and ground [14]. VAWT is able of accepting wind from any direction. A main difference between HAWT and VAWT is VAWT does not need the Yaw system to capture the wind [15]. Vertical axis of rotation will be focused in this research. Vertical axis wind turbine is chosen in this project as the methodology to be investigated due to its application to be implemented in Heat Ventilation Air Conditioning (HVAC) ducting system which is installed inside the buildings. Shah et. al. [16] in his research claimed that VAWT is relatively simple to implement in urban areas on ground or/and building-roofs.

Heat Ventilation Air Conditioning (HVAC) ducting system is air distribution in the building such as mall, hotel and etc. The function of this system is to control the temperature and ventilation [17]. Wind turbine is applying inside the HVAC ducting system and power management system, from air pressure in the ducting system indirectly can be harvested and store energy [18]. HVAC is chosen due to the turbines work best in environments with strong and consistent winds [19]. The concept is same that air flow crosses the earth surface will have produced kinetic and convert to electrical energy [20]. HVAC system in commercialize buildings can operate more than 12 hours and 24 hours for shopping complex and hotel respectively [21]. The pressure inside the HVAC system is come from blowers by the ducting system [22]. Meanwhile, in domestic building the energy that is harvested in through ducting system able to produce the constant power [23]. This is because the blower can generate air flow through the ducting system continuously. Air pressure in ducting system depend on the types of the facility, normally produce between 1000 cfm-15000 cfm. The benefits using ducting system is it can produce the power consistently and in a longer time period. Therefore, the application on the existing equipment in building, which is HVAC ducting system is proposed in this project by application of VAWT as a new renewable energy harvesting method. The performance on the output voltage will be measured by oscilloscope at the three phase generator located near to the VAWT.

2. RESEARCH METHOD

Four wind turbines are used in this project in which each wind turbine is 500W located in the ducting system. Arduino Uno is used as the interface with Anemometer and Temperature sensor. Data on speed air and temperature were collected and saved to the LabView. Power supply to the Arduino is 12V. Each of Arduino is setting in different parameters. Figure 1 shows the wind turbine off- grid system.

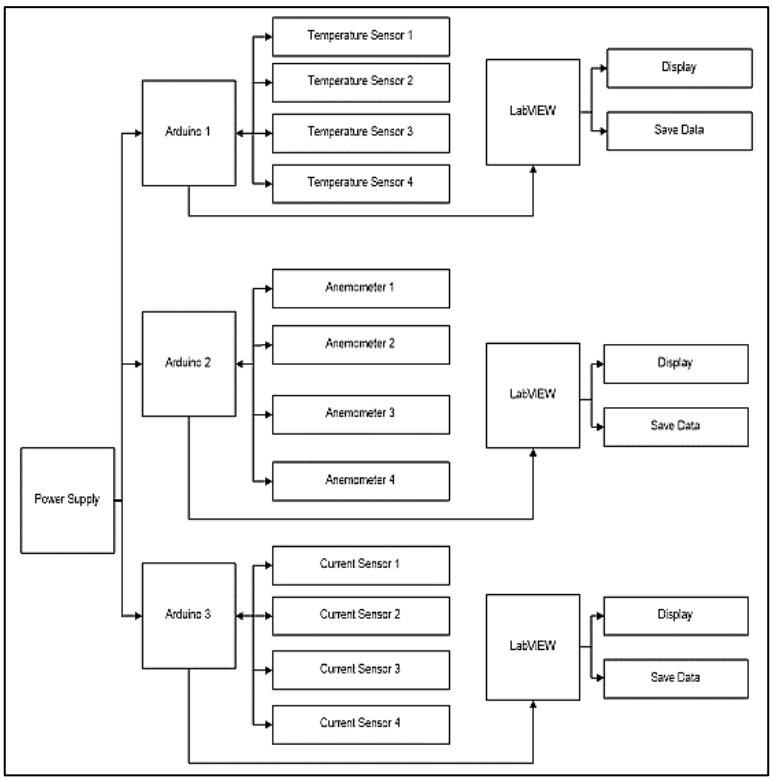

Figure 1. Block diagram of control and monitoring system

Arduino received the output sensor in analog signal form. Whenever the sensor detects any change on the parameter, the signal will be sent to the Arduino. Temperature sensor used is LM35 as shown in Figure 2, anemometer used is shown in Figure 3 and current sensor used is ACS758 as shown in Figure 4. Arduino consists of ADC converter that convert the signal from analog to digital since the sensor sent the signal in analog form. LabView does not consists ADC converter because it can locate the output voltage in the sensor mechanically. LabView will received the output voltage and immediately sent to the LabView Makerhub.

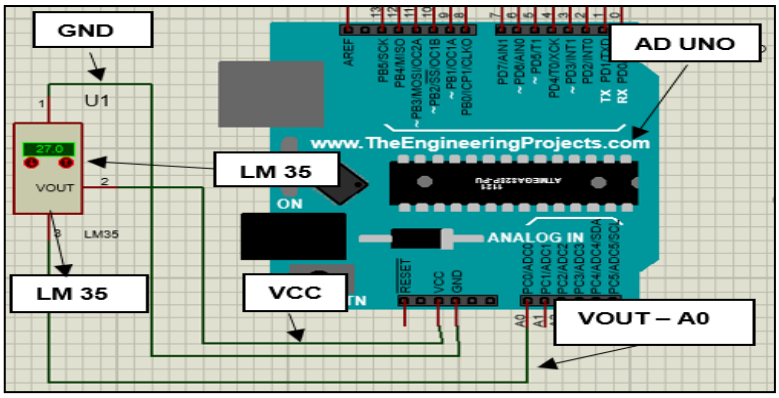

Figure 2. LM35 interface with the Arduino

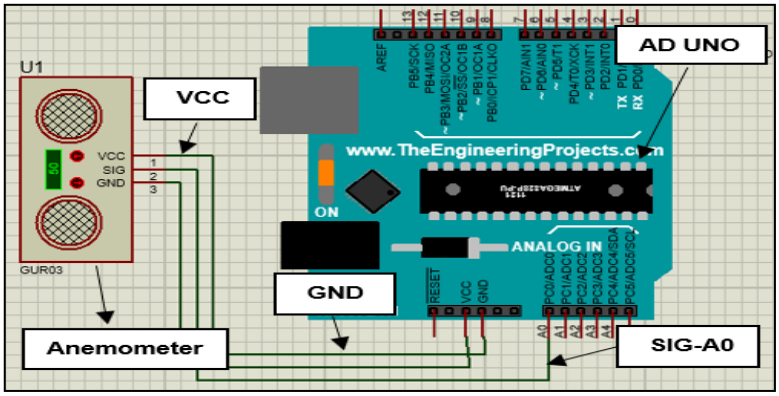

Figure 3. Anemometer interface with Arduino

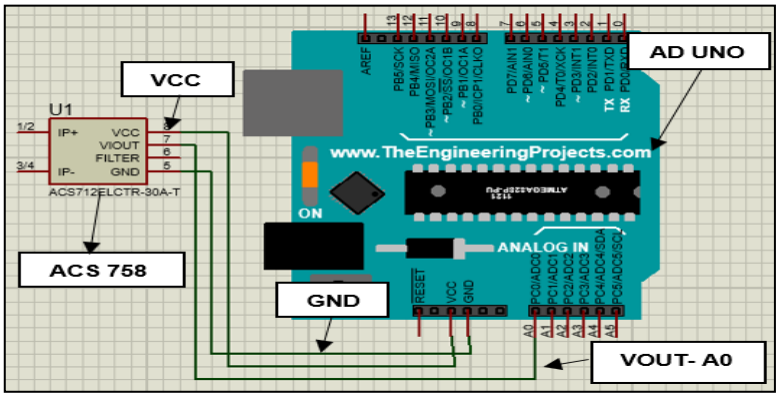

Figure 4. ACS 758 interface with Arduino

3. RESULTS AND DISCUSSION

Figure 5 shows the graph for air velocity input speed at the air blower versus the air velocity ouput at the wind turbine. The anemometer sensor has been located at one of the VAWT as shown in Figure 6.

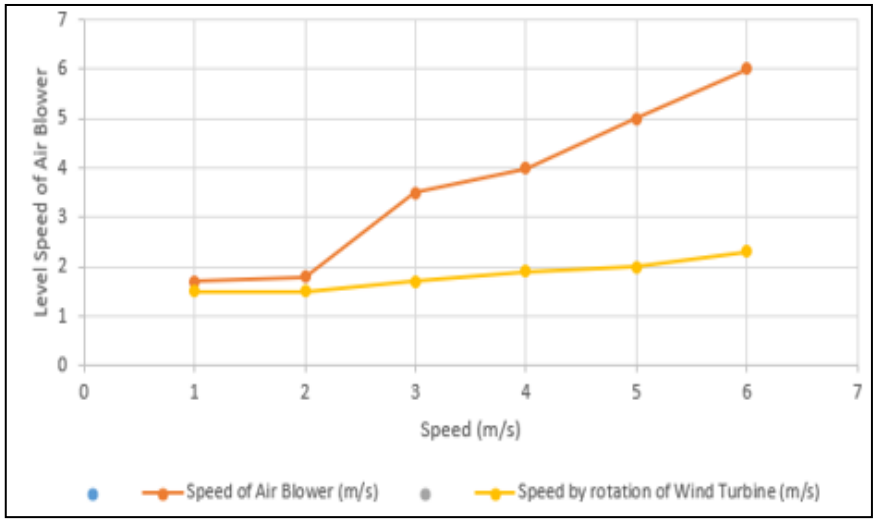

Figure 5. Air velocity output on air blower and wind turbine

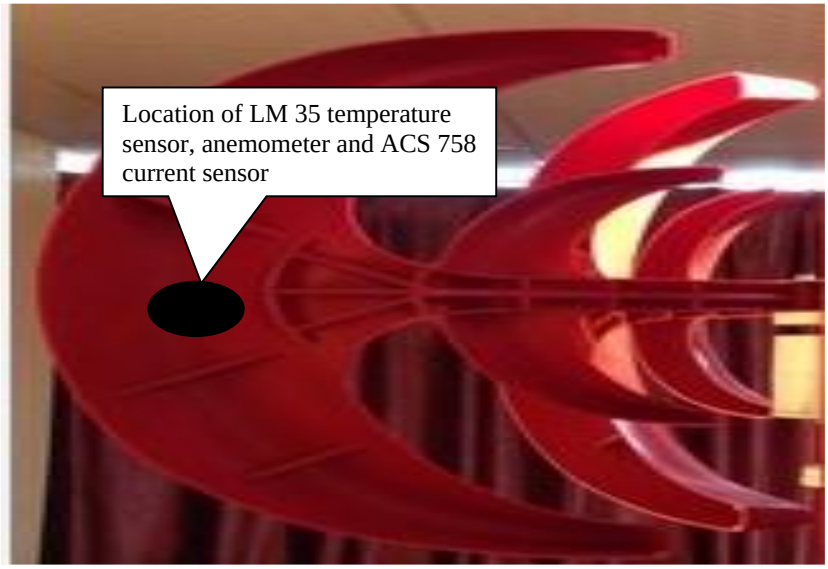

Figure 6. Location of sensors at the VAWT blade

Figure 7 reflects the value on the temperature inside the ducting system from minute 1 until minute 10. It shows that the value on the temperature inside the ducting system is not constant due to the friction produced between the air pressure and the wind turbine. It is important to monitor the temperature inside the ducting system since it can influence the stability on the electronics part of generator, cable wiring, converter etc.

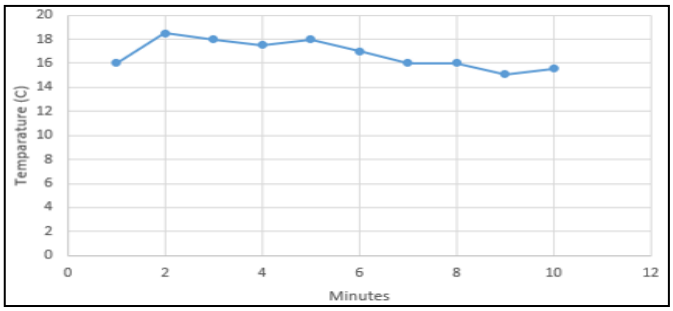

Figure 7. Temperature inside the ducting system

Figure 8 indicates the output voltage produced by wind turbine at each level of air velocity input. The measurement had been done at three phase generator located near the VAWT indicated by Live 1 (L1), Live 2(L2) and Live 3 (L3) as shown in Figure 9. These experiments are conducted based on the research carried out by Leow et. al. that wind speed does have the influence on the performance of photovoltaic panel [24]. Figure 8 shows that at level 3 in which the air velocity input of air blower is 3.5m/s, the maximum output voltage produced for all L1, L2 and L3. This indicates that the output voltage produced does not necessarily maximum when the air velocity is at maximum speed. This is believed due to cut-out speed phenomena in which as the speed increases above the rate output wind speed, the forces on the turbine structure continue to rise and, at some point, there is a risk of damage to the rotor. As a result, a braking system is employed to bring the rotor to a standstill [25]. In this project, the cut-out speed occurs at 3.5m/s.

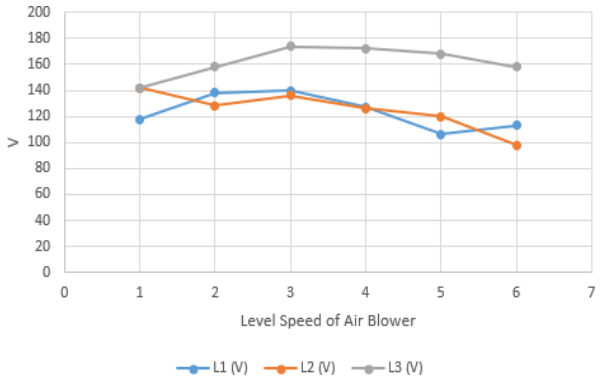

Figure 8. Output voltage produced by wind turbine at each level speed of air blower For Live 1, Live 2 and Live 3

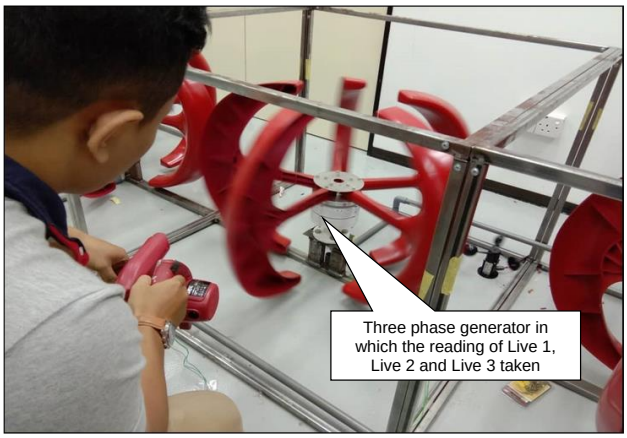

Figure 9. Location of Three Phase Generator VAWT

4. CONCLUSION

This paper presents the development on four wind turbines in which each wind turbine is 500W of power and located in the ducting system. Analysis on data taken which is temperature, air velocity and voltage have been done using VAWT located inside the ducting system. It was observed that minimum air velocity speed needed which was only 1.8m/s to generate an average voltage of 133V. With this minimum air velocity input speed air blower of 1.8m/s, the air velocity ouput at the wind turbine will be 1.7m/s. The average temperature in ducting system in 10 minutes is 16.73°C.

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