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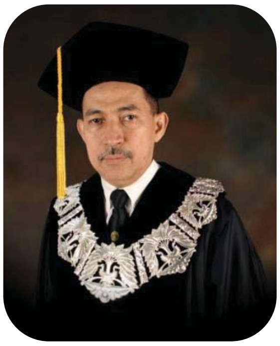
WELCOME FROM THE RECTOR OF UNIVERSITAS INDONESIA



It is both a pleasure and honor for me to welcome you all to the 13th International Conference on QiR (Quality in Research) 2013. In this globalization era, mankind's competitive explorations to find new and better ways to enhance their life has often resulted in sacrificing the environment for their convenience. To preserve the environment for our future generations, steps must be made to ascertain that development and innovation of mankind must be more sustainable, balancing both mankind's' effort in enhancing their quality of life and fulfilling their needs, with its harmony with nature.

Today, scientists and experts, in particular, people in engineering, architecture and design are looking to develop new environmentally friendly technologies, or eco-technologies. Innovation in eco-based multidisciplinary knowledge and skills becomes the important key, and this central issue should be encouraged for the motivation of current and future development. Eco-technology can help protect, conserve and even restore our precious shared environment. To develop this technology, we need to combine engineering, scientific or technological approaches, with ecology, economics and the social sciences and humanities. The eco-innovation field is now wide open and offers exciting new territories to explore and develop. Creative thinking by our top technical and scientific researchers is giving us a more and more treasures of new workable ideas.

However, innovations require more than just brilliant ideas. Innovations require resources, skills, technology, knowledge, tools, techniques and so much more. But most of all, innovations require people. People are the driving force behind every need of change, changes that are aimed to improve mankind's quality of life, to enhance their living conditions or to simply make life easier and more comfortable. This conference is about learning of the fundamental aspects which can transform the world and society, thinking ahead to possible challenges facing the globe, discovering innovations related to opportunities for industry, and most importantly, this conference is about bringing together interdisciplinary people to accelerate activities in many areas simultaneously. This is what makes the conference exceptional this year in terms of potential impact from this networking.

I extend my sincere thanks to the Faculty of Engineering Universitas Indonesia, supporting parties and institutions for their participation and contributions in QiR 2013. I would also thank the people of Yogyakarta for their gracious support and hospitality. Additionally, I extend a hearty thank you to the members of the organizing committees for dedicating their valuable time so that each one of us enjoys an exceptional conference program over the next several days. May we have a successful, stimulating, fruitful and rewarding conference.

Prof. Dr. Ir. Muhammad Anis M.Met.
Rector
Universitas Indonesia

WELCOME FROM THE DEAN OF FACULTY OF ENGINEERING UNIVERSITAS INDONESIA

Welcome to the 13th International Conference on QiR (Quality in Research) 2013. The Faculty of Engineering Universitas Indonesia is thrilled that, together with our co-hosts IST-Akprind and Gadjah Mada University, we are able to present an international conference of this magnitude. This two-day conference speaks to the importance of fostering relationships among national and international front liners, thinkers, academics, executives, government and business officials, practitioners and leaders across the globe in an effort to share knowledge and best practices as part of a worldwide network.

The quest for knowledge has been from the beginning of time but knowledge only becomes valuable when it is disseminated and applied to benefit humankind. It is hoped that QiR 2013 will be a platform to gather and disseminate the latest knowledge in engineering, architectural design and community services. Academicians, scientist, researchers and practitioners of these fields will be able to share and discuss new findings and applications of their expertise. It is envisaged that the intellectual discourse will result in future collaborations between universities, research institutions and industry both locally and internationally. In particular it is expected that focus will be given to issues on innovations for the enhancement of human life and the environment.

In accordance to this year's theme, this conference will cover a wide range of sustainable design and technology issues, especially state of the art information and knowledge of new innovations, ideas, creative methods or applications which can be implemented to enhance the human life and also our environment. The itinerary of the conference over the two days has been carefully planned to ensure a lively exchange of ideas and the development of innovative strategies and there will be many opportunities for everyone in attendance to share their expertise with, and learn from, peers from around the world.

We urge you to spend the next two days in interesting discussions and exchanging ideas among yourselves. We foresee more and more challenges in our future. Challenges in how to improve our life, how can we enhance our society, how can we make our lives and the lives or our society better? These challenges should be answered together by developing collaborations for future research in various engineering and design areas. It is our hope and aim that this conference would be able to provide an international media for exchange of the knowledge, experience and research as well as the review of progress and discussion on the state of the art and future trend of prospective collaboration and networking in broad field of eco-based technology development.

My deepest appreciation to our sponsors, supported parties and various contributors for their never ending supports of this conference. I would also like to convey my humblest thankfulness to all of our distinguished speakers for making the time to share their knowledge with us. To our fellow researchers and/or practitioners from Indonesia and overseas, welcome and enjoy your stay in this amazing historical city, Yogyakarta. I would also like to invite all participants in expressing our appreciation to all members of the QiR 2013 organizing committee for their hard work in making this conference another success.

Prof. Dr. Ir. Bambang Sugiarto, M.Eng.
Dean Faculty of Engineering
Universitas Indonesia

WELCOME FROM THE QiR 2013 ORGANIZING COMMITTEE

Welcome to the 13th International Conference on QiR (Quality in Research) 2013. It is a great pleasure for Faculty of Engineering Universitas Indonesia to be co-hosting this biennial event with IST-Akprind and Gadjah Mada University, in the spirit of strengthening of cooperation and mutual growth to be world class institution. For the first time, the QiR 2013 is held in one of the most historical city in Indonesia – Yogyakarta. It is with our utmost pleasure to hold this year's QiR 2013 in conjunction with the 2nd International Conference on Civic Space (ICCS 2013) and introducing the International Symposium on Community Development 2013 as a forum to share experience on engaging community for a better life and environment.

The aim of this International Conference with our selected theme, "Exploring Innovation for Enhancement of Human Life and Environment", is to provide an international forum for exchanging knowledge and research expertise as well as creating a prospective collaboration and networking on various fields of science, engineering and design. We hope this conference can be a kick-off for the strengthened action and partnerships on creating a platform for us; national and international thinkers, academics, government officials, business executives and practitioners, to present and discuss the pivotal role of engineers in innovative products which will reduce environmental impacts, applications in sustainable planning, manufacturing, architecture, and many more to grow and ensure the rising prosperity of our society going into the future. Under this theme, the conference focuses on the innovative contributions in science, engineering and design as well as their market perspectives to the existing and future enhancement of human life and environment quality.

Over the period of 15 years, this biennial conference has become an important place of encounter between scholars and practitioners from different countries, cultures and backgrounds discussing contemporary engineering and design issues dealt in their hometown, country or even region. Serving as a platform for an engineering and design dialogue, this conference will have 16 invited speakers and has gathered more than 500 papers from more than 20 countries all over the world:
92 papers on International Symposium on Civil and Environmental Engineering
51 papers on International Symposium on Mechanical and Maritime Engineering
97 papers on International Symposium on Electrical and Computer Engineering
111 papers on International Symposium on Materials and Metallurgy Engineering
31 papers on International Symposium on Architecture, Interior and Urban Planning
57 papers on International Symposium on Chemical and Bioprocess Engineering
71 papers on International Symposium on Industrial Engineering
25 papers on International Symposium on Community Development

My deepest gratitude to all of our speakers, participants and contributors who have given this conference their generous support. I would also like to thank all members of the Organizing Committee and our distinguished International Board of Reviewers for all of their support and advice. Our thanks to all of our sponsors, supporters, exhibitors, and professional associations for their great support and encouragement through committed funding and any other form of help and support. We also owe our success to the full support of the Rector of Universitas Indonesia and the Dean of Faculty of Engineering. Thank you to IEEE Indonesia Section that has supported QiR 2013 to be approved as IEEE Conference. Last but not least, a special thanks to our co-hosts, IST-Akprind and Gadjah Mada University for all of their immense supports in making this conference a success.

Allow me to wish all of you a meaningful and rewarding conference. We wish you a pleasant and memorable stay in Yogyakarta. Thank you and we hope to see you again at the QiR 2015.

Prof. Dr. Ir. Bondan T. Sofyan, M.Si.
Chairman of QiR 2013 Organizing Committee

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Development of Data Acquisition System for Hybrid Power Plant

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***Abstract*— In this paper, the data acquisition system is developed to monitor the wind speed, solar irradiation, and PV temperature based on a low-cost AVR microcontroller. Instead of using an expensive pyranometer, a low-cost PV module is used as the solar irradiation sensor. The integrated-circuit temperature sensor LM35 and a cup-type anemometer are used to measure the temperature and the wind speed respectively. To provide the flexibility of the data acquisition system, the Modbus protocol is adopted for communicating with other monitoring software or HMI. This feature enables the system to communicate with SCADA system. It provides useful information about the environment conditions for operating the hybrid power system effectively. The developed data acquisition system is tested in real environment and comparisons to the standard measurement instruments are conducted. The measurement errors of 4.46%, 3.45%, and 3.47% are obtained for the wind speed, solar irradiation, and PV temperature measurement respectively.**

Keywords— hybrid power system; data acquisition system; wind speed; solar irradiation; PV temperature; Modbus protocol.

I. Introduction

Recently, hybrid power system plays a significant role for providing electrical energy to the customer, especially in rural area. The hybrid power system combines several energy resources, usually the renewable energy such as wind power and solar power. The objective of hybrid system is to maximize the energy obtained from the resources, while maintaining the supply continuously. Naturally, the power generated by wind and solar power are affected by the weather or environment conditions, namely the wind speed for wind power, the solar irradiation and the temperature of solar panel for solar power. Therefore it needs to monitor those parameters in real-time for operating the hybrid power system effectively.

Many researchers have developed the data acquisition systems for monitoring the renewable energy plants [1] – [4]. The data acquisition system was developed to monitor the meteorological data such as wind speed, solar irradiation, humidity, temperature, and the operational parameters of the renewable energy sources such as the voltage and current of photovoltaic and wind turbine generator [1]. The system was implemented using DAQ card installed on a PC. The LabVIEW software was employed to control the system. The LabVIEW was also employed in [2] to monitor hybrid wind-PV power systems. The data acquisition system based-on client/server architecture was developed to monitor and control the wind-PV power systems [3]. In the system, a data acquisition unit is connected to the data collection computer using a wireless system, while the internet was employed to communicate between the client measurement station and the server measurement station. In [4], they proposed a low cost data acquisition system for renewable energy plants using an USB interface. The system was developed for developing countries, thus the firmware and hardware is free and open source.

Instead of using PC for data collection, a microcontroller-based data acqusition system was developed in [5], [6]. A 8-bit microcontroller system with analog input was developed for solar irradiation monitoring [5]. A serial EEPROM was used to store the measurement data. In [6], a 10-bit microcontroller system was used in the wireless data acquisition system to collect solar irradiation, temperature, photovoltaic voltage and current of the PV water pumping station. The system was equipped with GSM module for data transmission over GSM network.

To monitor and control hybrid wind-PV-battery power system, a SCADA (Supervisory Control and Data Acquisition) was proposed in [7]. It performed the real-time measurement of the electrical parameters of hybrid power system.

In this paper, the data acquisition system is developed to monitor the wind speed, solar irradiation, and PV temperature based on a low-cost 8-bit AVR microcontroller. The main contribution of the work is on the Modbus protocol which is employed for communicating between the data acquisition module and the other devices or PC. By introducing the Modbus protocol, the data acquisition system offers an easy way for reading the measurement data.

The rest of paper is organized as follows. Section 2 presents the hybrid power system which is considered in this work. The proposed data acquisition system is presented in section 3.

Experimental results are covered in section 4. Section 5 presents the conclusions of the paper.

II. HYBRID POWER SYSTEM

Fig. 1 shows the architecture of hybrid power system [8]. It consists of solar power, wind power, battery, and load. The maximum power generated by solar power system is 300 watt (6 x 50 Watt PV modules). The wind power system is able to generate the maximum power of 200 Watt. Thus the hybrid power system is suitable for supplying 500 Watt electrical power to a small home. The supervisory controller is employed to supervise the hybrid power system in providing continuous supply regardless of the environmental conditions. The environmental parameters that affect the ouput power of hybrid power system are solar irradiation, ambient temperature of PV panel, and wind speed as discussed below.

The I-V characteristics of PV are shown in Fig. 2 and Fig. 3. Fig. 2 shows the I-V curves under varying solar irradiation. From the figure, it is clear that when solar irradiation changes, the I-V curve changes accordingly. For a fixed voltage, the current of PV increases when solar irradiation increases. It means that by increasing solar irradation, the output power of PV will increase. Fig. 3 shows the I-V curves under varying PV temperature. The figure shows that for a fixed current, the PV voltage increases when temperature decreases. Thus increasing PV temperature affects in reducing the power output of PV.

Fig. 4 shows the wind turbine power curves under varying wind speed. In the figure, V_{Wx} is the wind speed, where $V_{W3}>V_{W2}>V_{W1}$. From the figure, it is shown that when wind speed increases, the ouput power of wind turbine increases.

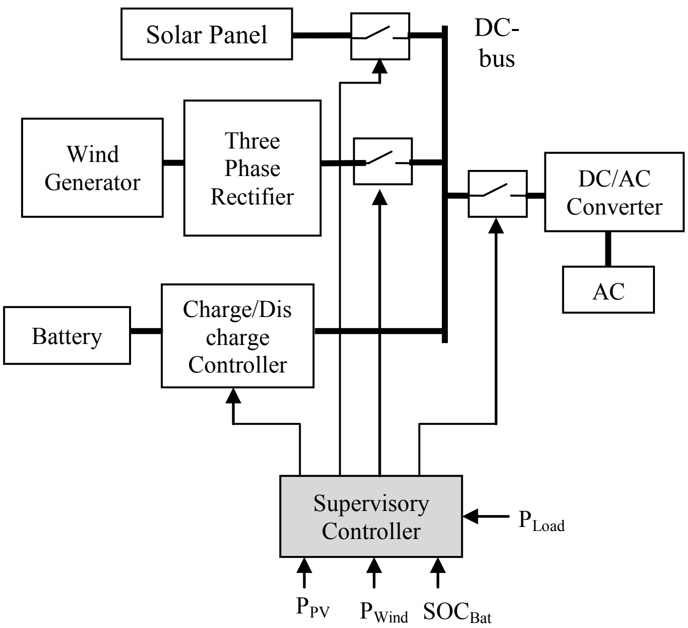

Fig. 1. Architecture of hybrid power system [8].

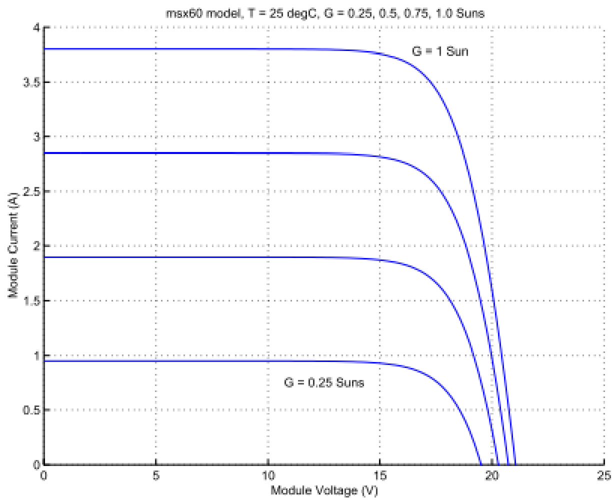

Fig. 2. I-V curves of PV under varying solar irradiation [9].

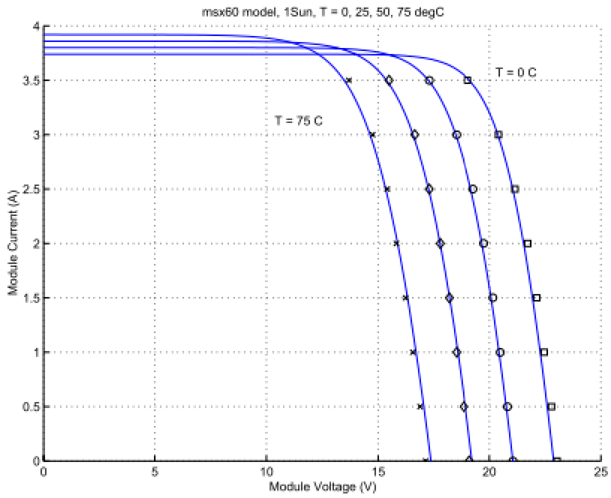

Fig. 3. I-V curves of PV under varying PV temperature [9].

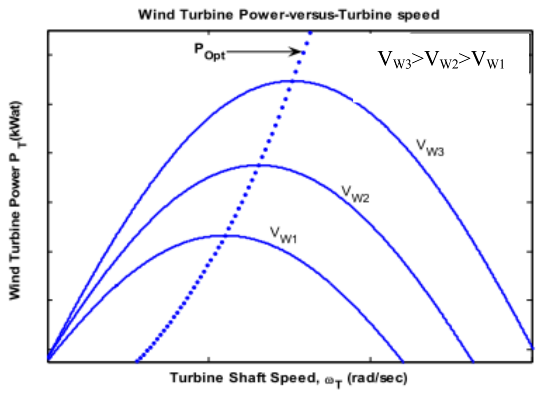

Fig. 4. Wind turbine curves under varying wind speed [9].

III. PROPOSED DATA ACQUISITION SYSTEM

A. Hardware

The block diagram of proposed data acquisition system is shown in Fig. 5. It consists of a 8-bit AVR microcontroller system, a PV cell, an anemometer, LM35 temperature sensor, a Realtime clock (RTC), a LCD module, and a serial communication interface (RS232). A PV cell is used to measure the solar irradiation level. An anemometer is a sensor to measure the wind speed. LM35 is an integrated circuit (IC) used to measure temperature. A RTC (DS1307) is aserial I^2C real-time clock module which is used as the clock/calendar. Using RTC, the measurement data could be recorded on time/calendar base. A LCD module is used to display the data measurement for local information or debugging the system. A serial RS232 is an interface for communicating between the microcontroller and a PC.

A small size PV cell (7 cm x 5.5 cm) is employed as the solar irradiation sensor. The output voltage and current of cell are 10 V and 30 mA respectively. In this work, the solar irradiation measurement is based-on the output voltage of PV cell. Since the maximum output voltage of the cell is 10 V, while the maximum input voltage of internal ADC of the microcontroller is 5 V, a simple voltage divider (divide by two) is employed.

A cup-type anemometer (from weather sensor assemby kit-Argent Data Systems) is employed to measure the wind speed. Fig. 6 shows the anemometer sensor. The anemometer has a contact switch which is closed when the cup rotates. The swicth is close once per second if the measurement wind speed is 2.4 km/h. To interface with the microcontroller system, a pull-up resistor is put on the contact switch and connected to the external interrupt port of the AVR microcontroller.

LM35 is a precision integrated circuit temperature sensor. The output voltage is linearly proportional to the measured temperature (10 mV/^{0}C). To interface this sensor to the microcontroller, a signal conditioner unit is added to gain the output of sensor by 5. Thus when measured temperature is 100 ^{0}C, the output of signal conditioner unit (input to ADC port of microcontroller) is 5 V.

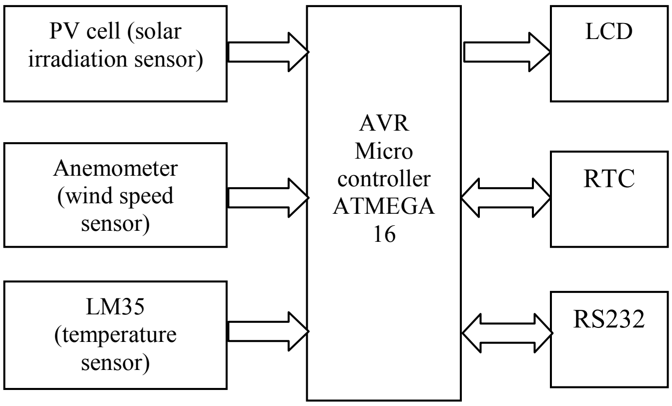

Fig. 5. Hardware architeture.

Fig. 6. Anemometer (Argent Data Systems).

B. Software

The program written for microcontroller system consists of the following parts : a) acquire data from sensor; b) display data to LCD module; c) transfer data to/from PC using Modbus protocol. To read data from solar irradiation and temperatur sensors, the built-in 10 bit-ADC is used. The program reads the data from ADC buffer when the conversion is completed. While to measure the wind speed, it uses timer to generate five seconds interval for reading the number of pulses on the external internal port connected to the anemometer. Since the anemometer switch closes (i.e. triggers/interrupts the microcontroller) once per second if the wind speed is 2.4 km/h, then by counting the number of pulses in five seconds, the wind speed could be calculated.

The communication between data acquisition unit and PC is performed via serial communication using Modbus protocol. In this configuration, the client is PC and the server is the data acquisition unit. Therefore Modbus slave is implemented in the microcontroller. Modbus frame is shown in Fig. 7, where it consists of a protocol data unit (PDU) which is independent of underlying communications layer, and the application data unit (ADU) for mapping the protocol on network [11].

Additional address is the slave address (one byte). Function code denotes the action should be perfomed by the slave. In this work, only function code of 03 (read holding register) is used. The register address of the measurement data is described in Table 1. When packet data is sent by master device (received by slave device), data field contains of the starting register address and the number of data to be read. If there is no error, slave device will send data contains of the number of bytes and the register's value to be sent. Error check is CRC (cyclic redundance check) value.

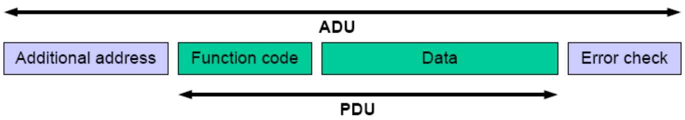

Fig. 7. Modbus frame [11].

TABLE I. REGISTER ADDRESS

Address	Content
16	Solar irradiation data
17	Solar temperature data
19	Wind speed data

IV. EXPERIMENTAL RESULTS

To test the functionality and performance of the developed data acquisition system, several experiments are conducted. In the experiments, the measurement data obtained by data acquisition unit are compared to the standard measurement instruments, i.e. solar power meter (TM-750, accuracy of +/- 5%), portable wind speed meter (Luxtron AM-4202, accuracy of +/- 2%), and room thermometer (accuracy of 1^0C).

Table 2 shows the experimental results of the solar irradiation measurements. This measurement is conducted during sunny day from 10:00 AM to 04:00 PM. The measured data of the data acquisition unit are the data displayed on the LCD module. From the table, it is obtained that the average error is 3.45%. It is noted here that there are inconsistency in the measurements. In the measurements No. 11 and No. 26, the solar irradiation measured by solar power meter is the same, i.e. 960 Watt/m^2, however the developed data acquisition system measures in the different values, i.e. 945 Watt/m^2 and 934 Watt/m^2 respectively. This phenomenom is caused by the non-linear I-V characteristic of PV under varying temperature as shown in Fig. 3. For a particular solar irrradiation level, when PV temperature changes, the output voltage of PV will change. It results the different measurements of solar irradiation. Since the solar power meter does not use the PV cell for measuring the solar irradiation, the inconsistent measurement does not occur.

The experimental result of temperature measurement is shown in Table 3, where the average error is 3.47%. The experimental result of wind speed measurement is shown in Table 4. The wind speed measurement is conducted outdoor at the normal wind speed during two hours from 09:00 AM to 11:00 AM. From the experiments, the average error is 4.46%. The inconsistent measurements occur in the wind speed measurement are caused by the fact that the wind speed is not the steady value. The other factor affects the error is the non deterministic starting time of the timer used for counting pulse employed in the anemometer.

By considering the accuracy of the standard measurement instruments and average errors obtained from the experiments, it could be said that the developed data acquistion system is reliable for measuring solar radiation, temperature, and wind speed.

To test the Modbus communication, the microcontroller is connected to a PC using serial cable (RS232). Two SCADA software (Winlog SCADA and IntegraXor) are used for testing the Modbus protocol. In the SCADA software, the scanning interval for reading data from microcontroller is set to one second. From the experiment, it is shown that the measurement data could be read by SCADA software in real-time.

TABLE II. SOLAR IRRADIATION MEASUREMENT

No.	Solar irradiation (Watt/m^2)		*% error*
	Measured by developed data acquisition system	Measured by solar power meter	
1	659	678	2.80
2	659	677	2.65
3	659	678	2.80
4	659	677	2.65
5	659	678	2.80
6	755	767	1.56
7	756	767	1.43
8	755	766	1.43
9	755	765	1.30
10	755	765	1.30
11	945	960	1.56
12	946	961	1.56
13	945	962	1.76
14	945	961	1.66
15	946	961	1.56
16	944	1004	5.97
17	945	1002	5.68
18	945	998	5.31
19	945	1002	5.68
20	944	1004	5.97
21	938	975	3.79
22	938	975	3.79
23	938	976	3.89
24	938	976	3.89
25	938	976	3.89
26	934	960	2.70
27	934	959	2.60
28	934	960	2.70
29	934	959	2.60
30	934	960	2.70
31	750	800	6.25
32	748	798	6.26
33	748	798	6.26
34	750	799	6.23
35	750	800	6.25
Average error			3.45

TABLE III. TEMPERATURE MEASUREMENT

No.	Temperature (^{0}C)		% *error*
	Measured by developed data acquisition system	Measured by thermometer	
1	28	29	3.44
2	28	29	3.44
3	28	29	3.44
4	27	28	3.57
5	29	30	3.33
6	27	28	3.57
7	27	28	3.57
8	28	29	3.44
9	28	29	3.44
10	28	29	3.44
Average error			3.47

TABLE IV. WIND SPEED MEASUREMENT

No.	Wind speed (Km/h)		% *error*
	Measured by developed data acquisition system	Measured by Wind speed meter	
1	4.8	4.8	0
2	4.8	4.5	6.25
3	5.9	5.6	5.08
4	7.2	7.0	2.77
5	7.2	7.0	2.77
6	7.2	7.0	2.77
7	6.0	5.6	6.66
8	5.8	5.6	3.44
9	5.8	5.6	3.44
10	9.2	8.6	6.52
11	4.8	4.6	4.16
12	5.9	5.6	5.08
13	6.0	5.8	5.00
14	9.6	8.6	10.41
15	8.4	8.1	3.57
16	6.4	5.6	12.5
17	2.4	2.4	0
18	4.8	4.6	4.16
19	2.4	2.4	0
20	8.4	8.0	4.76
Average error			4.46

V. CONCLUSIONS

A data acquisition system for measuring the environmental conditions in the hybrid wind-PV energy system is proposed. The proposed system employs the low cost sensors and microcontroler systems to measure the solar irradiation, PV temperature, and wind speed. Comparing to the standard measurement instuments, it is obtained that the proposed data acquisition system is reliable to monitor the environment conditions in the hybrid power plant. The simple and low cost PV cell shows a good accuracy in measuring solar irradiation. The Modbus protocol implemented on the microcontroller system allows the data acquisition unit to be interfaced to the wide range of data acquisition system software and the SCADA software.

In future, the measurement accurary will be improved and additional enviromental parameters as well as the electrical parameters of hybrid power system will be added. Further, the developed data acquisition system will extended for operating with SCADA system.

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