Development of a power breaker system in small-scale wind power plants when there is high rotation (over speed)

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Abstract. In a wind power plant (hereinafter referred to as PLTB), rotation stability is needed, to protect the system from sudden rising and unpredictable wind speed. Large-scale PLTBs are already equipped with a braking system, unlike small-scale plants that are generally not equipped with a braking system. In order for the electricity supply to be guaranteed properly and for the system to be protected, it is necessary to make a control device that will monitor the rotation speed of the generator and turn off the electricity supply to the system should there be any rotation that exceeds the specified limit / over speed. The use of small-scale for household purposes is generally equipped with an electric power storage / battery and an inverter to convert DC electricity into AC electricity which is then used by consumers. This research uses the research and development approach, namely research that will produce an effective and efficient power breaker system as a function of creation and innovation in solving renewable energy problems. Result; the automatic power breaker suitable for use in small-scale wind power plant has been assembled and tested with good results and is ready for use.

1. Introduction

Energy use in Indonesia is increasing rapidly in line with economic growth and population growth [1]. Meanwhile, access to reliable and affordable energy is the main prerequisite for improving people's living standards.

Energy diversification continues to be encouraged by the government in order to reduce dependence on oil and increase the use of renewable energy [2]. This has an impact on reducing energy costs and increasing national energy security. As it is known that fuel is a type of fossil energy with the highest price, even though Indonesia has reserves of coal, natural gas, and new and renewable energy that are potential to be used as a substitute for fuel. Optimum utilization of non-fuel fossil energy and NRE will increase energy security and reduce national energy costs. To that end, the Ministry of Energy and Mineral Resources in 2013 and 2014 has set various regulations in order to encourage the use of renewable energy and natural gas for transportation [3].

Currently, the dependence on fossil energy sources is very high, the reserves of fossil energy sources are limited, while the need continues to increase [4]. Oil production relatively did not increase, while subsidies tended to increase. It is necessary to find ways to produce and utilize other, renewable and competitive energy sources.
The dilemma that arises is that on the one hand, large power generation centers will certainly be oriented to meet the needs of large loads, such as industrial and commercial. On the other hand, small loads need to be considered too, such as housing in remote and coastal areas, can meet their needs for electrical energy. One alternative that can be pursued is to build small to medium power plants that utilize the potential of local energy resources, especially new and renewable energy resources [5].

Renewable energy is the energy generated from a sustainable and natural process, such as solar power, wind power, water flows, and geothermal. Furthermore, the renewable energy is certainly also a sustainable energy as it is always available in nature in a relatively long time. The nuclear energy is not included nuclear power as part of sustainable energy because the supply of uranium-235 is limited. However, the nuclear activists argue that nuclear can be included into sustainable energy as it can be replicated in fast breeder reactor /FBR.

The potential for wind power plants in Indonesia, especially in coastal areas and in the highlands of Central Java, including the city of Semarang, is quite potential [6]. For this reason, its existence needs to be developed to meet the electricity needs of households as well as people in remote areas. The problem that often occurs in small-scale wind power plant is the wind speed that changes and suddenly becomes fast so that it can cause system damage.

In large-scale wind power plants, the stabilization system due to changes in wind speed is fully available [7]. Meanwhile, there is no small-scale power plant yet, even though this is very important for the system itself and for the continuity of electricity supply for consumers. In order to avoid damage to the small-scale wind power generation system, a device is needed to stop the electrical power supply to the system automatically [8].

Based on the description above, the formulation of the problem is to develop a power breaker system in small-scale wind power plant when over speed occurs so that it can operate properly. The purpose of this study is to develop a power breaker system in small-scale wind power plant when over speed occurs so that it can operate properly. The specific purposes of this research are to uncover and find the following the design and manufacture an automatic power breaker suitable for use in small-scale wind power plant and to conducting trials, analyzing electrical data from tools that have been produced, and repairing power breaker devices automatically if needed.

1.1. Electrical energy
Electrical energy is one of the most widely used forms of energy, and the most widely used source to generate this electrical energy is using an electric generator. This energy is transferred in the form of a flow of electric charge through a metal conductor called an electric current. Electrical energy originates from an electric generator which is rotated by the prime mover of a water turbine, steam turbine, gas turbine, diesel engine and so on.

The principle of the generator is based on electromagnetic induction. After the rotor is rotated by the prime mover, the poles on the rotor will rotate. If the pole coil is given a direct current, then on the surface of the pole will arise a magnetic field (line of flux force) which rotates at the same speed as the pole rotation [9].

1.2. Wind Power Plant
The potential for wind energy in Indonesia is generally more than 5 meters per second (m/second). Mapping results from the National Institute of Aeronautics and Space (hereinafter referred to as LAPAN) at 120 locations show that several areas have wind speeds above 5 m/s, namely East Nusa Tenggara, West Nusa Tenggara, South Sulawesi, and the South Coast of Java. The wind speed of 4 m/s to 5 m/s is classified as medium scale with a potential capacity of 10-100 kW.

The district of Sidrap in South Sulawesi province has a good wind potential. Therefore, it is suitable for the wind – based power plant. The estimated wind speed at the site is about 7 meters per second (m/s). The wind – based power plant is now being built in the Mattirotasi and Lainungan village, Watangpulu sub-district, Sidrap District, South Sulawesi and it is targeted to be operational in 2018. It is the first largest wind power plant in Indonesia with the total capacity
reaching 75 Mega Watt (MW). This eco-friendly plant consists of 30 wind turbines with a capacity of 2.5 MWeach. The Gamesa Iolica Corporation turbine model was used on a steel tower as high as 80 meters with a blade length of 57 meters [10].

Renewable energy found in Central Java Province, especially in the city of Semarang, has quite large potential and according to the characteristics as an energy source that can be utilized, cheaply and environmentally friendly, one of which is wind energy. Based on previous research and studies, the minimum average wind speed that can be economically developed as a source of electrical energy generation is 4 m/s for small-scale power plants. Small-scale wind power plant is depicted in Figure 1.

![Figure 1. Small-scale Wind Power Plant](image)

The image above shows a model of a small-scale wind power plant using five blade fins. Where the wind energy is captured by the five blade fins that are used to turn an electric generator.

The conversion of wind energy into mechanical or electrical energy that is beneficial to humans is carried out using a Wind Energy Conversion System (hereinafter referred to as SKEA), while the conversion to electricity is called an electric SKEA or wind turbine. For its utilization, the selection of an SKEA is carried out based on supply (wind potential available at a location) and demand (use or utilization) according to the actual needs at that location. The amount of supply depends on the wind energy potential available at the location which can be expressed in terms of power density (W/m²) or energy density (kWh/m²), while demand is expressed in kWh of total energy use.

A wind turbine serves to convert energy / force from the wind into torque (rotating force) on the rotor. The amount of energy transferred from the wind to the rotor depends on the air density ($\rho$), the rotor sweep area (A), the rotor power coefficient (Cp), and the wind speed (V).

Wind turbine capacity is categorized into three capacities, including:

1. Small capacity: up to 10 kW
2. Medium capacity: 10 kW to 100 kW
3. Large capacity: above 100 kW

1.3. Wind Power Plant

Basically, the electric power generation system uses a synchronous machine that works as a generator. Small-scale wind power plant is shown in Figure 2. Some of the advantages of using synchronous generators in generating systems include:

1. Relatively wide loading range,
2. Capital investment is generally small,
3. Simple design and installation,
4. Simple maintenance,
Figure 2. Small-scale wind power plant

The working principle of a generator is based on electromagnetic induction. After the rotor is rotated by the prime mover, the poles on the rotor will rotate. If the pole coil is given a direct current, then on the surface of the pole will arise a magnetic field (line of flux force) which rotates at the same speed as the pole rotation.

A simple way to make a generator is to rotate a winding in a magnetic field, schematically shown in the figure below. Can also be made of rotating poles while the windings do not move. The electric current is drawn directly from the non-rotating winding, this is for large power, current, and voltage while in the picture below the electric current is drawn with the help of a pair of sliding rings and brushes for relatively small power.

1.4. Power Breaker

The power breaker is planned to use the Arduino Uno 328 module, the input sensor uses the ACS712 sensor and a relay to cut off electricity from the wind power plant to the electricity load that passes through it. The ATmega328 is a type of single-chip microcontroller built with Atmel in the mega AVR family. The Arduino Uno is a Harvard-built chip-set to an 8-bit RISC processor core.

1.5. Thinking Framework

In wind power plants, wind stability is needed, this is to ensure the stability of the voltage on the load so that fault such as damage to the generator, load and equipment will not happen. If the wind speed is getting faster, the voltage generated by the generator will also be higher. By using a voltage sensor, the breaker will work to turn off the flow of electric power from the generator to the battery. If the wind speed decreases, the sensor will detect the voltage generated by the generator and will reconnect the flow of electric power to the battery. The roadmap model is illustrated in Figure 3.

![Figure 3. Research roadmap model](image)

2. Research Methods

This study uses a research and development approach, focusing on research that produces a model as a function of creation and innovation in an effort to solve the energy crisis problem, namely realizing an automatic load breaker system in small-scale wind power plants so that they can operate properly. It is
hoped that this load breaker will be followed up by the industry as a superior product. The design of this research activity plan is more clearly described through a flow chart in Figure 4.

Phase I design planning and theoretical studies, phase II making/developing tool designs and theoretical studies, phase III laboratory trials followed by electrical data analysis, phase IV repair of power breaker devices.

![Flow Chart](image)

**Figure 4.** Research Activity Plan Design

3. Results and Discussion
The research has been completed and tests were carried out in the Electrical Engineering laboratory, FT UNNES and limited field tests. The figure below shows a small-scale wind power plant unit, test simulation and a power breaker system module.

The sequence of the research activities is survey and identification as well as collecting data related to small-scale wind power plants, power breaker control system modules, relays, then making the planning for work and material needed.

The next step is to assemble the components that have been prepared and to calibrate the control system on the Arduino Uno 328 module. The voltage setting is done so that when high rotation occurs, the wind power plant output voltage also increases. When the voltage exceeds 25 Volts, the module will work and the relay will turn off, so the power supply to the load will also turn off. After finishing assembling, proceed with conducting trials. Figure 5 describes the circuit breaker module.

![Circuit Breaker Module](image)

**Figure 5.** Circuit breaker module

The first test was carried out by rotating the wind power plant at a certain speed and then observing the output voltage without installing a power breaker module. The data obtained can be seen in table 1.
Table 1. Data of wind power plants output voltage without power breaker module

| No | Round (rpm) | Wind power plants Voltage (Volts) |
|----|-------------|----------------------------------|
| 1  | 208         | 10                               |
| 2  | 237         | 12                               |
| 3  | 256         | 14                               |
| 4  | 282         | 16                               |
| 5  | 345         | 18                               |
| 6  | 370         | 20                               |
| 7  | 384         | 22                               |
| 8  | 402         | 24                               |
| 9  | 428         | 26                               |
| 10 | 458         | 28                               |

In table 1 Wind power plant output voltage data without a power breaker module, it can be seen that the voltage will increase along with the rotation. This shows that according to the characteristics of the AC generator, the higher the rotation, the higher the resulting voltage.

The next experiment tested the ability of the power breaker module if given a certain voltage input. The voltage generator uses the AVR to obtain the desired voltage. Furthermore, the position of the relay on the breaker module is observed, on or off. This means that if alive means that there is a supply of electrical power to the system. If it turns off, it means that the supply of electrical power to the generating system has stopped. The test data can be seen in table 2.

Table 2. Testing data with voltage simulator (AVR)

| No | Simulator voltage (Volts) | Position of relay on module |
|----|---------------------------|----------------------------|
| 1  | 16                        | on                         |
| 2  | 17                        | on                         |
| 3  | 18                        | on                         |
| 4  | 19                        | on                         |
| 5  | 20                        | on                         |
| 6  | 21                        | on                         |
| 7  | 22                        | on                         |
| 8  | 23                        | on                         |
| 9  | 24                        | on                         |
| 10 | 25                        | on                         |
| 11 | 26                        | off                        |
| 12 | 27                        | off                        |
| 13 | 28                        | off                        |
| 14 | 29                        | off                        |
| 15 | 30                        | off                        |
In testing data given in table 2 with a voltage simulator (AVR), depicts that if the voltage is increased, when the voltage exceeds 25 Volts, it can be seen that the position of the relay is off. This shows that according to the plan, when the voltage exceeds the specified (25 Volts) the power breaker module will work automatically cutting off the electricity supply to the relay, so that the power supply to the load will be cut off.

From the experiment, it can be seen that the module can work well, so that the overall power breaker module that will be used to automatically cut off power when there is an over speed of small-scale Wind power plant can run well.

This study has limitations, namely; the research sample in the form of a power breaker module is only made one unit, and is not tested with a comparison tool that is similar, and is not tested with a maximum load.

4. Conclusions
The power breaker has been completed and assembled and it is suitable for the use in small-scale wind power plant. The power breaker has been tested with good results and is ready to use. However, this automatic power breaker needs to be tested for a long time so that its technical age can be identified so that it can have more detail calculation for its service life. It needs to be followed up with community service activities in the form of socialization and implementation of automatic power breaker for small-scale wind power plant that has been made to the wider community.

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