E3S Web of Conferences **43**, 01021 (2018) https://doi.org/10.1051/e3sconf/20184301021
ASTECHNOVA 2017

Research and Development of a Power Monitoring System for the Sustainable Energy Management System Implementation at Green School, Bali, Indonesia

Dita Anggraini[1,2], *Nazrul* Effendy[1,*], *Muhammad* Ihsan Al Hafiz[1], and *Daniel* Ojeda Luviano[2]

[1]Department of Nuclear Engineering and Engineering Physics, Faculty of Engineering, Universitas Gadjah Mada, 55284 Yogyakarta, Indonesia
[2]Green School, 80352 Bali, Indonesia

Abstract. Green School Bali, an international school which provides education for sustainability through entrepreneurial learning and natural environment won the Zayed Future Energy Prize for developing the new renewable energy projects. Currently, Green School is supported by 2 main power sources which come from Indonesian State Electricity Company (PLN) and Photovoltaics (PV) system electricity with power reach 23.1 kW and 21.6 kWp respectively. Both of the sources are distributed to the load based on the manual balancing and daily manual switching, which create the unbalanced load and high power loss. The key to achieving sustainable energy management is the availability of accurate measurement, recording, and analysis system of the power quality in the whole buildings. To meet the requirement of the sustainable energy management system at Green School, the monitoring system of the power and energy at Green School is developed. This system contains 2 data loggers and an Internet of Things (IoT) platform. The fixed data logger provides routine measurement and recording of power quality at the PLN meter, whereas the portable data logger provides the same function for each electricity panel. The monitoring system and human interface system integrate the intelligent human-machine interface to an Ubidots platform and completed with online and offline data storage. This system is useful for supporting the sustainable energy management goal of Green School and the daily energy practitioner's work with providing a proper advance power monitoring system that has low cost and compatible with Green School system's demand. This project will also be used as a platform and teaching tool for students to develop similar projects and learn about IoT and cloud-based monitoring solutions with other measurements in the classroom.

1 Introduction

Green School is an international school which is located in Jalan Raya Sibang Kaja, Banjar Saren, Abiansemal, Kabupaten Badung, Bali, Indonesia and it provides education for sustainability through community-integration, entrepreneurial learning in a natural wall less environment [1]. Green School has specific characteristics of green building model such as no wall in the buildings, no air conditioning except for several rooms, low current system, and goals to implement sustainable energy solutions. The existing main power sources at Green School come from a mix of the public PLN grid and Photovoltaics (PV) system electricity. The available grid power is 23.1 kW and the PV system has 21.6 kWP capability. Both of the sources are switched daily with manual switching and balancing. Due to the inaccurate switching and balancing processes at Green School, it is estimated that 40% of the available PV power is not used. Although the majorities wiring systems of Green School are in 3-phase, several buildings still use separate single phase. The unbalance system will affect not only the harmonic distortion but also can cause the electrical equipment damage. To attain efficient power management, synchronization of the power is needed between the renewable energy and PLN grid based [2]. Green School won the Zayed Future Energy Prize from Ruler of Abu Dhabi and Founding Father of the United Arab Emirates, Sheikh Zayed bin Sultan Al Nahyan at the beginning of 2017. With this funding, Green School receives a 100,000 USD funding to create the sustainable renewable energy system and energy hub at Green School. This renewable project has been named as Operation Rain or Shine (OROS) Project. To achieve the project Green School also created collaboration with TH Köln University and Engineering Studio in Germany and Universitas Gadjah Mada to create the learning experience opportunity for the students in conjunction with the technical development. During this project, Green School will be expanding the renewable energy contribution to the school and environment, also build an energy hub which can be the energy and related technologies center at the school.

One of the key goals of the OROS project is to implement the sustainable energy management system at Green School. To support the sustainable energy management system, an instrument system that can

* Corresponding author: nazrul@ugm.ac.id

measure the required parameters and provide data storage, backup, visualization, and analysis is required and the basis of this paper. Smart monitoring is used to provide an efficient energy management for sustainable and energy-efficient building [3]. In this paper, the design, assembly, evaluation and implementation of a monitoring system of the PLN power and usage in Green School is discussed. The development of this monitoring system includes hardware, software and web-based monitoring and is aimed to achieve the sustainable energy management system implementation at Green School, Bali, Indonesia.

2 Methodology

This research is aimed to build the instruments that can provide the measurement of power quality at Green School, the data storage system, and the visualization platform to facilitate the sustainable energy management process. To collect the information and theoretical background, literature study about power quality in a building is conducted by the authors. The development of hardware and monitoring website will be conducted with quantitative research methods and supported by experiment and participant observation. This project is located at Green School, Jalan Raya Sibangkaja, Banjar Saren, Abiansemal, Badung Regency, Bali, Indonesia. All of the project cost is funded by OROS Project and should be inherited into Green School's students learning activities.

3.1 Literature Study

3.1.1 Power Quality in a Building

There are several international standards which define the power or voltage quality parameters. The IEEE Standard Definitions[1] defined the power measurement when the voltage and current are not sinusoidal, when the energy is dissipated when the load is unbalanced and when the voltage is asymmetric. The standard power resolution has the key concept which is the separation of the fundamental components of voltage and current from the entire of the harmonics components. It can improve the measurement quality of the instrument. The IEEE Trial-Use Standard gave a great explanation of the power quality parameters. In order to measure the 3-phase current into separated 1 phase current system, the system in each phase is assumed to be single-phase sinusoidal.

A sinusoidal voltage source can be represented as:

$$v = \sqrt{2}V sin(\omega t) \tag{1}$$

If a linear load is supplied, will produce a sinusoidal current of:

$$i = \sqrt{2}I sin(\omega t - \theta) \tag{2}$$

With *V* is the Root Mean Squared (RMS) value of the voltage (*V*), *I* is the RMS value of the current (A), ω is the angular frequency or $2\pi f$ (rad/s), f is the frequency (Hz), θ is the phase angle (rad), and *t* is the time (s). The instantaneous power *p* is given by:

$$p = p_a + p_q \tag{3}$$

$$p_a = P[1 - \cos(2\omega t)] \tag{4}$$

$$p_q = -Q\sin(2\omega t) \tag{5}$$

$$P = VIcos\theta \tag{6}$$

$$Q = VIsin\theta \tag{7}$$

Power on the system consists of 3 kinds of power, the apparent power S in VA, the active power P in W, and the reactive power (Q) in var.

- *Apparent Power (S)*

The apparent power (S) is the power that we can measure it with common measurement device. The apparent power S is the product of the RMS voltage and the RMS current. The equation can be shown as follows:

$$S = VI \tag{8}$$

$$S = \sqrt{P^2 + Q^2} \tag{9}$$

- *Active Power (P)*

The active power (*P*) is the average value of the instantaneous power that obtained during the observation time interval from τ to τ + kT. Where:

$$P = \frac{1}{kT}\int_{\tau}^{\tau+kT} pdt \tag{10}$$

$$T = \frac{1}{f} \tag{11}$$

Where T is the cycle or period (s). The active power (*P*) can be described with the following equation:

$$P = VIcos\theta \tag{12}$$

.

- *Reactive Power (Q)*

The reactive power (Q) can be obtained by measuring the amplitude of the oscillating instantaneous power p_q.

$$Q = VIsin\theta \tag{13}$$

If the load is inductive then $Q>0$, but if the load is capacitive, then $Q<0$.

At Greenschool Bali there are very few inductive loads, nearly all loads are simple resistive loads. For this

 https://doi.org/10.1051/e3sconf/20184301021

project, it has been decided to measure only the active power based upon current measurement assuming a stable grid voltage of 220VAC.

3.2 Green School's Energy System

Green School has 2 main electricity sources, those are PLN (Indonesian government-owned corporation of the national electricity) and Photovoltaics (PV) system. The main PLN power at Green School is 35 Ampere, 220 Volt with 23,100 Watt power. The PV system contains 6 arrays with 18 panels and produces 3 phase AC power. Each panel has 200 Watt capacity, therefore the total PV system's capacity at Green School is 21,600 Watt. The PV energy is stored in a 72 kWh battery bank. Green School also had a micro hydro system (Vortex) that operated from October 21, 2016, until December 20, 2016. After a major flooding event this system was destroyed and cannot operate anymore. During 2 months operation, the vortex system produced only 761watts of average power. This system is currently under rebuild with a goal to achieve more than 8kW of power. Based on the current inventory data, Green School has 90 kW potential loads from all installed equipment, with measured daily loads reaching 44 kW while the average daily usage is 300 kWh. The Green School's energy profile can be shown in Figure 1.

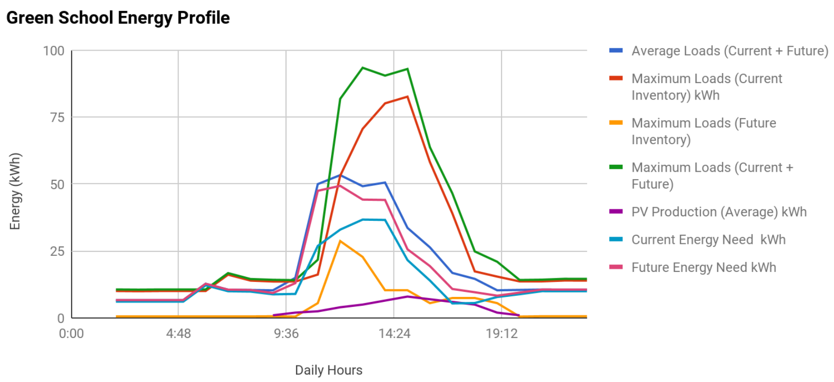


Fig. 1. Green School Daily Energy Profile [6]

Green School electricity circuit cabling is predominantly 3 phase (Phase-R, Phase-S, and Phase-T) system except for a few buildings connected as single phase. There are 30 electricity panels at Green School which distribute the PLN and solar system's electricity around Green School. The biggest problem of the 3 phase electrical system is the manual balancing. Currently, the manual balancing is only conducted in the main PLN metering by Green School's maintenance team and creates an unbalanced load resulting in inefficient use of the PV power. Therefore, the sustainable energy management system should be developed at Green School.

3.3 System Requirements

The monitoring system which contains 2 data loggers and an IoT dashboard are designed with specific requirements from Green School, Bali, Indonesia. Appropriate with the information in the introduction, Green School has 2 main power sources, the PLN and PV system. The PV system at Green School consists of 6 sets of 18 panel-arrays with 200 W capacity per panel.

The maximum PV power is 21,600 W. Green School has average of 300 kWh daily usage.

The monitoring system consists of two data loggers linked to an IoT server delivering a dashboard to the users. There is one fixed data logger and one portable data logger developed for this project. The fixed data logger is implemented on the main PLN meter, whereas the portable data logger will be able to do remote measurement at each distribution panel. Currently, there are 30 building and distribution panels at Green School. The data loggers utilize clamp type current sensors and are designed to support 24/7 continuous monitoring with 15 minutes default time interval for each-recording. Although the default is 15 minutes, the recording interval is changeable if required.

For the General User Interface (GUI) the data loggers use intelligent Nextion HMI TFT Human Machine Interfaces. The measurement result is displayed on the Nextion screen, and transferred to the cloud in the Ubidots platform. Ubidots is Internet of Things (IoT) Host specializing in hardware and software development. Ubidots application enablement platform effortlessly integrates device production, cloud computing, and deployment[2]. Both the portable and fixed data loggers have two current measurement ranges and sensors. For the fixed data logger, the low current range is 0-30 A and the high current range is 0-100 A. For the portable data logger, the low current range is 0-10 A and the high current range is 0-30 A. The lower current range will have higher sensitivity, the utilization will depend on the user's requirements.

3.4 Overall Monitoring System Design

The power monitoring system at Green School is proposed to provide the more flexible, reliable, and economical power monitoring system. This system is the part of the evolution from metering to monitoring on the energy management system. The classification of the power measurement system according to their objectives can be shown as follows:

Table 1. Classification of the Power Measurement System[3]

Group	Objective	Measurement
Meter	Instantaneous	V,I,P
Analyzer	Periodic, Reactive	V,I,P, harmonics, waveform, event
Monitor	Continuous, Proactive	Above contents+statistis+indices

The proposed system is developed to continuously measures the current and power at from PLN Grid at Green School and the each building consumption and provide the statistic and indices. Appropriate for the previous discussion about system requirement, the monitoring system of power quality at Green School consists of 2 data loggers and 1 monitoring website. The simple diagram of the system design can be shown as follows:

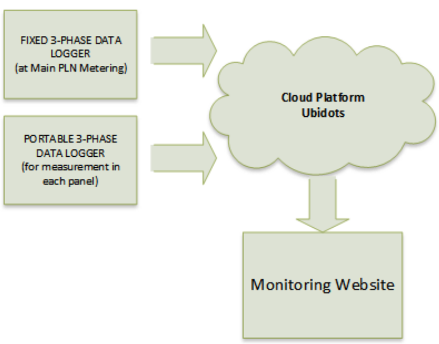


Fig. 2. Green School's power quality monitoring system design

The hardware development using Arduino Mega 2560 and interactive Human Machine Interface display Nextion 3.2″ . The hardware systems were selected to achieve complex connections and codes, Arduino Mega 2560 is used for the complex projects and larger space for the sketch. Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button[4]. Both of the data loggers use the Nextion NX4024T032-3.2" HMI TFT Intelligent LCD Touch Display Module. The nextion HMI TFT facilitates the development of an analog touch screen user interface with programmable function buttons. It facilitates string instructions, assigns values on run time and provides the automatic updates for the editor and firmware[5]. The IoT platform that used for this project is Ubidots. Ubidots is an IoT Hosting Service with expertise specializing in hardware and software development which enables the platform to effortlessly integrate device production, cloud computing, and deployment[2]. The clear explanation about each system will be discussed in the following section:

3.4.1 Fixed 3-Phase Data Logger

The fixed 3-phase data logger is located in the main grid meter at Green School which comes from PLN source. This fixed data logger provides automatic recording of the current and power measurement of each phase with the adjustable time interval. The default of the time interval is 15 minutes and 5 seconds for the testing mode. This hardware consists of 3 Current Transformers (CTs) which connected into microprocessor through signal conditioning. As the Greenschool loads are mainly resistive loads with few rotating machines it was decided to measure only the current and infer no power factor loss. Two types pf CT have been selected: 3 SCT-013-030 with current range 0-30 A and 3 SCT-013-000 with current range 0-100, one sensor for each phase. A Nextion NX4024T032-3.2" LCD is used for the interactive human interface and coded with the Nextion editor. The recorded data will appear in real-time on the Nextion LCD display and be automatically recorded on the IoT platform. This device will calculate 1 second RMS power values, average the power over the recording interval and record average and peak power for each time interval. The values than will appear on the LCD every time interval loop and will be automatically clouded into the IoT platform. The data is also stored into an SD card for backup. The electrical circuit diagram of the fixed 3-phase data logger can be shown in the following figure 3:

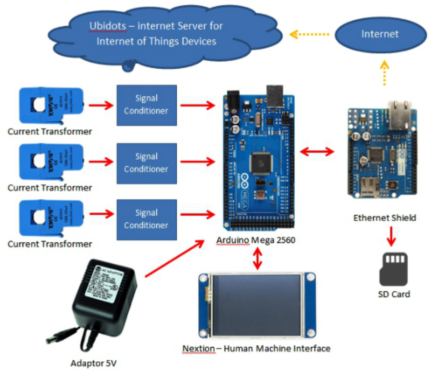


Fig. 3. System diagram of the fixed 3-phase data logger

The fixed 3-phase data logger is completed with 2 different ranges current transformers which are 0-30 A and 0-100 A. The default implemented CTs are the 0-100 A as the current at the PLN meter has been observed to fluctuate up to 35 A. The internet connection for this device is supported by the wired LAN cable connection from Green School's IT team to support a robust internet connection for the fixed system.

3.4.2 Portable 3-Phase Data Logger

The portable 3-phase data logger has the same concept with the fixed 3-phase data logger but has more features.

This data logger enables the remote measurement of RMS current and RMS power of each phase at each electricity panel. The portable 3-phase data logger uses the Arduino Mega 2560 as the microprocessor and Nextion NX4024T032-3.2" HMI TFT Intelligent LCD Touch Display Module as the interactive UI. Through the Nextion HMI TFT module, the users will be able to set the current range (low: 0-10 A or high: 0-30 A), recording duration, recording timer, and panel number. At Green School, there are 30 electricity panels which have the different storage system identification on this device, this device will provide real-time measurement and data on every electricity panel. Similar with the fixed 3-phase data logger, the portable 3-phase data logger will measure average and peak power for each time interval. The values than will appear on the LCD every time interval loop and will be automatically clouded into the IoT platform. The data also stored into an SD card for backup. This device is powered by a LiPo rechargeable battery of 1200 mAh for the power source and Arduino Wi-Fi Shield for the internet connection. This device uses the Wi-Fi connection at Green School for communication. The electrical circuit diagram of the portable 3-phase data logger can be shown as follows:

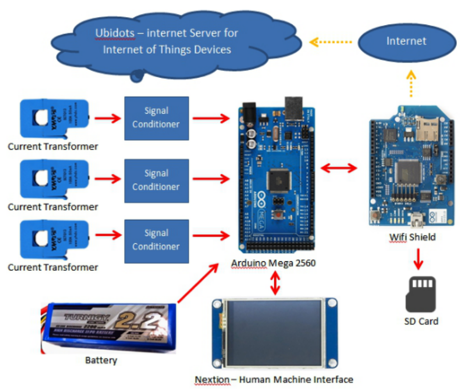


Fig. 4. System diagram of the portable 3-phase data logger

3.4.3 Monitoring Website

The Green School monitoring website enables the real time monitoring of current and power values on each phase and can be accessed by all levels of Green School community. The monitoring website actually is an IoT platform hosted by Ubidots. Ubidots is not only a ready use IoT platform that can accelerate the hardware and software development, but also has several useful features such as the live dashboard, proven device libraries, time series storage and playback, trigger events, math and statistical engine, multi protocols and comprehensive API. Ubidots supports the most general protocols for IoT such as HTTP and MQTT, it can securely clouding the data with the utilization of a token-based authentication and an optional HTTPS/SSL encryption layer, where it can remain in renowned cloud providers[2]. This website enable the user to see a live dashboard of recorded data, arrange and analyze the raw recorded data to see the average, sum, and other arithmetic calculation. Also the platform provides the capability to download the csv file source of the raw data. This monitoring system also provides different statistical graphs that can help the energy practitioners at Green School to analyze the energy condition.

4 Results and Discussion

4.1 Green School's Existing Energy Performance Analysis

The total energy yield of the PV system from 2012-2017 can be shown as follows:

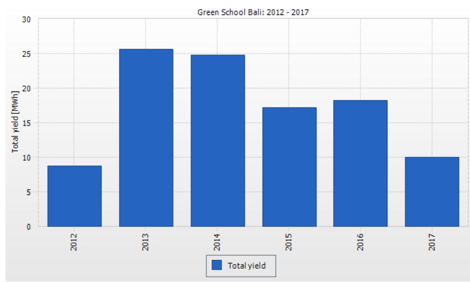


Fig. 5. Total yield of the PVs farms[6]

From the following picture, it can be shown that the PV system's performance is decreasing from 2013 till 2017. This condition can happen because of several possible conditions such as climate, shading, or improper energy management system. The big problem on the energy management at Green School is the manual switching between PLN electricity and the PV system electricity production. Both sources are connected into a Master Distribution Panel (MDP) and divided into seven 3-phase switching relays. The 7 switches allow the distribution of electricity into all Green School's buildings. Every day, the maintenance team will review the PV production and monitor the battery percentage. Then the maintenance team will do select switching between PLN and PV electricity manually. On the weekend commonly there is no body that will do the switching so the PV power on the weekend is unused [6]. This creates a big power loss and has the potential to damage the batteries of the PV system if switches are let connected. In 2013 at the beginning of the PV system implementation PV provided for 35% of Greenschool power needs as follows:

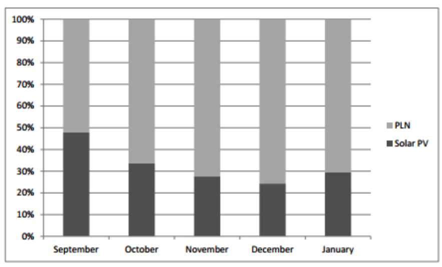


Fig. 6. Green School's Energy Consumption 2013[7]

Whereas the data from the last energy audit shows that the contribution of the renewable energy system is decreased to less than 20%. It is clearly represented by the following data:

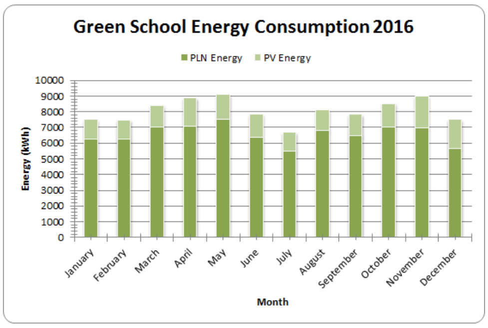


Fig. 7. Green School's Energy Consumption 2016[6]

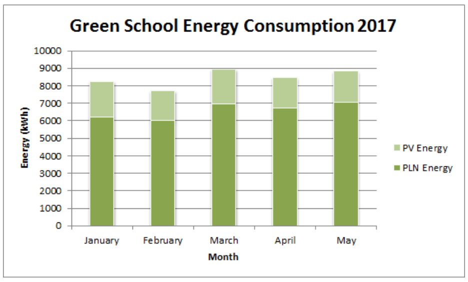


Fig. 8. Green School's Energy Consumption 2017[6]

Based on this data it is important for Greenschool to focus on improving the amount and use of renewable energy. A better energy management system is extremely important to improve the renewable energy system performance, reduce the energy cost and carbon footprint, and increase the positive impact of energy efficiency on the society and environment.

4.2 The Sustainable Energy Management System Goal at Green School

Currently, the sustainable energy management topics are concerned to the rising costs, energy efficiency and environmental impact in energy generation, distribution, management and usage. The conditions make the innovation on the energy management system is needed. On this project, Green School developing a team of dedicated scientists, engineers, practitioners, researchers, and students to make the energy cleaner, more reliable, more efficient, more secure and gives the positive impacts around Green School.

Energy consumption is a dominant component of the organization's sustainability cost structure. In case of the increasing energy cost, the energy efficiency currently becomes an important thing that should be realigned to accommodate the volatile energy prices in the future. Information technology, advanced automation, and the trained practices for energy management are the key factor for the success of sustainable energy management[8].Obtaining the visibility into energy reduction goals and empowerment of the workers at every level in the organization will bring positive impacts on the energy consumption, therefore the education of energy efficiency should be given to all level of students and staffs of Green School.

The first step of creating the sustainable energy management is the energy audit. Energy audit provides a tool that enables an institution to track the progress of the energy management program. It can identify which is the most inefficient equipment or process, and how they affect the energy performance in an institution [8]. The routine energy audit is one of the goals that must be achieved by Green School. By performing the routine energy audit, it will provide a good assessment of the effectiveness of energy management programs compare to past performance.

Siemens create the strategies for sustainable energy management which can be summarized in Table 1. A monitoring website is important on the energy management system to enable the workers at an organization to monitor their energy consumption in a real time manner, therefore they can evaluate their usage and improve their management system. At Green School, a monitoring system of current and power in each phase also important for the balancing and switching process. On the previous discussion, the energy system at Green School is already discussed and it is very clear that the balancing and switching process of Green School's electricity sources are conducted manually.

Table 2. Strategies for Sustainable Energy Management [8]

Domain	Key Attributes
People	- Management commitment and Resolve - Corporate energy coordinator which directs and coordinates the energy management activities across the sources - Energy management considered a core competence
Processes	- Energy management initiative in place - Routine energy audit to measure the progress against a benchmark - The capital projects need to be justified based on energy saving purpose
Technologies	- Investment of Research & Development (R&D) to change the energy generation process and reduce the energy consumption - Electrical automation integrated with process automation systems - Advanced simulation and process control or homegrown application for the energy management -
Information	- Monitoring the processes and equipment to track energy usage and problem areas identification - More granular accounting methods for energy use - Energy prices and energy

 https://doi.org/10.1051/e3sconf/20184301021

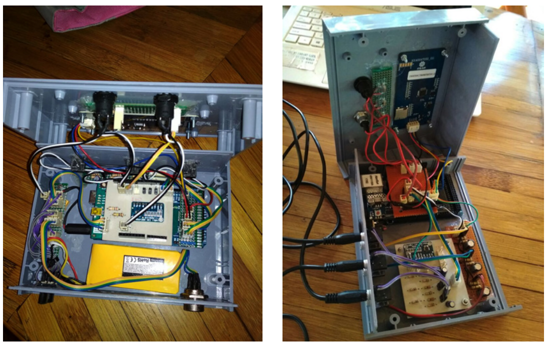
	consumption consistently monitored

At Green School, the sustainable energy management goal is to connect the people, processes, technologies, and information to create a system that can cover the followings steps:

- Has the standard method of energy efficiency which economically feasible for Green School
- Developed the energy efficient buildings both for the existing buildings and the future buildings.
- Perform the routine energy audit to find the equilibrium between the present and future energy necessity and demand.
- Maximize the usage of clean energy and high-efficiency energy conversion which give positive impacts to the environment.
- Develop the short and long term high-efficiency energy storage.

To start all the goals, the developed power monitoring system is proposed to provide the real-time measurement devices that can help the realization of the routine energy audit and support the decision making for the energy practitioners at Green School. This proposed system will provide the continuous data availability, statistical analysis, and real-time monitoring dashboard.

4.2 Power Monitoring System Implementation at Green School



(a) (b)

Fig. 9. a. Portable data logger electrical circuit b. Fixed data logger electrical circuit

On September 3rd, 2017 this Power Quality Monitoring System was installed at Green School, Bali. The fixed 3-phase data logger is located beside the main grid meter (PLN meter) and the system is successfully recording data and clouds them into the IoT platform. The electrical circuit physical forms of both fixed and portable 3-phase data loggers are shown on the figure 9. The fixed 3-phase data logger is connected beside the PLN meter and the clamp sensors are calibrated against a commercial clamp meter as shown in the figure 10. The Nextion design examples are shown on the figure 11 and the real display snapshot of the Nextion at the device is shown in the figure 12.

(a) (b)

Fig. 10. a. Portable data logger electrical circuit b. Fixed data logger electrical circuit

The HMI provides the interactive way for the users to monitor the system and give control and feedbacks to the energy management system. One of the excellences of Nextion display is its ability to create a user interface without coding but more based on design. With importing the image files into the Nextion Editor software, a developer can easily design their interface display. In figure 11, the design example of user interface is shown and in figure 12 the real display of the Nextion is shown. From those pictures, it can be seen that what we get on the display is similar with what we design on the editor.

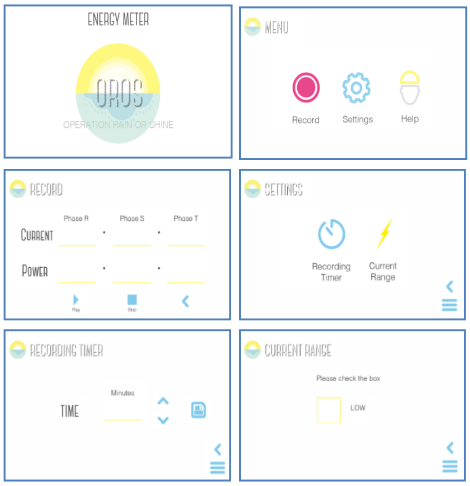


Fig. 11. Nextion display design examples

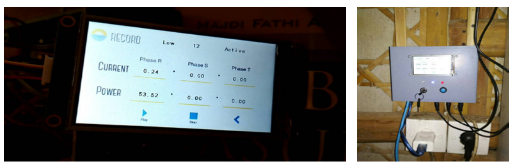


Fig. 12. The Nextion display

After the data is recorded, the data is automatically uploaded into the IoT platform. The Green School's IoT server login can be shown as follows figure 13:

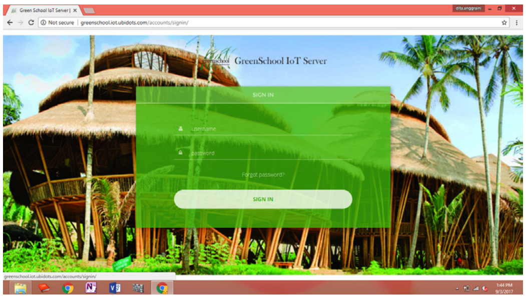


Fig. 13. Green School's IoT system server login

The Green School's IoT server dashboard will be the real-time monitoring system that can be accessed by the society at Green School, the device administration will be managed by the IT team and energy audit team. The examples of the recorded data dashboard are shown on the following figure 14 and figure 15:

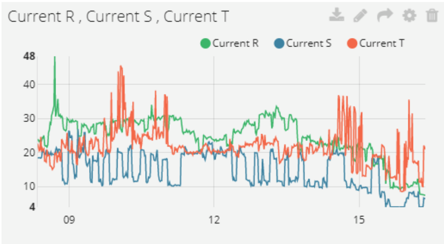


Fig. 14. Current Ubidots Dashboard-Every Minutes Recording

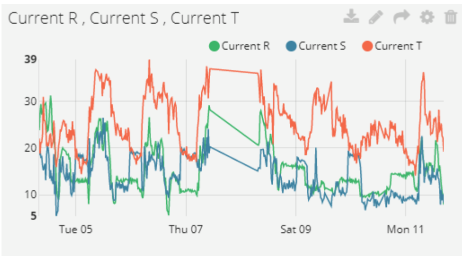


Fig. 15. Current Ubidots Dashboard-Hourly Recording

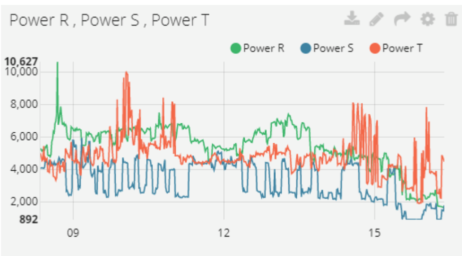


Fig. 16. Power Ubidots Dashboard-Every Minutes Recording

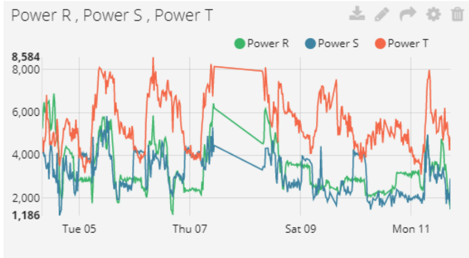


Fig. 17. Power Ubidots Dashboard-Hourly Recording

From the power value per phase, the total power that consumed from PLN grid can be calculated by adding all the power from phase-R, phase-S, and phase-T. The total power real-time data visualization can be shown as follows:

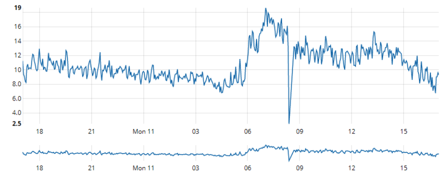


Fig. 18. Hourly Total Power Data (kW)

Fig. 19. Daily Total Power Data (kW)

The energy data every hour can be shown in the following picture:

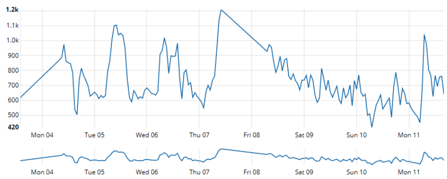


Fig. 20. Hourly Energy from PLM Grid Data Visualization (kWh)

To support the proper balancing method, the peak current measurement is also important. The data of the peak current from the electricity grid can be shown as follows:

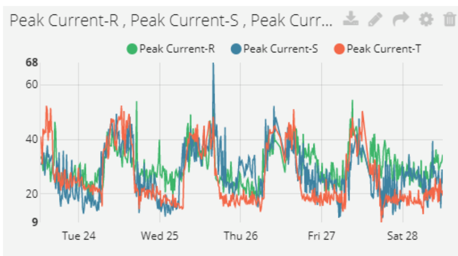


Fig. 21. Peak Current Data (Ampere)

Based on the pictures, the real-time current and power on each phase can be obtained and the energy practitioners at Green School can get the better understanding of the energy performance at Green School. From the data, it can be concluded that the electricity load at Green School is a relatively unbalanced load system. The data from the monitoring system shows that the average current on the phase-R, S, and T are 24.46 A, 14.80 A and 21.74 A respectively. The average power on phase R, S, and T are 5,374 watt, 3,253 watt and 4,784 watt respectively. The data shows that the fluctuation of the current in each phase is not balance each other. From figure 21, it can be concluded that the difference between 1 phase to the other phases is quite big. This information should be one consideration for the future expansion of existing electrical system performance. For the future building and inventory, the load should be distributed equally. Likewise if there are any projects that need the additional equipment, with this real time data the workers can analyze the energy condition and have the good understanding to choose where they can connect the equipment to approach more balance load system. The full picture of the Green School's IoT system dashboard is shown in the figure 21.

Having a monitoring platform through a website based system gain several benefits compare than using software. The following benefits can be got through Ubidots application:

- Open system architecture support: Ubidots Support the most general protocols for IoT (such as HTTP and MQTT). It supports several programming language such as Python to accelerate the application development time. From the API authentication, to data transport and storage, it adheres to web security best practices. Provides the user-friendly and consistent HMI: with internet based platform especially Ubidots service, the users do not need to learn the difficult commands for any developed application.
- Good scale ability:[9] it can be developed gradually. Ubidots also provides the system expansion and the addition of the organizations and devices.
- Time series storage and playback: the backend is a time series that can ingest or retrieve the millions of data-points in short time, helping the developer to scale the application easily.
- Math and Statistical Engine: It allows statistical operation, will give benefit to the data processing.
- Provide the ready trigger events: Create SMS, Email, Telegram or Web hook alerts based on your sensor data that can trigger thousands of events, even if they happen at the same time[2].

5 Conclusion

5.1 Summary of Findings

On this paper, the power monitoring system as the part or OROS project is described. This monitoring system will be useful for supporting the sustainable energy management goal of Green School and the daily energy practitioner's work at Green School. Since Green School is an environmentally conscious school which consumes relatively low energy, this project provides the proper advance power quality monitoring system which is suitable with Green School system's demand and has low cost. The monitoring system is developed by the reliable microprocessors and sensor devices which are connected into advance usable human interface and IoT platform. More than that, this project also gives place for the students learning experience by provide new

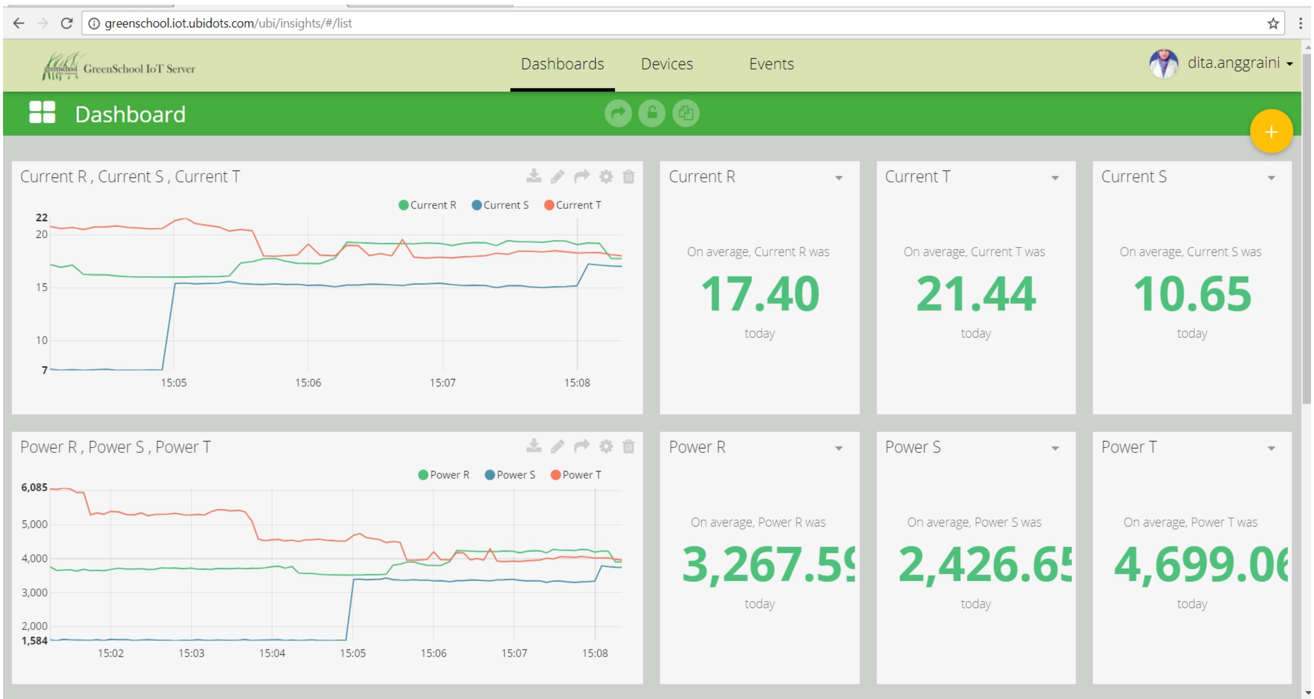


Fig. 22. Green School's Monitoring System Dashboard

technologies that can be easily adopted and developed. This system has been used to integrate the technology and human sources to support and improve a regular energy audit and sustainable energy management system. With the implementation, the proper data storage, visualization, and analysis are available for further development.

5.2 Future Development Plan

The power quality monitoring system should be improved by better calibration and testing process and improved analysis of the sampling and statistical calculations. The improved selection of RMS, average, or peak sampling that will give better results. Management of the data set and handling of internet outages.

This research was fully funded by Operation Rain or Shine (OROS) Project, Green School, Bali, Indonesia. The authors are thankful to the OROS team, Green School's society, Engineering Studio Berlin, and Green School's Maintenance Team who provided expertise, materials, learning opportunity, knowledge and support for this research. The authors also like to show the gratitude to Tony Vovers for the guidance, evaluation, and advices that greatly improved the project and manuscript.

References

1. M. Committee, *IEEE Trial-Use Standard Definitions for the Measurement of Electric Power Quantities Under Sinusoidal , Nonsinusoidal , Balanced*, The Institute of Electrical and Electronics Engineers, Inc., **vol. 40**, no.3. (2000)
2. "Ubidots Official Website." [Online]. Available: https://ubidots.com/.
3. D.-J. Won, I.-Y. Chung, J.-M. Kim, S.-I. Moon, J.-C. Seo, and J.-W. Choe, *Development of power quality monitoring system with central processing scheme*, IEEE Power Eng. Soc. Summer Meet. 2002, **vol. 2**, pp. 915–919 (2002)
4. "Arduino Website." [Online]. Available: https://www.arduino.cc/en/Main/arduinoBoardMega2560/.
5. "Nextion Intelligent Display."
6. D. Anggraini, *Green School's Energy Audit Report*, (2017)
7. Akuo Energy Indonesia, "*Annual review - PV power station*, (2014)
8. A. A. Group, *A Strategic Roadmap for Sustainable Energy Management and Energy Efficiency for Industrial, Commercial, Municipal and Manufacturing Operations*, (2009)
9. R.-C. Leou, Y.-C. Chang, and J.-H. Teng, *A Web-based Power Quality Monitoring System*, **vol. 0**, no. C, pp. 1504–1508 (2001)