DESIGN AND PERFORMANCE EVALUATION OF A 50 WP OFF-GRID SOLAR PV TRAINER KIT AS AN INSTRUCTIONAL MEDIA FOR RENEWABLE ENERGY

Rion Michael Potoe[1], Silvy Dollorossa Boedi[2*], I Gede Para Atmaja[3]

[123] Politeknik Negeri Manado, Indonesia
*Corresponding Author: silvyboedi@gmail.com

ABSTRACT
Renewable energy has become a global priority to reduce dependence on fossil fuels, with solar power offering significant potential, particularly in equatorial countries like Indonesia. Despite abundant solar energy resources, its utilization remains limited, underscoring the need for educational interventions that build technical competencies in renewable energy. This study aims to design, construct, and evaluate the performance of a 50 Wp off-grid Solar Photovoltaic (PV) Trainer Kit as an instructional medium for vocational and higher education laboratories. The research employed a design-based approach consisting of planning, product design, fabrication, and testing. The trainer kit integrates essential components including a polycrystalline solar module, inverter, charge controller, VRLA battery, and monitoring devices. Performance testing was conducted using true outdoor experimental methods, focusing on solar radiation intensity, charging efficiency, and discharging duration. Results indicate that under clear weather conditions, the trainer achieved full battery charging in 3.5 hours, while battery discharge under a 100 W AC load lasted approximately one hour. These findings confirm the trainer's functional reliability and its potential as an effective learning medium. The study concludes that the developed trainer kit not only enhances practical learning of photovoltaic systems but also supports national efforts in renewable energy education. The research recommends further development with larger solar module capacity and alternative battery types to expand instructional applications.

Keywords: Battery; Instructional Media; Off-Grid; Solar PV; Trainer Kit

INTRODUCTION

Electrical energy is a vital need for society, both for households, industry, communication, and other sectors. In order to meet these needs while reducing dependence on fossil energy, the Indonesian government through the National Energy Policy (KEN) targets a new and renewable energy (NRE) mix of 23% by 2025 and 31% by 2050. In fact, in 2019 the contribution of NRE only reached 9.3%, and it is predicted that in 2050 it will only be around 18% if there are no acceleration efforts [1].

To achieve the target, the use of various NRE sources such as hydro, geothermal, biomass, and solar energy continues to be developed. Indonesia's geographical position on the equator provides enormous solar energy potential, with daily global radiation of 3.45–5.74 kWh/m² and a potential PV output of 2.82–4.62 kWh/kWp per day [2]. The total potential of Solar Power Plants (PLTS) is estimated to reach 3,294 GWp, but its utilization until now is only around 100 MWp [3]. Therefore, the government has set a roadmap for the development of solar power plants with a target of 0.87 GWp installed capacity by 2025 or around 50 MWp per year. The success of achieving this target requires the synergy of all parties, including improving the quality of human resources. Universities as centers of education and research have an important role in supporting the development of competencies and renewable energy technology in Indonesia.

One way to prepare experts is to provide teaching equipment (trainer kit) as a learning medium in the laboratory. Solar installation trainer kits can be used in physics, electrical, and mechanical engineering energy conversion labs to help students deepen their understanding of theory through hands-on experience.

Solar Power Generation Systems (PLTS) are generally divided into two types, namely off-grid (stand-alone) and on-grid (connected to the PLN network). The main components of solar power include solar panels, solar charge controllers, batteries, inverters, and other supporting components [4]-[8]. So far, research has focused more on the characteristics and performance of solar panels through simulations and indoor and outdoor testing [4]-[11].

To support the improvement of students' skills, especially in vocational education/polytechnic, it is necessary to conduct research and development of solar installation trainer kits. Ranjit et al. [12] designed a simple trainer kit in the form of an installation consisting of a PV module that can be varied in series or parallel, a solar charge controller, and a battery. The power variation of the PV module is obtained using a shunt element with a DC load test system, while the charging/discharging process is indicated by the PIC indicator on the battery. Another researcher [13] developed a solar panel installation kit trainer for an on-grid system with solar panel components, PWM controller chargers, batteries, and DC/AC inverters. In addition to focusing on making tools, several studies have also conducted feasibility tests and user response tests [13]-[15]. The ADDIE (Analysis, Design, Development, Implementation, and Evaluation) approach has also been used in designing on-grid solar PV trainer kits [16].

The development of the trainer kit was also carried out by adding a sun direction tracking feature. The researcher [17] designed a solar panel directional adjustment system so that it can compare the output power of a 50 Wp panel between a fixed position and moving with the sun. Meanwhile, Rumokoy et al. [18] discussed the design of the modular solar rooftop installation props in the form of a 3D model.

These studies show that there is a diversity of types and test methods of solar panel installation kit trainers. However, most of them are still limited to certain aspects so they are not exhaustive. Therefore, this study aims to design, manufacture, and test the performance of solar panel installation kit trainers. The test was focused on the characteristics of the 50 Wp polycrystalline solar panel and the performance of the MPPT type solar charge controller. The results of the design are expected to be used as a medium for learning practice in the laboratory.

The learning media of the Solar Power Plant (PLTS) developed aims to improve the previous media in the form of portable trainers. This trainer is designed with an arrangement of solar PV components that can be observed directly, so that students can learn about the installation, understand how the system works, and measure the voltage and current produced. In addition, the trainer is equipped with a solar panel tilt angle analysis feature to determine its effect on current and voltage output. Charging analysis facilities and battery capacity draining facilities were also added to make learning more comprehensive. Based on these problems, this research was conducted to develop a solar PV learning media trainer that can support the student learning process [19].

METHOD

The creation *of this trainer kit* begins with the design/design process. The design method used is a design method which consists of stages: (1) planning and explaining tasks, (2) designing product concepts, (3) designing product forms, and (4) designing details. After the design process, a machining process is carried out in the manufacture of the frame which is followed by the assembly of the props. The materials and specifications of the *50* Wp solar panel installation kit trainer tool are shown in Table 1, as follows:

Table 1. Specification of Trainer *Kit Installation*

No.	Name	Specification	Image
1	Solar panels	GH Solar 50 Wp: *Polycrystaline,* 50Wp/18.80V/2.66A	
2	Iron frame of solar panel	Pixels x H (2000x50x1000)mm	

No.	Name	Specification	Image
3	Controller Solar Panel	CSP-20A	
4	Inverter	Taffware power inverter NBQ 1000W Power 500W	
5	Power monitor DC	DC 150 A	
6	Power monitor AC	Model P065-100	
7	Battery	KAYABA VRLA 12V 18 AH	

The manufacturing and testing process *of the* solar panel installation kit trainer is shown in the flowchart Figure 1. Testing data collection was carried out from 3 – 20 September 2025. The intensity of solar radiation was measured with the Lux meter UT383 BT from 08.00 to 16.00 WITA. Time, current and voltage are displayed in the *display* on the *Solar Panel Controller* used. Data recording is carried out by connecting manual recording, video recording and photos. Figure 2 shows *the experimental setup* of the 50 *Wp capacity solar panel installation kit trainer* tool.

Meanwhile, testing this *trainer kit* is carried out based on *the true outdoor experimental method*. So there are several research variables, namely: independent variables (solar radiation), bound variables (voltage and current), controlled variables (location, time, and capacity of solar panels).

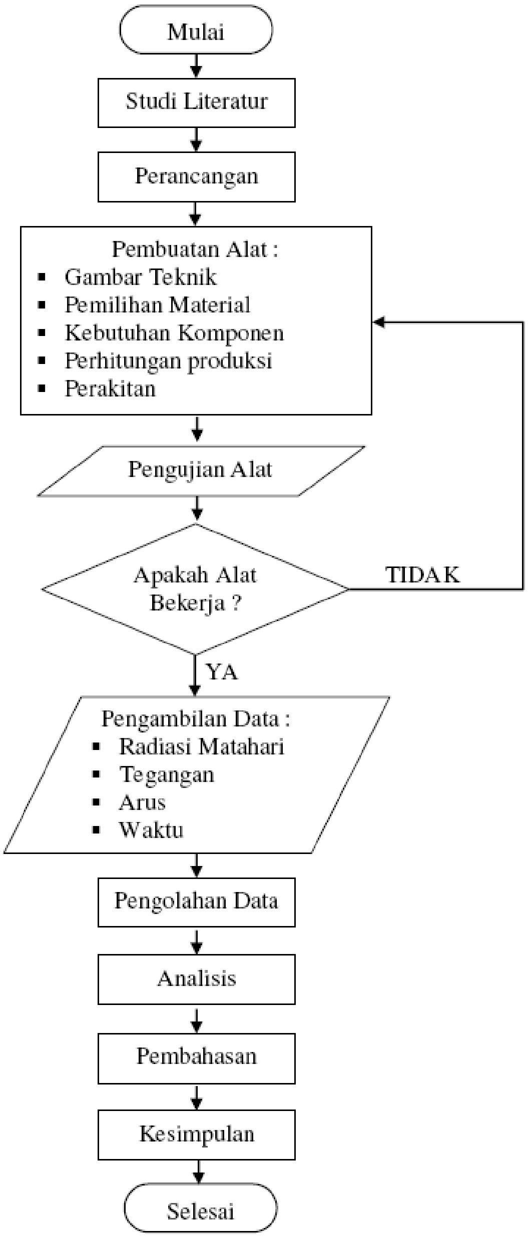

Figure 1. Research Flow Diagram

Figure 2. *Experimental setup* testing *trainer kit*

RESULTS AND DISCUSSION

The test used a 50WP polycrystalline type solar panel with a 15-degree tilt in a vertical plane using a 100 watt AC lamp load.

Solar panel testing while charging

Table 2. Data of test results dated September 11, 2025 when charging the battery

Time (WITA)	Light Intensity (Lux)	Temperature (Celsius)	Weather conditions	Panel Voltage (Volts)	Battery Voltage (Volts)
08.00	69710	27	Sunny, Hot	24,67	12,6
08.30	70130	29	Sunny, Hot	24,28	12,5
09.00	93010	30	Sunny, Hot	24,29	12,6
09.30	11540	31	Sunny, Hot	24,22	12,7
10.00	12800	31	Sunny, Hot	24,25	12,8
10.30	37970	32	Sunny, Hot	24,16	13
11.00	13890	32	Sunny, Hot	24,22	13,2
11.35	14050	32	Sunny, Hot	24,2	13,2

Solar panels receive the amount of light intensity value produced from sunlight in the form of photon energy that is not fully absorbed, some of the energy is reflected depending on the fervance of the photon and the amount of energy needed for the release of electrons from the bond of sunlight intensity to the voltage of the solar panel. In the collection of polycrystalline solar panel data , a test was carried out for 8 hours, showing that the intensity of light tends to decrease due to uncertain weather factors, wind gusts and clouds. In hot and sunny weather conditions, the battery charging process is fully charged at 11.35 WITA, so it takes 3.5 hours to charge.

Testing of solar panels during discharge

Table 3. Data of test results dated September 11, 2025 at the time of loading

Time (WITA)	IDC	VDC	PDC	IAC	VAC	PAV (kWh)
14.15	9,96	11,97	110	223	0,43	0,01
14.30	9,36	11,74	109	223	0,43	0,01
14.45	9,09	11,49	103	219	0,43	0,01
15.00	8,78	11,12	95,7	216	0,42	0,01
15.15	0,26	11,05	0	-	-	

Charging is done by turning on a 100 Watt AC light, and the time it takes until the battery is empty is 1 hour. If calculated based on the capacity of a 12V 18 Ah battery, the battery should last about 2 hours.

CONCLUSION

The solar PV trainer kit has been tested and every component of the solar power plant functions well, so it can be used as a laboratory-scale learning medium. The test results show that solar radiation greatly affects the battery charging process. Data was obtained that the fastest battery charge was for 3.5 hours. Likewise with the charging test, data was obtained that the time required for battery discharge is about 1 hour, which should be calculated based on battery capacity estimated battery discharge is about 2 hours. It is predictable that the addition of measurement control devices also absorbs electrical energy which causes the charging time to be reduced. In addition, the performance of the solar panel can also be determined from the test results, where further development needs to be carried out by increasing the capacity of the solar panel (more than 50 Wp) and other types of batteries, so that trainer kit It can be used for larger feeding capacity.

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