ICSTSI 2020
Proceeding ICSTSI 2020 : 21 – 32
ISBN : 978-602-53575-1-0

Development of IoT web box on net metering bidirectional renewable energy for real-time and mobile monitoring

A Rintiasti, I P Wulandari, and A A Suhartono

Baristand Industri Surabaya

E-mails: anekerintiasti@gmail.com, wulanluvspink@gmail.com, aan.baristand@gmail.com

Abstract. Net Metering is a way to trade electricity from new and renewable energy sources, but until now the owner has not been able to monitor production results in real-time, especially the export and import of electrical energy from and to the State Electricity Company. The purpose of this research is to develop a Web Box that can read and send two-way data from the existing KWh Meter to the server via the Internet of Things technology so that it can be monitored on a mobile basis. First, the installation of 2 KWh 1 phase Solar Panel with the AC Coupling method was carried out. The second is to collect data from the KwH meter that is readily available in the market. Third, developing the Web Box communication with Web API. Fourth, the Web box tested using the CISPR32 standard. The results were Web Box used RS485 and python communication to retrieve data from the existing KWH Meter to the Raspi B + microprocessor. The IoT function used wifi to send data to the server via the Web API developed using Code Igniter. Web Box data transmission was performed every 3 seconds. The Web Box has been proven to meet the requirements of the CISPR32 standard. So it can be concluded that Web Box can read bidirectional data from existing KWh Meters and send it to the server through Web API every three seconds so that it can be monitored on mobile basis and meet the requirements of the CISPR32 standard.

1. Introduction

Figure 1 shows how the net measurement works. The customer's renewable power plant generates DC energy then converts it to AC energy with an inverter. On the other hand, the provincial power grid also produces and delivers energy. The excess energy is sent back to the provincial grid and recorded by Bidirectional Meter.

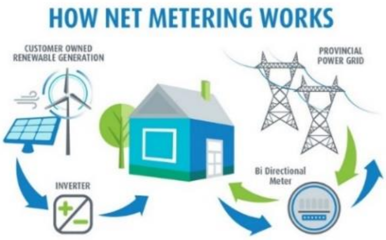


Figure 1. How Net Metering Works.

Net Metering uses a counter meter that can rotate back and forth (bi-directional). The State Electricity Company uses the EXIM (export-import) meter as a term for net metering. The usage surplus is calculated as credit for electricity usage in the following month, with a tariff structure of 65% of the normal price in accordance with the following net metering regulations:

a) Regulation of the Board of Directors of the State Electricity Company number 0733.K / DIR / 2013 concerning Utilization of Electric Energy from Photovoltaics by State Electricity Enterprise Customers.
b) Circular Letter of the Board of Directors of the State Electricity Company number 0009.E / DIR / 2014 concerning Operational Provisions for the Integration of Customer-Owned Photovoltaics into the Electric Power System Area of the State Electric Company.

Systems for controlling, diagnosing and monitoring power consumption using the Raspberry Pi, Arduino Uno, non-invasive AC current sensor and Relay Board 4 channel as an integrated system to control, diagnose and monitor equipment to check its efficiency in power consumption proposed by [1]. An enterprise energy monitoring system application which is based on IoT (Internet of Things) architecture and combines several technologies proposed by [2]. Automated systems that allow monitoring and control of electrical devices connected to the Internet via Wi-Fi are denominated by iPlug [3]. Application of energy monitoring based on IoT stands for a supervising system for solar photovoltaic power generation that can greatly enhance the performance, monitoring, and maintenance of the plant that is presented by [4]. A real-time energy consumption monitoring system was presented for large public buildings, which is beneficial for energy saving and helps to establish the building energy consumption performance evaluation is presented by [5]. Several studies have been conducted that can prove the system can reduce energy consumption by 1030% [6-7]. Tsuyoshi Ueno et al developed a monitoring system that was installed in 10 residences and its effects on energy consumption have been analyzed. Energy consumption is reduced by 12% after system installation and 60% from homes reduces the consumption of power that is used continuously [6].

The results of interviews with the East Java State Electricity Company, currently monitoring of electricity usage is only on the internal side of the State Electricity Company and not on the customer side. Problems will arise when the surplus balance has accumulated enough but cannot be cashed or sold. Especially if the minimum tariff or interconnection fee is still charged. Previous studies have not yet taken KWh meter data from measuring instruments that are already on the market and are plug play and utilize IoT technology.

The purpose of this research is to design net metering that can measure the production and use of electricity bidirectionally that can be monitored mobile. This paper describes the Web Box System, developed by authors, which aims to ensure, autonomously, accurately, and simultaneously, the energy consumption monitoring of energy consumption. The system consists of a low-cost energy monitoring system based on IoT, developed using microprocessor Raspi B+ and use a Wi-Fi connection to the Internet, for storage and availability of monitoring data on a Web portal in real-time. This system is capable to monitor the energy consumption of the KWh Meter Provincial Power Grid, KwH Meter Load, KwH Meter Solar Power Plant connected to it considering the current consumed by the equipment and the mains voltage. Real-time energy monitoring system provides feedback to the consumers, thus the consumer will be able to identify the opportunities to adjust and identify how to conserve energy. This paper presents a real time energy monitoring system that is cost-effective and reliable, it can be used to analyze and evaluate the output voltage or generated energy from a household appliance.

2. Methodology

In figure 2 the methodology is: first, the installation of 2 KWh 1 phase Solar Panel with the AC Coupling method is carried out. The second is to collect data from the KwH meter that is readily available in the market, third, the development of Web Box communication with Web API. Fourth, the Web box tested using the CISPR32 standard.

ICSTSI 2020
Proceeding ICSTSI 2020 : 21 – 32
ISBN : 978-602-53575-1-0

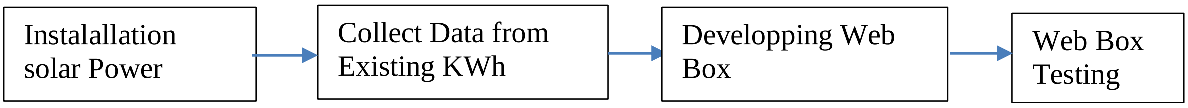


Figure 2. Methodology.

2.1 Installation of solar power plant

The installation of 2 KWh 1 phase Solar Panel Photovoltaic modules are set up with a minimum angle of 10° to obtain a self-cleaning mechanism, especially on rainy days [shown in figure 3]. In the southern hemisphere or below the equator, the photovoltaic module 8 X 280 Wp must face north or 0° [figure 4]. The electricity production from the solar panel will be combined with electricity from the State Electricity Company in the same phase.

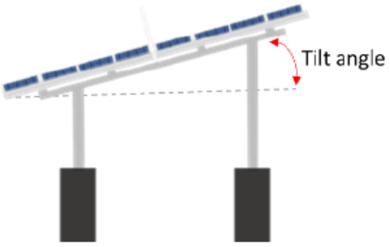


Figure 3. Azimuth Angle.

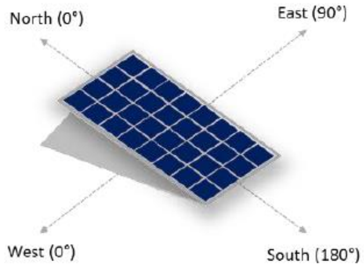


Figure 4. Inclination Angle of Solar Panels.

The way of combining the two power sources is an AC-coupling system that connects the solar module circuit and the State Electricity Company to the AC side via a network inverter [shown in figure 5]. Solar Power Plant will be On-Grid Solar Power Plant.

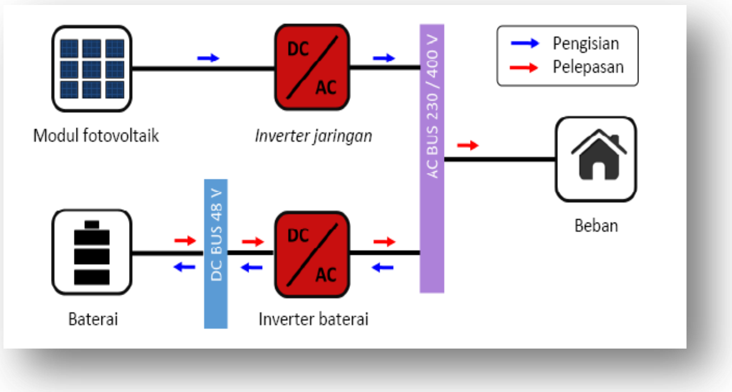


Figure 5. AC Coupling

2.2 *Collect data from existing kWh meter*

A local monitoring system is needed to provide basic information such as instantaneous voltage, current, frequency, power, and total energy flowed to the load. The local monitoring system consists of an energy meter, voltage measurement and current transformer (CT) as input for the meter. Manual inspection is the most reliable way to monitor the system because the operator will check the system directly and report it in the form of a logbook. However, the detailed data that can be obtained from this manual inspection method is limited, making it less profitable for further analysis.

Local monitoring uses KWh meters that are already on the market, most of which are imported products. As shown in figure 6, the renewable energy from power solar plant goes to DC Meter. Then it goes to the inverter to change DC to AC. After that goes to panel AC. In Panel AC we have 3 kinds of KWh Meter: KWh Meter Provincial Power Grid, KwH Meter Load, and KwH Meter Solar Power Plant. On the other hand, electricity from the provincial power grid is imported, the energy goes to the AC Panel as well along with the output from the inverter and makes the AC Coupling. If there is excess energy sent back to the Provincial Electricity Network, it will be recorded in the KWh Provincial Electricity Network as export energy. This KWh Meter has communication using RS485 so that the Web Box gets data from the KWh Meter via a communication cable.

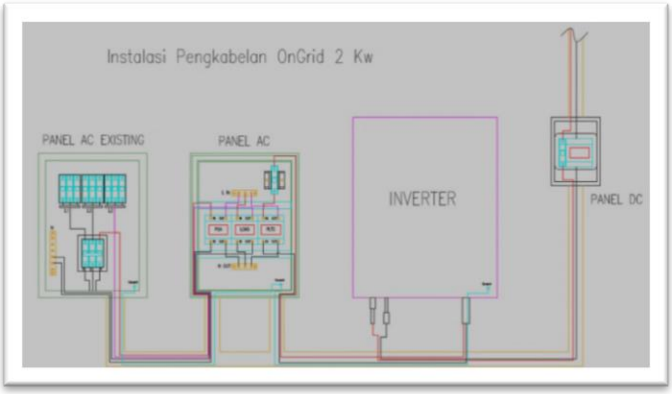


Figure 6. KWh Meter

2.3 Developing web box communication

Web Box Development Methods [shown in figure 7] include: After the Web Box gets data and manages data using Raspi B +, it will be sent to the server using Wi-Fi with an interval of 3 seconds. Data will be forwarded IoT technology into Server. The parameters planned to be monitored are described in table 1.

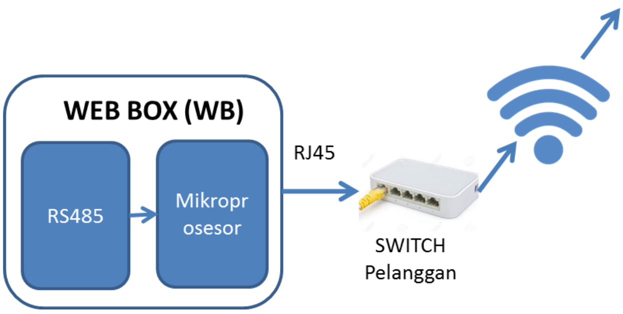


Figure 7. Plan of Web Box Development.

Table 1. Monitoring Parameter.

No	Parameter	Unit	Information
1	Output Voltage of Photovoltaic Modul Circuit	V	DC Production
2	Output Current of Photovoltaic Modul Circuit	A	DC Production
3	Output Voltage Network Inverter	V	AC Production
4	Output Current Network Inverter	A	AC Production
5	Active Energy at Load	KWh	Load
6	Remaining Active Energy / exported to the State	KWh	Export

ICSTSI 2020 | Proceeding ICSTSI 2020 : 21 – 32
ISBN : 978-602-53575-1-0

	Electricity Company		
7	Remaining Reactive Energy / exported to the State Electricity Company	KWh	Export
8	Active energy entering/imports from the State Electricity Company	KWh	Import
9	Reactive energy entering / importing from the State Electricity Company	KWh	Import

Web Box is used to gather energy data passed and stored to a database through cloud-based RESTful API resources. These resources are then used by the mobile web application for displaying real-time and historical energy readings. Remote Monitoring System is the process of monitoring carried out by taking data, Furthermore, the data can be directly visualized and can be accessed from a computer through a browser (Web browser) or through a mobile phone [5].

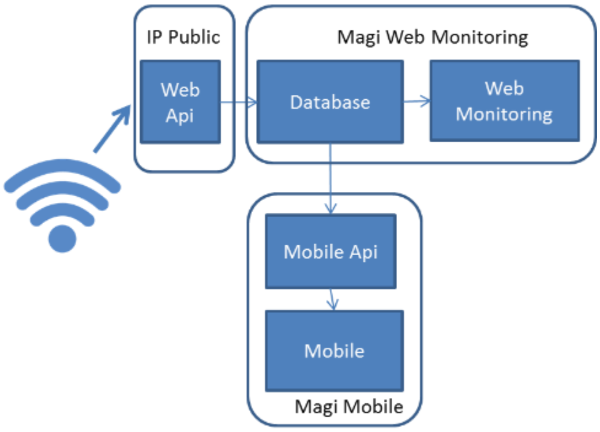


Figure 8. Plan of Monitoring Software Development.

Figure 8 explains the method of developing remote monitoring. Development of web monitoring uses Code Igniter. Monitoring Software itself uses Web API technology so that it can be accessed by customers through many devices. Data from the Web Box is sent via the Rest API which will be saved to the database. Web API can be accessed from various types of media. Web-based monitoring will be developed using Code Igniter. REST (Representational State Transfer) is a standard model of web-based communication architecture.

2.4 Web box testing

After the development process, Web Box will be tested with the CISPR32 standard in the EMC Laboratory Baristand Industri Surabaya. This test is a fulfillment of the regulation of the Ministry of Communication and Information, namely Perdirjen SDPPI Number 3 of 2019 - Technical Requirements for Telecommunications Equipment and or Equipment for Low Power Wide Area. Figure 14 shows the results of radiation testing at a frequency of 30 MHz - 1 GHz.

3. Results and discussion

3.1 Installation of solar power plant

Before installing the solar panels, the selection of load paths is borne by the building panels. With a capacity of 2000 Wp, the burden borne by Solar Power Plants is 2 (two) room air conditioners. Measurements were made using the Ampere Meter tool in accordance with figure 9. As we can see in Figure 13, A x 220 V = 2860 Watt, with 2000 Wp it can be shown that the energy exports and imports are bidirectional.

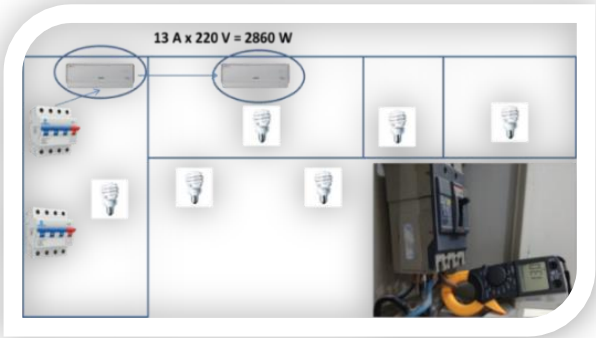


Figure 9. Selection of Load Paths.

Electricity is supplied by two electricity sources such as the State Electricity Company and Solar Power Plants, but this case takes preferably in Solar Power Plants. This load will use the energy source from the Solar Power Plant first, but if there is residual energy that is not used, it will be the energy released and recorded by the KWh meter. During the export process, electricity will be flowed back to another panel above it, which will then be transferred to another panel or other load. The choice of place, building and panel installation process can be seen in Figure 10. The specifications of the panels used are described in table 2.

Figure 10. Panel Installation.

Table 2. Specifications of Solar Panel.

No	Item	Specification
1	Solar Panel	Seraphim 280 Wp – 8pcs
2	Solar Panel Supports	
3	Distribution Board	MCB, PVC white cable, PVC Flexible House
4	Cabling and Accessories	Solar panel cable, inverter cable, grounding cable, MC4
5	Grounding	Copper Rod, Copper ring, Cable clamp

Production solar power plant was shown in table 3. Even though the solar power plant has a capacity of 2000 Wp, what is obtained is not optimal because it can take advantage of many factors such as weather, cloud conditions, etc. and in Surabaya's rating the temperature is above 30°C, while at 25°C.

Table 3. Production Solar Power Plant.

No	Time	DC Meter
1	12.06.2019 13:59	1264 Watt Hour
2	12.06.2019 14.31	1105 watt Hour

ISBN : 978-602-53575-1-0

From the normalized values of current, voltage and power at 25°C, with an increase in temperature, cell current increases slightly, but the voltage drops at a larger rate, leading to the larger drop in the power output. If the cell temperature drops below 25□C, the current drops slightly but the voltage and power increase. In general, up to about 0.5% loss in efficiency per degree Celsius of temperature increase is typical in silicon cells [8]. Figure 11 shows the ideal temperature for silicon cells.

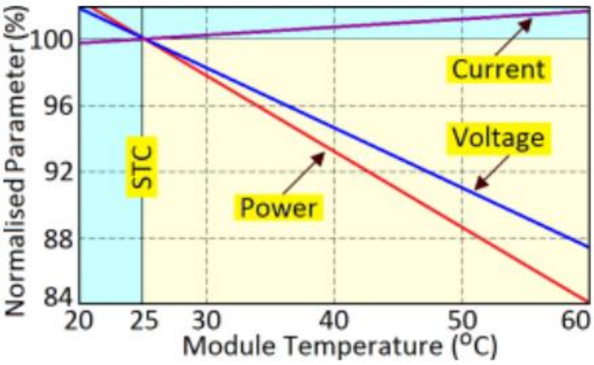


Figure 11. Ideal Temperature for Silicon Cell.

3.2 Collect data from existing kWh meter

Figure 12. Local Monitoring.

Local monitoring has been installed using available equipment existing at the market. 1 is dc meter, 2 is inverter, 3-panel ac, 4-panel ac existing. [shown in figure 12]. The brands and specifications installed are described in table 5.

Table 5. Brand and Specification of Local Monitoring Devices.

No	Item	Specification	Quantity
1	DC Meter		1 pcs
2	Inverter	Solis Mini 2000 4G	1 pcs
3	KwH Meter	Eastron SDM220	2 pcs
4	KwH Meter	Eastron SDM230	1 pcs

After local monitoring has been installed, monitoring of energy production and energy use by this device has been carried out as described in table 6.

Table 6. Local Monitoring Analysis.

No	Time	DC Meter	Inverter	KWh Meter Solar Power Plant
1	12.06.2019 13:59	1264 Watt	1235 Watt	1194 watt
2	12.06.2019 14.31	1105 watt	1076 watt	1037 watt

Based on table 6, it can be seen that the energy produced by solar panel never reach 2000 W. This is because the city of Surabaya is not in optimal conditions for the energy achievement of the Peak Watt Solar Panel and many other factors that affect such as clouds. The energy consumption factor by the sensor must also be considered in the sensor selection. The local monitoring product (Table 6) shows a 1264 Watt DC Meter, when entering the 1235 Watt Inverter, after entering the 1194 Watt Solar Power Plant. It is estimated that the energy consumed is between 3-10 watts per unit meter or inverter.

Figure 12. Web Box Design.

Figure 12 shows the designed Web Box has the following specifications: there are 8 RS485 slots, of which the first 4 slots for Solar Power Plant, monitoring 3 AC sensor values and 1 DC sensor. In addition, there are 4 other slots that are used to monitor the results of the sensor box. Tools for developing webboxe are explained in table 7.

Table 7. Tools for Developing Webbox.

No	Item	Quantity
1	USB to RS485 Serial Converter	1
2	Raspberry Pi 3 B+ New Edition	1
3	MICRO SD CARD V-GeN 8GB Class 10	1

Figure 13. Communication RS485 to Get Data.

Figure 13 use cable to connect KWh meter and Web Box. Every KWh meter has an id to take data. The connection and the data in process inside of Web Box.

3.3 Developing web box communication

The firmware of the Web Box was developed in Raspi 3b + with the algorithm described in the flowchart in Figure 14. Firmware development is processing using python. After Data are taken from the existing KWh Meter, these data are compiled in Json and sent to the server through API.

ISBN : 978-602-53575-1-0

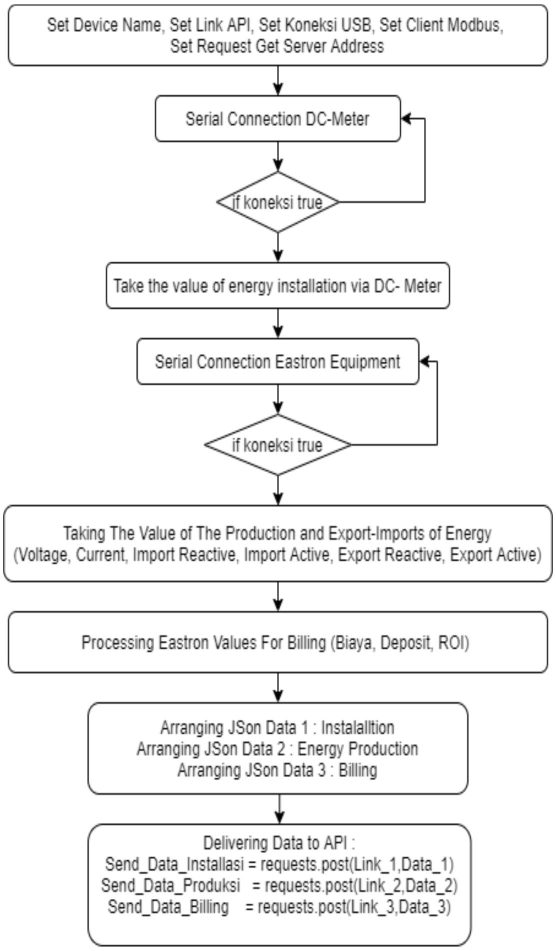
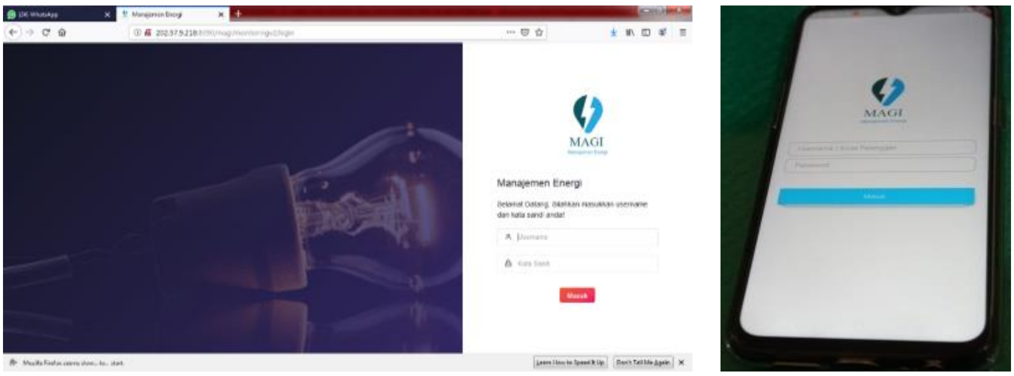


Figure 14. Flowchart Firmware.

In figure 14 also can be seen that data are delivered via the IoT function and RS485 data communication. Data managed using the Rest API is expected to reach many devices and with internet technology can reach all parts of the world. WiFi has a distance range of 22-60 m, whereas internet technology can reach anytime, anywhere and in real time. Remote monitoring can be observed using a website and also by a mobile phone.

The access right of the Customer can monitor the Result of the Installation of Solar Power Plants, Energy Production, and Billing. The menu in the mobile phone application is the same as the web-based application figure 15.



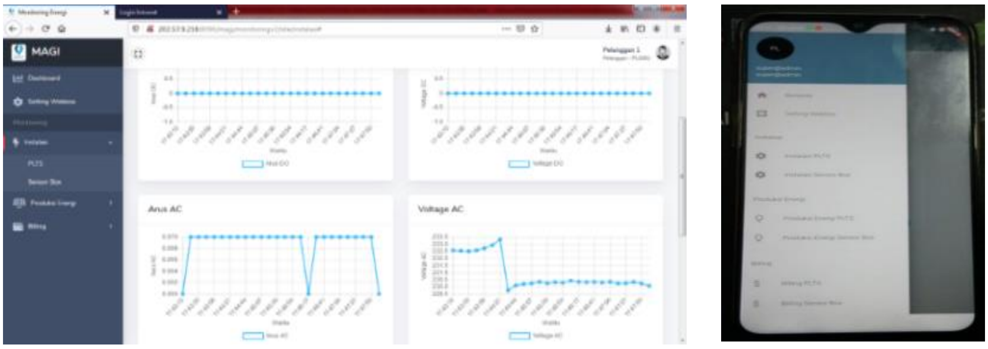


Figure 15. Web Aplication and Mobile Application for Customer.

In the administrator permission level figure 16, it contains : webbox settings, sensor box and customer data.

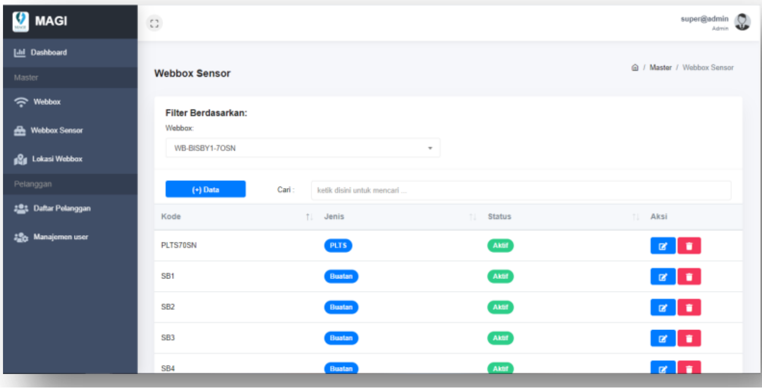


Figure 16. Administrator Permission Level Web Application.

3.4 Web Box Testing

Electromagnetic Compatibility testing has been carried out on the IoT Web Box device. In figure 17 can be seen on the graph that the Quasi Peak value of Radiated Emissions generated by the device is below the red limit line. From the results of these tests, it can be concluded that the product meets the requirements of the CISPR32 standard. Figure 18 shows the conducted test.

The main purpose of this test is to measure how much potential the device has to interfere with the function of other electronic devices in the immediate environment.

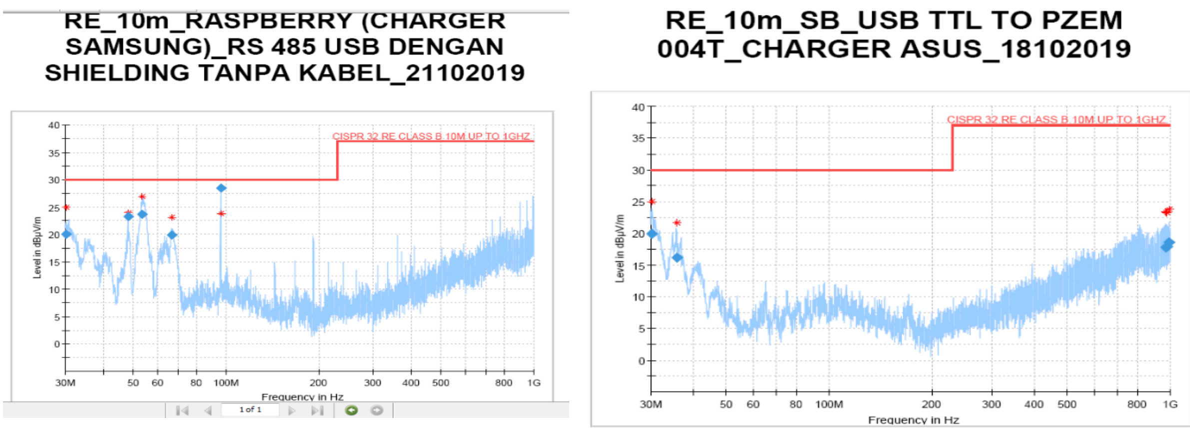


Figure 17. EMC Test Result for Radiated Emission Parameter [freq. 30 MHz – 1 GHz] in 10 m distance of measurement.

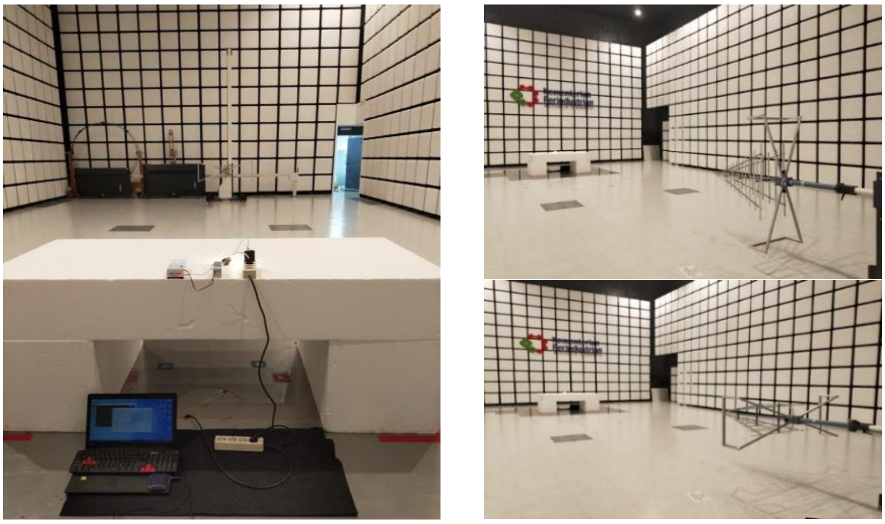


Figure 18. Conducted EMC Test.

4. Conclusion

Solar Power Plant which is carried out using 8 (eight) of 280 Wp solar panels can not produce 2240 Wp but only reach 1600 W maximal because optimal energy produce by the solar cell is 25 Celcius degree. Local monitoring is installed using any tools that are already on the market and they are important things that consist of DC sensors, 3 KWh Meter and inverters. Local monitoring consumes 3-10 watts of energy so that in selecting local monitoring energy consumption needs to be considered. Webbox was developed using Raspi B+ and RS485 communication to get data from the existing KWh Meter. Web Box delivers data every 3 seconds to the server through Rest API to reach many devices and with internet technology can reach all parts of the world. Web Box is tested using Electromagnetic Compatibility testing and results Quasi Peak value of Radiated Emissions graph generated by the device is below the red limit line. From the results of these tests, it can be concluded that the product meets the requirements of the CISPR32 standard.

Acknowledgments
The researchers would like to thank Baristand Industri Surabaya EMC laboratory for the Lab equipment and for letting us operate their laboratory for the conduct of this research.

References

[1] Putra L, Michael, Yudishtira, Kanigoro B 2015 Design and Implementation of Web Based Home Electrical Appliance Monitoring, Diagnosing, and Controlling System. International Conference on Computer Science and Computational Intelligence (ICCSCI 2015), Procedia Computer Science 59(2015) 34 – 44

[2] Luan H, Leng J, 2016 Design of energy monitoring system based on IOT. In: Chinese Control and Decision Conference (CCDC) 6785–88

[3] Marques G and Pitarma R 2017 Monitoring Energy Consumption System to Improve Energy Efficiency, Polytechnic Institute of Guarda, Unit for Inland Developement, Advances in Intelligent Systems and Computing March 2017

[4] Adhya S, Saha D, Das A, Jana J, Saha H 2016 An IoT based smart solar photovoltaic remote monitoring and control unit, in 2nd International Conference on Control, Instrumentation, Energy & Communication (CIEC) 432–6

[5] Zhao L, Zhang J, Liang R 2013 Development of an energy monitoring system for large public buildings Energy & Build. 66(2013) 41–8

[6] Galera K M E and Llantos O E 2017 Mobile Web Energy Monitoring System Using

DFRduino Uno, 4th Information Systems International Conference (ISICO) 6-8 November 2017 Bali Indonesia 124(2017) 706-13
[7] Rholam O, Tabaa M, Monteiro F and Dandache A 2019 Smart Device for Multi-band Industrial IoT Communications The International Workshop on the Future of Internet of Everything (FIoE) August 19-21, 2019, Halifax, Canada 155(2019) 660-5
[8] Vidyanandan K V 2017 An Overview of Factors Affecting the Performance of Solar PV Systems Energy Scan 27(2017) 2-8