Design and Implementation of Trainer Kit for Hybrid On-Grid Solar Power Generation System

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Abstract. New and renewable energy is one of the hot issues discussed by various energy experts in many countries. As a country that has enormous renewable energy potential, Indonesia has not utilized it optimally. One of the reasons is the inadequate learning of new and renewable energy in schools and colleges. This article will discuss the design and implementation of a Trainer Kit for Hybrid On-Grid Solar Power Generation System (TK-HOGS). With this Trainer Kit, it is hoped that vocational education students will increase their competence in new and renewable energy. This study uses a research and development approach that adopts the ADDIE model. The development stages include Analysis, Design, Development, Implementation, and Evaluation. The results showed: (1) The TK-HOGS can produce an average power of 22.74 Watt with an estimated electrical energy of 136 WH and (2) Media experts and electric power engineers stated that this TK-HOGS is "Very Good" and very suitable to be used to help lecturers in carrying out learning.

Keyword: trainer kit; TK-HOGS; solar power generation; renewable energy.

1. Introduction

Energy is one of the primary resources most needed by humans being. One of the central issues in the industrial revolution 4.0 era is new and renewable energy. Indonesia has great potential for new and renewable energy, including 450 MW of mini/micro hydro, 50 GW of Biomass, 4.80 KWh / m2 / day of solar power, 3-6 M/sec wind power, and 3 GW of nuclear energy. [1]. However, the reality is just the opposite. The utilization of new and renewable energy, such as solar cells, wind turbines, and other renewable energies, is minimal below twenty-five percent [2]. One of the problems with the lack of use of new and renewable energy in Indonesia is the lack of learning that provides awareness and competence in new renewable energy.

Figure 1. On-grid power generation in Indonesia, 2010 and 2014
Education has an essential role in developing science and technology, especially in renewable energy. Currently, the 2030 Sustainable Development Goals are being echoed, where one of the goals is related to the use of renewable energy. Energy and renewable energy management systems are required in the Sustainable Development Goals [1]. One education institution that has a relationship with energy is a vocational school. Vocational education institutions aim to prepare their graduates to become a professional workforce [3]. For that, vocational education needs to explore energy issues. One of the subjects related to energy in the electrical engineering department of YSU is power generation. This course discusses the concept of electrical energy generation and the development of new and renewable energy. The learning process was conducted by providing lecture material in class and practice in the laboratory. One of the problems in practical learning is the lack of facilities and infrastructure to learn in the laboratory. One of the obstacles in practical learning is the lack of learning facilities and infrastructure in the laboratory. The practical equipment for power generation courses relies on practice units developed by students. This practical tool is limited to only providing an overview of the various types of existing power plants, both hydropower, wind power, and solar power.

In order to prepare a professional workforce, vocational colleges need to equip students with adequate competencies. The industrial revolution era requires a workforce capable of mastering various science and technology [4]. Therefore, vocational learning needs to make a revolution, especially in learning technology. The Learning Process in the electric generator course needs to be carried out with supported by adequate quality teachers and the right equipment.

According to [10] to achieve learning objectives, media is needed to improve students' abilities in the learning process. Agreeing with this, [11] explained that learning media could stimulate feelings, thoughts, and interests and the willingness of students so that an effective and efficient learning process occurs. Learning media can increase student participation and abilities [12]. Based on the above opinion, to achieve the objectives of learning to practice electric power generation, learning media are needed that can stimulate students' thoughts, interests, and feelings. A Trainer kit For Hybrid On-Grid Solar Power Generation System can be used as a practical educational medium.

Based on observations and interviews with lecturers and students of the Department of Electrical Engineering, Yogyakarta State University, the following data were obtained: (1) Learning about power plants is more focused on large power plants such as steam power plants, gas turbine power plants, and diesel power plants. The discussion of new and renewable energy focuses more on reserve energy if the primary source fails. The renewable generator practice tool used is to stand alone without being integrated into the network system so that it is not optimal. This condition causes the learning of electricity generation practices to be less than optimal in equipping students' competence with new and renewable energy.

Thus, efforts are needed to improve the quality of learning in power generation courses in the Department of Electrical Engineering Education, Yogyakarta State University. One of them is by designing and implementing the TK-HOGS. This Trainer can make it easier for lecturers to provide explanations and demonstrations of generating electrical energy from various sources and integrated with a grid system. Likewise, students can understand the material on generating electrical energy from renewable sources and integrate it into the grid system easily.

2. Related Works

2.1. Hybrid Power Plants

Hybrid power plants that combine various power plants is one concept that can be implemented to improve energy effectiveness and efficiency [5]. Combining two sources of electricity is one solution to solve the problem if the main power supply experiences a problem.
Additionally, uplift usage of renewable energy resources means reducing the nation's dependency on fossil fuels leading to a drop in CO₂ emission [6], which is highly encouraged by the Indonesia government through President Regulation No. 61/2011 in order to ease the damage arisen by greenhouse effect to global climate change. Furthermore, participating in alleviating the environmental issues caused by the emission of carbon dioxide, namely global warming, seawater rise, oil spills, air quality deterioration, acid rain that caused by overuse fossil fuels, is in line with the climate action campaign launched by the United Nations (UN) [7].

The use of renewable energy combined with the grid is an essential requirement in the era of the industrial revolution 4.0. Human needs who want good quality electric power and high reliability make hybrid systems better reliability. Solar power plants generally use photovoltaic or concentrated solar power as their working principle. The development of increasingly efficient solar cell technology has driven the production and use of this technology in many countries. Kurtz [8] explained that ten years ago, the efficiency of solar cells was still relatively low, only around 30%. However, with current technology, the efficiency of solar cells can reach 40%, and it is even predicted that in the future, it will be close to 50% [9].

2.2. Modul of Hybrid Power Plant

The solar module is the main component in the solar power generation system that converts sunlight into electricity, where the electricity generated is in the form of DC voltage and current [8, 16]. The power capacity of the solar module is measured in Watt peak (Wp), the amount of which is determined based on the specifications of the solar module. The peak wattage states the amount of power generated by the solar module when the incoming and received solar radiation is 1000 W/m² with an ambient temperature of 25°C. The power and electric current generated by the solar module varies depending on the intensity of the solar radiation received. The output power of the solar module is also influenced by environmental factors, shadows, installation tilt angles, and cleanliness of the surface of the solar panel. The solar panel module can be shown in Figure 2 below.

![Figure 2. The Solar Cell Integrated on a Grid](image-url)
optimal energy flow management strategies [17]. Kaabeche et al. [18] recommend a hybrid power generation system between photovoltaic and wind. The system optimizes the integration concept model by utilizing iterative optimization techniques. This method can address possible power supply shortages, the relative excess power generated, and the total annual costs for power reliability and system costs.

The integration of solar power plants into the PLN grid can help reduce overall costs and increase the reliability of a renewable power plant to supply its load. The grid takes excess renewable power from renewable energy locations and supplies electricity to site loads when needed. Fig. 2 shows a typical DC and AC bus network connected to solar Photovoltaic hybrid systems.

3. Methods
The TK-HOGS was developed using the ADDIE model research and development approach. The steps for developing this Trainer consist of five stages, namely 1) Analysis of trainer needs, 2) Design of Trainer kit, 3) Making of Trainers kit, 4) Implementation of practical learning of power plants, and 5) Evaluation of the final product [19, 20].

![Research Stage with ADDIE Model](image)

**Figure 3.** The research stage with the ADDIE Model

The analysis aims to identify the needs of TK-HOGS according to the syllabus and objectives of this course. The analysis was carried out through observation of the practical learning process and interviews with lecturers and students. This activity includes identifying the components needed. The results of the analysis are used as the basis for designing TK-HOGS that will be used in learning power plants. The design consists of designing hardware, software, and data required for practical measurement. The next stage of development is to make a TK-HOGS unit according to the design results. The manufacturing process is carried out carefully in order to meet the predetermined requirements. The learning media product of the TK-HOGS developed must meet the validation test criteria conducted by experts in the appropriate field. After the product in the form of a Trainer is finished, the implementation is carried out by validating the media experts and education experts. Furthermore, a trial was conducted on students to determine the effectiveness of
this Trainer. The last stage is to evaluate the products that have been made based on input during implementation in the field.

Results and Discussion

After the development process is complete, the next process is the implementation or trial process. The trial was carried out in the Department of Electrical Engineering Education, FT UNY. Picture of the trial implementation in Figure 9.

![Figure 4. The Trainer Kit for Hybrid On-Grid Solar Power Generation System](image)

The functional test was conducted to determine the performance of the on-grid system of the TK-HOGS. The test is carried out without the load to determine the power generated by the system. The trial is carried out by taking observational data every 10 minutes, starting from 12.00 to 13.00. At these hours is the time the sun is at its hottest. The results of the on-grid system trial are shown in Table 1 below.

| Time   | Temperature (°C) | Luminance (Lux) | PV Voltage (V) | PV Current (A) | PLN Voltage (V) | PLN Current (A) | Output Voltage (V) | Output Current (A) | Output Power (W) | Freq. (Hz) | Cos Φ |
|--------|------------------|-----------------|----------------|----------------|-----------------|-----------------|--------------------|--------------------|------------------|-----------|-------|
| 12.00  | 29               | 7840            | 42.7           | 0.58           | 225             | 0               | 228                | 0.16               | 23.5             | 50        | 0.64  |
| 12.10  | 29               | 7350            | 42.5           | 0.58           | 225             | 0               | 229                | 0.15               | 22.1             | 50        | 0.63  |
| 12.20  | 29               | 7780            | 42.7           | 0.58           | 225             | 0               | 229                | 0.15               | 22.1             | 50        | 0.63  |
| 12.30  | 29               | 9860            | 44.5           | 0.56           | 225             | 0               | 227                | 0.16               | 23.4             | 50        | 0.63  |
| 12.40  | 29               | 7950            | 42.7           | 0.58           | 225             | 0               | 226                | 0.15               | 22.0             | 50        | 0.63  |
| 12.50  | 29               | 8970            | 43.8           | 0.56           | 225             | 0               | 229                | 0.15               | 22.8             | 50        | 0.65  |
| 13.00  | 29               | 7640            | 42.7           | 0.58           | 225             | 0               | 227                | 0.16               | 23.3             | 50        | 0.63  |

Based on Table 1, it can be explained that the trainer kit can function correctly. The electricity generated is stable when tested at 12.00 to 13.00 with an ambient temperature of 29°C. The grid-tie inverter can connect the solar power generation system made with the PLN Grid network. The average electric power that can be supplied to PLN is 22.74W. If it is assumed that the average
duration of solar irradiation is approximately 6 hours in a day, then the electrical energy generated by the system reaches 136 Wh. When given a 20W TL lamp load, the TL lamp can light up.

TK-HOGS is able to function correctly, which can work properly. The solar panels are able to work off-grid and on-grid with PLN electricity sources. However, the ability of solar panels is still relatively low. The PV specifications used have a maximum power of 150 WP. However, it is only able to provide 24.91W of power or 16.6%. This condition because the solar panel is not new but has been in use for more than ten years so that efficiency has decreased.

After the trial is complete, the next step is to analyze the reliability of the instrument using Cronbach's Alpha. The results of the reliability of the instrument obtained a value of 0.89 with a very feasible category. After being declared feasible, the next step is to test the validity of the trainer kit. Validity testing uses an assessment of two aspects, namely media and material. Validity testing on the media aspect includes four things, namely benefits, in terms of hardware, operations, and visual communication. Testing the validity of the material aspects includes two things: the quality and relevance and the quality of learning. The results of testing the validity of the media by experts are shown in Figure 4 below.

![Figure 4. Graph of test results for media aspects](image)

Based on Figure 5, it can be explained that the media aspect gets a minimum value of 87.5 and a maximum value of 92.18 from a maximum total value of 100. It means that the Trainer kit For Hybrid On-Grid Solar Power Generation System, in terms of the media aspect, is categorized as Very Feasible. Furthermore, the results of the material test are shown in Figure 6.

![Figure 6. Graph of material aspect test results](image)
Based on Figure 6 shows that the material aspect scores 87.5 on quality and relevance. Meanwhile, the learning quality obtained a score of 89.59. So it can be interpreted that the Trainer kit For Hybrid On-Grid Solar Power Generation System in terms of material aspects is categorized as Highly Feasible. The results of the validity test in both media and material aspects of the Trainer kit frame are in the Highly Feasible category. The results of this study follow the results of research [14], which explains that learning media in the form of trainers can increase student learning activities. A Trainer kit with a suitable category can help students in the learning process [15].

4. Conclusion

The results of the study concluded that: (1) The average power generated by the TK-HOGS reaches 22.74 Watt with an estimated electrical energy of 136 WH and (2) The feasibility of the TK-HOGS as a learning media falls into the “highly feasible” category. The TK-HOGS can support the learning process in the power generation practical course.

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References

[1] Anon 2015 Indonesia Energy Policy, Laws and Regulation Handbook Volume I Strategic Information and Basic Laws (Washington DC: International Business Publications)
[2] IRENA (2017), Renewable Energy Prospects: Indonesia, a REMap analysis, International Renewable Energy Agency (IRENA), Abu Dhabi, www.irena.org/remap
[3] M. Ali, Djemari Mardapi, Thomas Koehler, Identification Key Factor in Link and Match Between Technical and Vocational Education and Training with Industry Needs in Indonesia, Proceedings of the International Conference on Online and Blended Learning 2019 (ICOBL 2019), Advances in Social Science, Education and Humanities Research, Volume 440, Published by Atlantis Press
[4] M Ali1, L D Prasojo2, D Maedapi3, and Soenarto, Design of Self-evaluation Management Information Systems (SEMIS) for Vocational School Based on National Education Standard, IOP Conf. Series: Journal of Physics: Conf. Series 1140 (2018) 012008 DOI:10.1088/1742-6596/1140/1/012008
[5] Rashid Al-Badawi, Mohammad Abusara & Tapas Mallick (2015) A Review of Hybrid Solar PV and Wind Energy System, Smart Science, 3:3, 127-138, DOI: 10.1080/23080477.2015.11665647
[6] Tan Yingjie, Meegahapola L., Muttaqi K.M., A review of technical challenges in planning and operation of remote area power supply systems. Renewable and Sustainable Energy Review. 2014. 38: 876-889.
[7] Climate Action Campaign Launched by the United Nations. December 3, 2018. Retrieved from https://www.un.org/sustainabledevelopment/blog/2018/12/united-nations-campaign-to-promote-climate-action-by-the-people-launched-by-sir-david-attenborough/ on September 21, 2020, at 11.03 PM.
[8] S. Kurtz, "Opportunities and challenges for the development of a mature concentrating photovoltaic power industry," Technical Report NREL/TP-520-43208, Revised November (2009)
[9] EPTP, "A strategic research agenda for photovoltaic solar energy technology," September (2011) [second edition]
[10] Sukiman, Pengembangan Media Pembelajaran. Yogyakarta: Pedagogia. 2012.
[11] Kartikasari, Pengaruh Media Pembelajaran Berbasis Multimedia Terhadap Motivasi dan Hasil Belajar Materi System Pencernaan Manusia. Jurnal Dinamika Penelitian (63). 63-68. 2016.

[12] Damarwan, E. S., & Khairudin, M. Development of an Interactive Learning Media to Improve Competencies. In International Conference on Technology and Vocational Teachers (ICTVT 2017). Atlantis Press. 2017.

[13] Solanki, B. V., Bhattacharya, K., & Cañizares, C. A, A Sustainable Energy Management System for Isolated Microgrids. IEEE Transactions on Sustainable Energy, 8(4), 1507-1517. 2017.

[14] Setiawan, Muhammad Eko. "Model Trainer Pembangkit Listrik Tenaga Surya Sebagai Media Pembelajaran dalam Materi Ajar Pembangkit Listrik Tenaga Surya di SMK Negeri 1 Magelang." Edu Elektrika Journal 3, no. 1. 2014.

[15] Faiz, M. Rodhi, and Dedi Tri Laksono. "Pengembangan Trainer Integrasi Pembangkit Listrik Skala Piko." TEKNO 21, no. 1.2015.

[16] J. Karp, "Concentrating solar power: progress and trends," Jacobs Schol of Engineering, University of California San Diego, Triton SPIE/OSA, February 12 (2009) http://psilab.ucsd.edu/research/Multiband%20Solar%20Concentration/files/UCSD_CP V.pdf

[17] P. Bajpai and V. Dash, "Hybrid renewable energy systems for power generation in stand-alone applications: A review" Renewable and Sustainable Energy Reviews, 16, 2926-2939, (2012) DOI: 10.1016/j.rser.2012.02.009

[18] A. Kaabeche, M. Belhamel, and R. Ibitouen, "Techno-economic valuation and optimization of integrated photovoltaic/wind energy conversion system" Solar Energy, 85, 2407-2420 (2011) DOI: 10.1016/j.solener.2011.06.032

[19] Morrison, Gary R. Designing Effective Instruction, 6th Edition. John Wiley & Sons, 2010.

[20] Davis, A. (2013). Using instructional design principles to develop effective information literacy instruction: The ADDIE model. College & Research Libraries News, 74(4), 205-207. DOI:10.5860/crln.74.4.8934