

Developing a simulator of renewable energy as a learning media of energy conversion

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Abstract. A renewable energy is a new topic in education in Indonesia, especially for vocational education. The problem is the teaching trainer as a learning media is still not available at Universitas Negeri Malang while developing a trainer is expensive. This paper introduces a renewable-energy simulator, which can show the process of converting energy using hybrid solar cell and wind power systems. In case of the solar cell system, the simulator shows the process of converting the sunlight beam to energy production. Furthermore, the simulator shows the watt peak (WP) of the daily solar beam. In the case of the wind-power system, the simulator shows the capacity of power generator considering the size of rotor, wind speed, and the type of generator. The unique point of this simulator is that the hybrid systems of solar cell and wind power systems are demonstrated. While solar cell can't be effective if the sunlight beam is not available, it can be supported by the wind-power system, which is available for 24 hours, but it is depending on the speed of wind. Thus, implementation of this simulator can help students easier to understand and optimise the development of power generation using renewable energy.

1. Introduction

Nowadays, the use of new and renewable energy is a major issue in many countries, the purpose is to maintain of sustainable energy. One of the country who has an enormous potential for renewable energy is Indonesia. Indonesia has a large new and renewable energy potential, which includes 450 MW of mini/micro hydro power, 50 GW of Biomass, 4,80 KWh/m²/day solar power, 3-6 M/sec wind power, and 3 GW of nuclear energy [1]. This new and renewable energy potential is explained by the Director General of Electricity and Energy Conservation at the Focus Group Discussion on the Supply and Demand of New and Renewable Resources held by Pusdatin ESDM [2]. Indonesia's government have been prioritizing the development of the renewable energy sector to increase the low supply and to meet the growth in consumption of electrical energy. The government's ambitious plan to raise renewable share to 23-25 percent by 2025 from just 6 percent now would expand access to electricity, support industrial growth, and support the country's less developed regions [3].

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Education also has a crucial role in the development of the renewable energy industry [4]. Renewable energy is seen by many as part of the appropriate response to these concerns and some national Governments have put programs in place to support the wider use of sustainable energy systems in education vocational education [5]. The education purposes are to prepare engineers, scientist, and energy planners to research and produce sustainable energy generation systems. The problem is that the teaching trainer as a learning media is still not available at Universitas Negeri Malang while developing a trainer is expensive. The aim of this paper is to introduce a renewable-energy simulator, which can show the process of converting energy using hybrid solar cell and wind power systems. A renewable hybrid energy system consists of two or more energy sources [6,7]. The Simulator is capable to simulate and demonstrate the development of renewable energy sourced to the solar and wind power. Solar PV has the highest resource potential in Indonesia at 532.6 GW, explained by the high solar resource across Indonesia, which is in the range of 4.0-6.9 kWh/m² and averages 4.8 kWh/m² [8]. However, the solar power system will not able to produce the electricity when there is no solar source for example at the time of evening. The unique point of this simulator is the hybrid systems of the solar cell and wind power systems can be demonstrated. While solar cell can't be effective if the sunlight beam is not available, it can be supported by the wind-power system, which is available for 24 hours, but it is depending on the speed of the wind and another condition.

In the case of the solar cell system, the simulator shows the process of converting the sunlight beam to energy production. Furthermore, the simulator shows the watt peak (WP) of the daily solar beam. In the case of the wind-power system, the simulator shows the capacity of power generator considering the size of the rotor, wind speed, and the type of generator. Simulator usage will help the user easier to understand the deference result of each type of power plant generation based on environment condition input by user. This will construct the user comprehension by simulator demonstration, thus the user can do observation without using the real equipment.

2. Simulation of Renewable Energy Development

In this section, the simulator of renewable energy is introduced. The simulator is developed using ADDIE model consists of analysing, designing, developing, implementing and evaluating [9]. The simulator has the ability to demonstrate and calculate power result of development for three kind of power generation i.e. 1) solar power generation, 2) wind power generation, and 3) hybrid power generation. Solar power generation simulator is developed to show how solar panels harvest light then converting it into electricity [10]. Wind power generation simulator is developed to show how the wind turns the blades, which spin a shaft, which connects to a generator and makes electricity [11]. Hence, hybrid power generation simulator is developed to show the combination of solar and wind power generation. The detailed simulator device is described as follows.

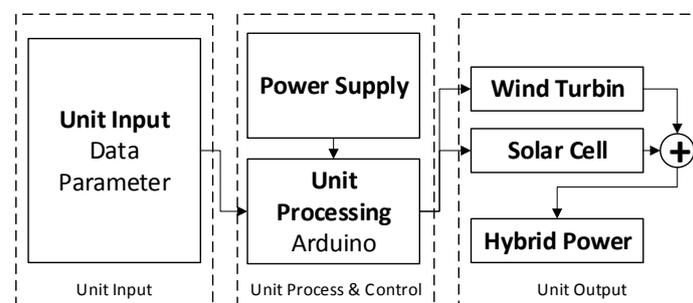


Figure 1. Block Diagram of Simulator Device

2.1. Simulator Device

Simulator device is built in a box of 80 mm height and width 120 x 40 mm. Here, the simulator device is controlled by arduino as unit processing and controlling. The simulator requires some input

parameter by user indicate environment condition to start the simulation of development power generation. Solar and wind power generation have different input of variable depending on power resources to result the electricity. Solar power generation require three kind of input variable i.e., solar intensity (lux), solar power (Wp), and number of solar panel while wind power generation need the following input of variable i.e. density (Kg), velocity (m/s), and length of turbine (m). This input is used to calculate the power generation considering kind of power generation. The power result is shown in display monitor while the demonstration is shown till the electricity distribution process into costumer. The block diagram of detailed simulator device is shown in figure 1.

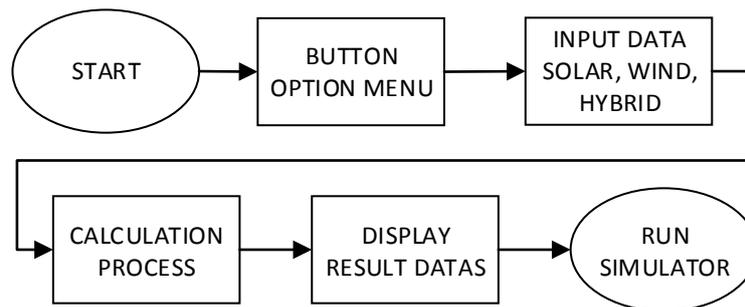


Figure 2. Flowchart of Simulator Device

Based on the simulator demonstration user are capable to analyse the result using hybrid power generation and stand-alone power generation. This simulator is designed to show the real condition of power plant development result based on the power generation usage. Figure 2 shows the flowchart of simulator device usage. Firstly, the user has to choose the type of power plant generator. Then input the variable of parameter needed by the chosen power plant generator based on the system guide. If the user chooses the solar power generation, the hardware simulator will not activate the wind power generation and also the reverse of it. The hardware simulator will show the power output and demonstrate the real condition of the actual system, display the environment effect and the electrical result transmitted to the consumer. Here, figure 3 shows the specification of the simulator device.

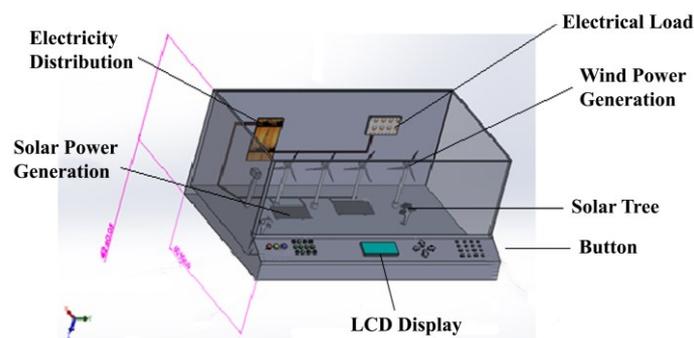


Figure 3. Specification of Simulator Device

2.2. Implementation

This learning media will be implemented into subject of new and renewable energy (code NTEL649) Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Malang. The Simulator is designed for the following basic competence i.e. 1) to clarify the working principles of new and renewable energy conservation in terms of technical, economic, financial, socio-cultural and environmental aspects and with a description of competence; 2) clarify the principle of solar energy conversion; 3) clarify the wind energy conversion principle; 4) clarify the working principle of a

hybrid generating system; and 5) predict the prospects for the provision of renewable energy in a decentralized and sustainable manner.

As shown in figure 4, the concept using simulator device will construct the students understanding to analyse environment potential before developing the power generation of renewable energy. Analysis result are capable to demonstrate using the simulator device. Thus, students have experience to study the effect and result of power generation process using miniatur equipment. Based on the result, the students will have the ability to optimise the power generation development considering potential environment and applying the energy management.

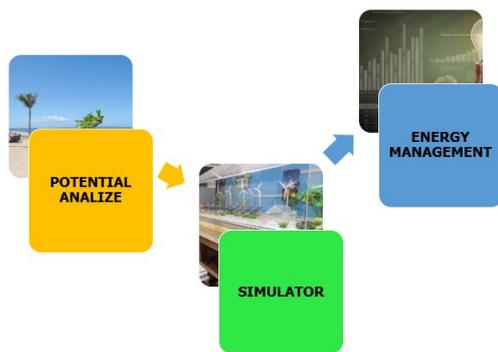


Figure 4. Learning concept using simulator device

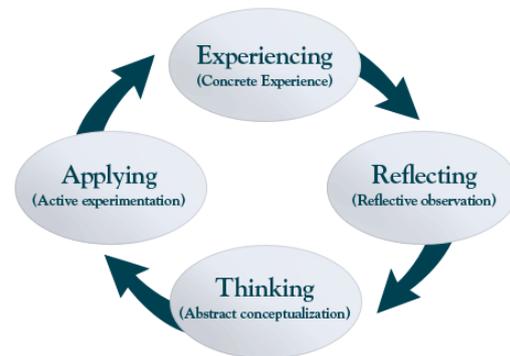


Figure 5. Kolb's Experiential Learning Cycle

Figure 5 shows the implementation of learning media use Kolb's Experiential Learning [12]. Simulator implementation on the learning process allows the students to get an experience to develop power generation of renewable energy. Thus the students can observe the results obtained by simulator. It has the ability to construct the student's thinking to plan the development of power generation considering the environmental conditions to produce optimal power.

Based on the implementation of the simulator which used as learning media of energy conservation, this simulator is equipped with job sheet as the guide the user when using the simulator. The jobsheet consists of 1) purpose and competence of learning, 2) theoretical concept of solar, wind, hybrid power generation, 3) job steps description, 4) analysis sheets, 5) questions of evaluation, and 6) simulator maintenance and repair guide.

3. Simulator of Renewable Energy Utilization

This section shows the result of power generation by the simulation process considering the parameter input manually inserted by user.

3.1. Solar Power Generation

Indonesia as an equator area has the maximum value of Sun's light i.e. 98000-116200 lux [13]. Based on the output power results of the measurement at maximum power solar panel from a voltage and electric current is proportional to the intensity of sunlight and temperature on the solar panels on the solar panels.

$$P_{Solar} = \frac{solar_absorbed}{max\ solar_Intensity \cdot WpSolar} \quad (1)$$

The formula used in the simulator is taken from the value of the middle light solar maximum i.e. 107000 lux, so the equation obtained by the formula (1). Figure 6 and 7 shows the input and output process of solar power generation. Parameter usage of this attempt are 100 Wp of P max and 8920 for solar intensity. Based on the input, the calculation result is 12,14 (Watt).



Figure 6. Solar power generation input



Figure 7. Solar power generation output

3.2. Wind Power generation

The wind power generation with horizontal axis used formulas (2). P (Watt) is power output, ρ (Kg/m^3) is power density, v (m/s) is velocity, and A (m^2) is the length of turbine. Figure 8 and 9 shows the input and output process of wind power generation.

$$P_{wind} = \frac{1}{2} \cdot \rho \cdot v^3 \cdot A \quad (2)$$

Parameter usage of this attempt are 5 Kg/m^3 for density, Wp 20 m/s for velocity, and 5 m^2 for length of turbine. Based on the input, the power calculation result is 1696 (Watt).



Figure 8. Wind power generation input

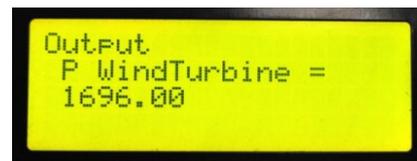


Figure 9. Wind power generation output

3.3. Wind Power generation

The hybrid power generation is generated based on the previous solar and wind power generation by sum the solar and wind power result as shown in formula (3). It combines the solar and wind power generation at the same time. The result of hybrid power generation is $12,14 + 1696 = 1708,14$ (Watt) as shown in Figure 10.

$$P_{hybrid} = P_{solar} + P_{wind} \quad (3)$$



Figure 10. Hybrid power generation output

4. Conclusions

In this paper, a simulator device has developed using ADDIE method. Based on the evaluation process, the simulator has ability to demonstrate a power generation development into a miniature equipment. Simulator implementation are capable to minimize the time, avoid an accident, and reduce the expense during the education process. The presence of this simulator gives a basic experience for the students before apply it into the real development of power generation. The advantages of the simulator are spending low cost, modelling the real condition by insert the variable of parameter

influence the power generation. The testing result shows that the simulator work properly. The implementation as a learning media has been confirmed by the expert judgement.

5. Acknowledgments

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