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PREFACE

The theme of the 1st International Conference on Applied Science and Technology (iCAST) in 2018 is "Applied Intelligence Technology for Supporting 4.0 Industrial Revolution and Its impact on Sustainable Social and Economic Development." The 1st iCAST aims to bring together researchers and experts in intelligent technology from educational institutions, R & D, industry, government and the community to exchange and share ideas, knowledge through a discussion of a wide range of issues related to industrial revolution: potential, roles, needs, opportunities and challenges as well". This conference is also held as a media in establishing a partnership within industry and technology institutes, nationally and internationally.

The 1st iCAST was attended by nearly 300 presenters, co-presenters and participants from various countries such as USA, Australia, Japan, Malaysia, and from different cities of Indonesia. We would like to thank keynote speaker Prof. RW (Bill) Carter from University of the Sunshine Coast, Queensland, Australia, Prof. Eddy Yusuf from Management and Science University, Shah Alam Selangor, Malaysia, Prof. Yasushi Kiyoki from KEIO University, Japan, Assoc.Prof. Bambang Trigunarsyah from RMIT University, Melbourne, Australia. Our gratitude is also addressed to all presenters and participants of The 1st iCAST from 43 Polytechnics.

We would like to express our gratitude to Leader of Indonesia Polytechnic Director Forum (locale abbrev. FDPNI), Dr.Ir. Rachmat Imbang Tritjahjono, M.T and all vices; Leader of Bakor P2MI, Dr. Anang Tjahjono and core commit and all members of the Steering and Organizing Committees, for all the assists, supports, participation and cooperation in carrying out this 1st iCAST well.

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Synchronization and Application of IoT for on Grid Hybrid PV-Wind System

Ahmad Taqwa
Electrical Engineering Department
Politeknik Negeri Sriwijaya, Jalan
Srijaya Negara Bukit Besar, Palembang,
South Sumatera Indonesia 30139
a_taqwa@yahoo.com

Rusdianasari
Chemical Engineering Department
Politeknik Negeri Sriwijaya, Jalan
Srijaya Negara Bukit Besar, Palembang,
South Sumatera Indonesia 30139
rusdianasari@polsri.ac.id

Budiman
Applied Master of Renewable Engineering
Politeknik Negeri Sriwijaya, Jalan
Srijaya Negara Bukit Besar, Palembang,
South Sumatera Indonesia 30139
hanafiah_b@yahoo.com

RD.Kusumato
Electrical Engineering Department
Politeknik Negeri Sriwijaya, Jalan
Srijaya Negara Bukit Besar, Palembang,
South Sumatera Indonesia 30139
manto_6611@yahoo.co.id

Tresna Dewi
Electrical Engineering Department
Politeknik Negeri Sriwijaya, Jalan
Srijaya Negara Bukit Besar, Palembang,
South Sumatera Indonesia 30139
tresna_dewi@polsri.ac.id

Abstract—**Renewable energy is a sustainable solution for global warming and climate change. Most commonly renewable energy to be harvested and available everywhere in this area are solar and wind energy. Hybrid or combination of power sources cannot be avoided since the existence of renewable energy is limited by time, condition, climate and weather. The storage and distributing the energy on-grid or connected to grid require a synchronizing system, therefore switching and synchronizing equipment are needed for this purpose. Implementation of IoT (Internet of Things) technology through GPRS GSM internet gateway will give us the capability to control, monitor, data logging and analyze the system both manually and automatically either local or remote operation. The efficiency of time, energy and financial can be achieved by implementing this technology for the operation of this hybrid power system.**

Keywords— GPRS, GSM, Internet gateway, Hybrid, PV-wind turbine, IoT Monitoring

I. Introduction

Clean renewable energy provides an option to overcome global warming and climate change and the world struggle against the highly polluted air and increasing danger of carbon monoxide footprint [1]. Solar energy and wind turbine, both renewable energy if combined will become a solid hybrid system and noble attitude application against climate change and green house effects [2]. Solar power and wind turbine power plants have been in operation worldwide, and many countries have implemented these type of power plant to overcome their electric power shortage with these clear and clean energy. The solar energy and wind movement energy can be converted to electric energy. This electric energy can be reconverted and synchronized to the power grid to enable the export and import capabilities for a better and uninterruptable quality power supply [3].

Using IoT technology in hybrid power system gives many advantages, IoT is an open source application protocol interface with the ability to control, monitor, data logging and analysis for ensuring efficient and optimum power delivery using a smart automatic transfer switch. IoT web base server application will store any commands, and changes in parameter sensed or measured by the sensors or transducers of the controller and stored the data in the cloud server chose by the user [4].

The embedded coding and logics could be programmed into microcontroller to perform these operations. The microcontroller possessed the ability to prioritize the selection of dc power inputs from PV or wind turbine as input power source of the inverter and placing grid ac power (PLN) or generator set power as backup power. The priority and sequence selections are the logics embedded into an Arduino ATMega328 microcontroller and its accessories. All control component applied are using lowest cost components and affordable materials available in common market next door.

The equipment applied on this research are: 4 Ea Mono Si / mono crystalline PV with 250 Wp, 12 vdc, 1 Ea Savonius – rotor VAWT 300Wp 12/24 Vac output, 20 Amps PWM charge controllers, 60 AH battery, 1000 watt Inverter, Synchronizer Panel and ATS enclosure with a microcontroller with IoT technology.

II. Experimental

A. Mono Crystalline PV

Mono Si (mono crystalline) photovoltaic (PV) panel is the most efficient type of solar panel in absorbing and harvesting solar energy, but unfortunately, it is more expensive compared to poly crystalline PV panel. The efficiency enables the application of maximum current and voltage in its operation [5]. While efficiency is calculated with the following quotations:

$$P_{MAX} = V_{OC} I_{SC} FF \qquad (1)$$

$$\eta = (V_{OC} I_{SC} FF) / P_{in} \qquad (2)$$

Where:

V_{OC} is the open-circuit voltage; I_{SC} is the short-circuit current; FF is the fill factor; and η is the efficiency.

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Figure 1. Mono Si PV Solar Panel Unit Installation

Roof top installation with metal base and water slope to drain any rain water from the surface of SPU. All panels are arranged and connected in parallel to get bigger DC current output.

The calculation of maximum power point of PV is given by equation:

$F_1 = V_{MPP} / (V_{OC\text{-}STC} \times N_P)$ (3)

$F_2 = I_{MPP} / (I_{SC\text{-}STC} \times N_S)$ (4)

$F_3 = G_i / 1000$ (5)

$F_4 = T_i / 1000$ (6)

Where:

V_{MPP} is the maximum power point (MPP) voltage, I_{MPP} is the MPP current, $V_{OC\text{-}STC}$ and $I_{SC\text{-}STC}$ is the open-circuit voltage and short-circuit current of PV array under standard test condition (STC), respectively; N_P is the number of string in parallel of PV array, N_S is the number of module in serial of each string. G_i is the irradiance of the PV array, T_i is the temperature of the PV array. Hence, the four attributes are F_1, F_2, F_3, and F_4.

B. Savonius Rotor VAWT Wind Turbine

VAWT basically savonius and darieus types is a turbine with a vertical axis of the blades perpendicular to the wind direction and the shaft is mounted vertically to the generator in extracting wind energy [6]. Savonius turbines have lower efficiency values than Darieus due to its turbine working principle only utilizing more drag force dominantly and not even utilizing lift force. Compared to HAWT, VAWT is more suitable for extracting vertical wind both on high and low landscape installation.

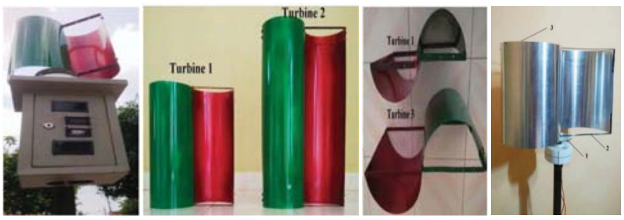


Figure 2. VAWT Control panel with 2 different height and size turbine blades

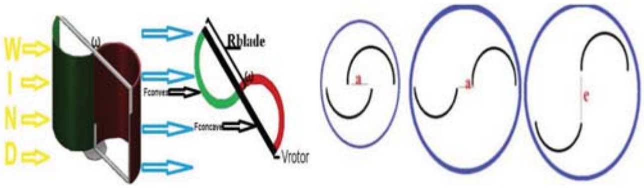


Figure 3. Wind direction and blade overlapping ratio design

Figure 4. VAWT Generator

The complete setup of the Savonius VAWT mounted on the generator, and its control panel is shown in Figure 2, The panel power system converts the 12 V_{ac} from the generator by rectifying the voltage and current to dc power before the power is connected to PWM charge controller in its control panel.

Figure 3. illustrates the overlapping ratio design of the blades. The blades are designed in overlapping design in order to maximize the absorption of the wind movement.

Alternating current generator on Figure 4 is installed in vertical axis where the shaft of the rotor is vertically inserted to the rotor. The generator capacity as indicated on the nameplate is 300 Watts with $12V_{ac}$ and 24 V_{ac} output, Rated wind speed is 13 m/s, start-up wind speed is 2.0 m/s and max speed is 45m/s. The 3 leads come out of the generator which are Neutral, 12 V_{ac} and 24 V_{ac} leads. Since the battery used is 12 Vdc. Therefore the output used is 12Vac, then this voltage must be rectified to 12 Vdc before it can be connected to PWM Charge controller, battery and inverter [7].

The maximum efficiency in wind turbine rotor is given in the following equation:

$P = ½ (\dot{\rho} A V^3)$ (7)

Where

P = kinetic energy,

$\dot{\rho}$ = air density,

A= the swept area and

V= air velocity.

This savonius VAWT in its propulsion movement uses drag force with a peak efficiency of 16%.

III. Result and Discussion

A. Microcontroller Power Transfer Switch Panel

The dc power output of the 2 hybrid renewable energy system (RES) are routed to a microcontroller with the capability of making an automatic and manual selection of the power sources in accordance with the priority or sequences embedded into the microcontroller using IoT technology based network.

The system is designed to give priority to use RES and putting the grid power (PLN) and generator as a backup input power source in UPS mode.

The IoT web database cloud server collects the information from the sensors for both ac and dc power input.

The microcontroller converts these energy by using analog to digital converter (ADC), then using serial communication interface (SCI), these parameters are transmitted via GPRS GSM mobile radio network module SIM800L to internet gateway and cloud storage server using user friendly Graphical User Interfaces (GUI) [8].

The equipment diagram is shown in Figure 5 for the integrated hybrid PV wind turbine diagram. Using dc bus and ac bus, both power inputs are separated. The AC bus separates the AC power output of the inverter. The inverter is the main equipment to generate the AC power output.

While battery functions as the power storage from all the dc power source from hybrid PV and wind turbine or the ac grid power source. This battery installation on this system enables the system to be uninterruptable power system.

The inverter selected on this project is a dual mode input inverter. It can be supplied with ac or dc power input, while in ac mode, it also has a charge mode for the battery at the same time.

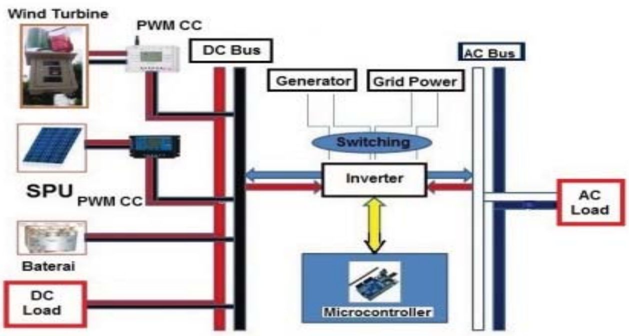


Figure 5. Integrated hybrid PV-Wind Turbine Equipment Diagram

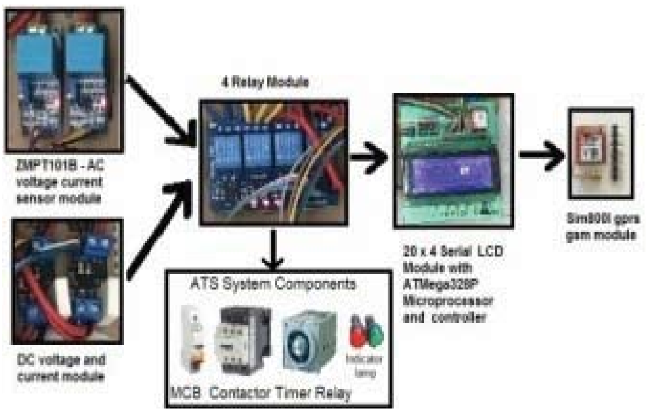


Figure 6. Microcontroller Energy Metering and Power Transfer Switch Components

Figure 6 shows the microcontroller components which are composed of:

- 2 units - ZMPT101B single phase ac voltage current sensor module
- 2 units - DC voltage and current module max 50V, 20A dc
- 1 unit - 4 relay module
- 1 unit - 20 x 4 Sainsmart IIC/12C/TWi Serial 2004 LCD Module shield
- 1 Unit - Custom made microcontroller unit using ATMega328P microprocessor
- 1 Unit - Sim800l GPRS GSM module

The 2 units ac power sensors and the 2 units dc power sensors are connected directly to a power source and routed to the 4 relay module as the input and output relay.

The relay will be energized as per command given to and by the microcontroller ATMega328. The energy parameters are then displayed by the 20 characters 4 row LCD display called 20 x 4 Sainsmart IIC/12C/TWi Serial 2004 LCD Module shield.

Then the parameters and command given to microcontroller are transmitted to IoT web database storage by using sim800l GPRS GSM module. This module is the modulator demodulator (modem) of the internet connection if it is installed with valid and enough internet quota GSM card.

For the power transfer switch operation, the following components are installed in the panel :

- 1 unit Miniature Circuit Breaker (MCB) 2 amp, $220V_{ac}$
- 1 unit H3BA timer relay, 220 V_{ac}
- 1 unit Contactor LC1D09M7, 220 V_{ac}/50 Hz
- 2 units pilot or indicating lamps, $220V_{ac}$, 50Hz

The complete panel assembly with all energy sensors, 4 output relay module, LCD displays, microcontroller ATMega328P complete with the modem and power transfer switch components, the 2 pilot or indicating lamps are shown on the panel door indicating the input power sources selected to deliver power output.

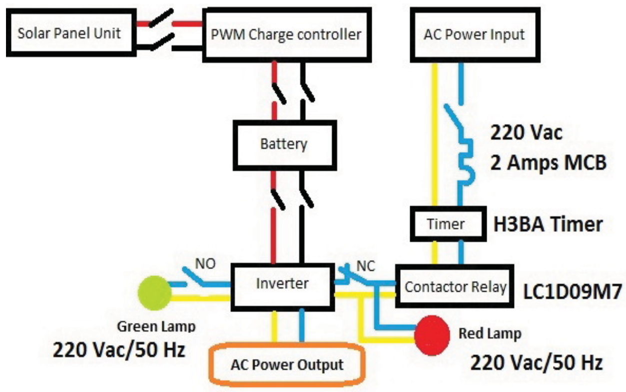


Figure 7. Manual operation ATS wiring diagram

Automatic power transfer switch system is composed by using the components such as a contactor, timer relay and miniature circuit breaker wired as shown on Figure 7, The miniature circuit breaker is used as a safety device for over current or short circuit protection.

The H3BA timer relay is used for giving time to contactor to make the power transfer switching. Contactor LC1D09M7 with 220 V_{ac}/50 Hz coil is installed as the switching contactor for input power sources.

The selection of the input power sources is also indicated by using 2 units pilot or indicating lamps, 220V_{ac}, 50Hz. The red lamp is used to indicate that grid power is used as the power input source while green lamps indicates that the renewable energy is used as the power input source.

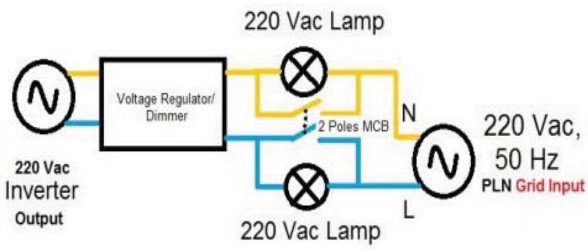
Figure 8 shows the complete system parameters displayed on The LCD 20 x 4 Sainsmart IIC/12C/TWi Serial 2004 module shield.

Figure 8. LCD 20 x 4 Sainsmart IIC/12C/TWi Serial 2004 module shield

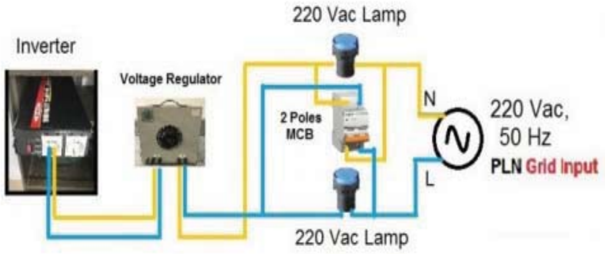
This display clearly shows the operation date and time, the hybrid system input both PV (SC) and wind turbine (WD) voltage, Grid power source (PLN) and inverter (INV) voltage, the fourth row showing connecting to server means the system is transmitting data through modem network module and connected to IoT website or cloud server through internet gateway. Since all the parameters could be collected and displayed, therefore the hybrid power system switching could be controlled by the microcontroller locally or remotely by using the 4 relay module.

B. Hybrid PV-Wind Turbine on grid Synchronizers

The synchronizing system for this hybrid system is wired as Figure 9 A&B using lamps dark bright method.



(A)



(B)

Figure 9A&B. Lamps dark bright synchronizing method wiring Diagram

When both lamps are bright, it means a big different occurred in the frequency and voltage of both inverter and grid power[9], Voltage regulator or a dimmer can be applied to adjust the inverter output voltage to the amount close to grid power. Once both lights start showing dark, the two poles MCB can be energized and synchronizing of inverter output to grid input power can be achieved. This operation is performed only if export and import power capability to the power grid is needed.

C. IoT Database cloud server

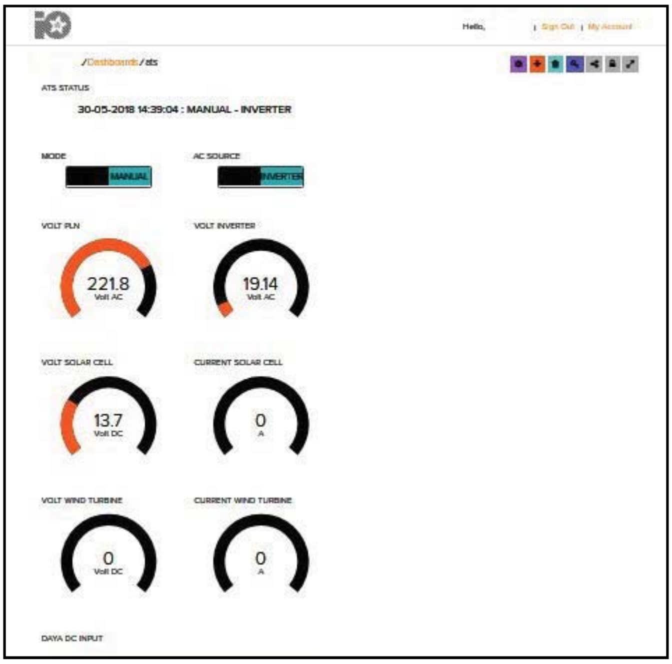


Figure 10. Automatic Power Transfer Switch IoT Dashboard GUI

The dashboard graphical interface unit display shown in Figure 10 enables the operator to change the mode from manual to auto mode and from dc or ac power input source selection. The energy parameters are shown in circular mode display. This Graphical User Interface (GUI) enables the parameter of the system to be monitored as well as giving the command to the power transfer switch system.

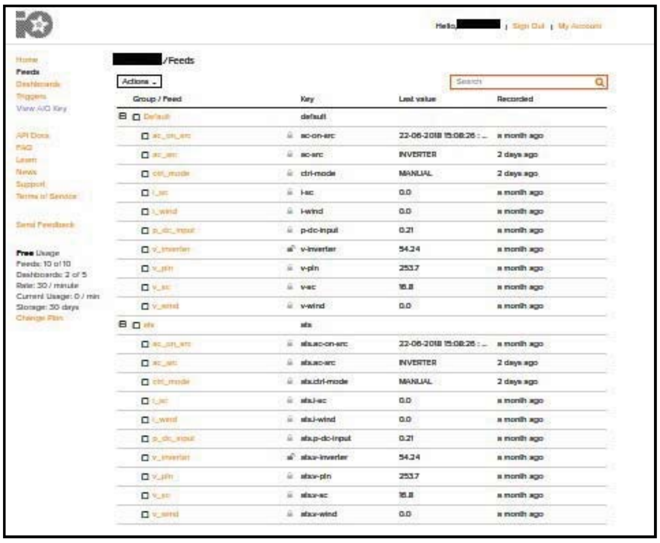


Figure 11. IoT Database Feed Display

Figure 11 Shows all parameters collected by IoT sent in the real time measuring activities done by the sensors of the microcontroller. The data is classified into groups and individuals and in the tabulation for easy selection.

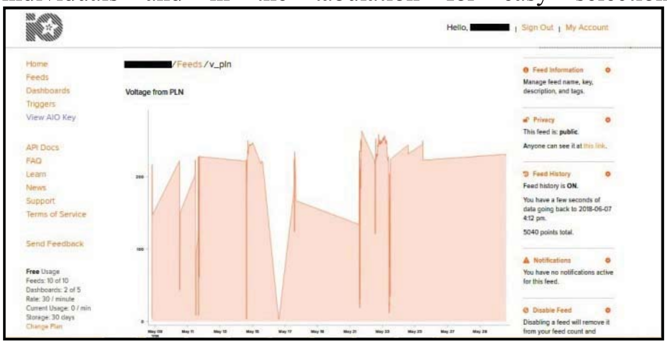


Figure 12. Fluctuation of AC Power Souce Graph

By Using IoT Technology, we can always observe and analyze the quality of AC or DC input power source to the system. Figure 12 data shows that AC power input from the grid used by the system has fluctuations and even the lost of power when the straight line declined to zero. This graph can be presented and retrieved as digital evidence of the ac power input quality used by this system or surrounding system.

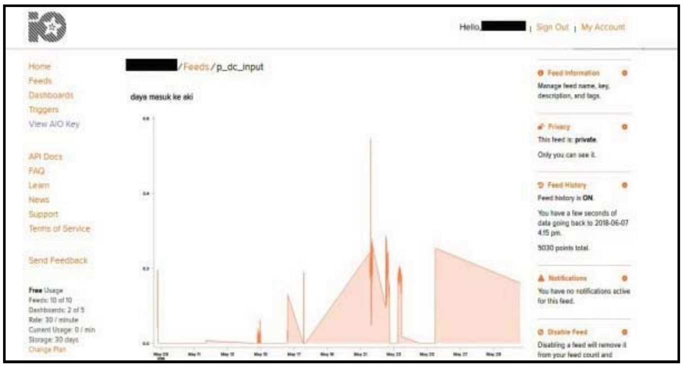


Figure 13. IoT Feed - SPU DC Power input Graph

Figure 13 shows the graph of power energy collected by SPU sent and stored to the battery. This IoT Feeds GUI will display the historical of period of time for any actions or commands given to the system and records all the energy parameters received from both ac and dc sensors in the cloud database server including fluctuation of power collected by the battery due to cloud shading in the sky and rapid changing in local weather.

IV. Conclusion

IoT for hybrid PV wind system has given a great efficiency both cost and energy. Synchronizing power output from renewable energy sources and integrating with utility grid power will make the system more convenience in export and import of the electric power. IoT based remote monitoring system is the system for automation and sequencing of the hybrid system. The system will enhance the operation and data analysis. The approach of this paper is the implementation of remote transmission of data and command to a server for supervision and analysis by using low power consuming advanced wireless modules in a very low cost way. The most benefit of operating this system is the convenience way of switching and transferring fossil fuel power source to renewable energy power source. Implementation of this system will hopefully reduce the carbon foot print.

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