

# Design and Analysis of DC Electrical Voltage-Current Data Logger Device Implemented on Wind Turbine Control System

Sri Murti<sup>1</sup>, Prisma Megantoro<sup>2</sup>, Gabriel De Brito Silva<sup>3</sup>, Andino Maseleno<sup>4</sup>

<sup>1,2</sup>Department of Electrical Engineering and Informatics, Universitas Gadjah Mada, Yogyakarta, Indonesia

<sup>3</sup>School of Engineering and Applied Sciences, Nile University, Giza, Egypt

<sup>4</sup>Institute of Informatics and Computing Energy, Universiti Tenaga Nasional, Malaysia.

sri.murti@mail.ugm.ac.id, megantoro.prisma@gmail.com, gabriel.silva@eu4m.eu, andimaseleno@gmail.com

**Abstract**—DC electrical voltage-current measuring instrument and data are an instrument used to measure the current and voltage generated by wind turbines and record the measurement results. The function of this instrument is to activate the dummy load on the wind turbine control system to reduce the voltage that exceeds the safe limit when saving electrical energy. The research aimed to manufacture and analyze DC electrical voltage - current measuring instrument using the Arduino Uno based data logger, capable of measuring the DC and voltage generated by Hybrid Power Plants (PLTH) and use the metrology method to analyze the degree of uncertainty of the measuring instrument. In this research, the heuristic method was used to determine the characteristics of the sensor. Sensor characterization was followed by calibration of a measurement instrument to determine the values of the uncertainty of the measurement instrument. The results of this research indicated that the characteristics of voltage sensor (CR5310-300) obtained linear regression equation  $y=0.29253x + 0.662$ , while the current sensor characteristics (WCS1800)  $y=0.072978x - 37.2408$ . After the characterization procedure, the measuring instrument was calibrated using a traced clamp meter. The calibration results indicated that the accuracy of the voltage sensor was 99.99%. The uncertainty of the current measuring instrument was 0.316 amperes, at the standard current 0 - 9 amperes, and 0.317 amperes, at the standard current of 9.7 amperes with an accuracy of 99.98%. Based on the research results, the current and voltage measuring instrument maintain a good accuracy level.

**Keywords**— *Heuristic Methods, CR5310-300, WCS1800, Uncertainty, Accuracy*

## I. INTRODUCTION

The need for electricity has increased every year. The increasing need for electrical energy is causing a fossil energy crisis because most of the electrical energy produced requires fossil fuels. As we know, fossil fuels are non-renewable fuels. Therefore, renewable energy is the solution to the energy crisis, and now this renewable energy technology is starting to develop. One example of renewable energy is wind energy.

Some researchers have conducted studies to convert wind energy into electrical energy. Chen et al. investigated harvesting wind energy using a hybrid blade flapping model based on the vortex shedding effect. The tool used piezoelectric and triboelectric based wind energy harvesting machines with high output performance [1]. Goksu et al.

investigated the field validation model IEC 61400-27-1 type 3 wind power plant with power factor control. The IEC type 3 wind turbine models with wind turbine level voltage and wind power plant power factor controllers were validated based on field measurements from a 52 MW wind power plant [2]. Abdeltawab and Mohamed examined strong energy management of the hybrid wind wheel and flywheel storage system, considering the flywheel power losses minimization and code-grid constraints. The flywheel energy storage system (FESS) had the advantage of high efficiency and long life [3]. Hassan Zamani studied the increased rotor speed stability from wind farms based on dual stator wind induction generators by voltage-oriented control windings. The increased speed stability was investigated in wind induction wind stator-winding rotor generators (DWIG), under the power system fault conditions [4]. Buhan introduced wind patterns and reference correlation of wind pole data with NWP for increasing wind-electric power forecasts. A new statistical approach was proposed to improve the short-term wind-electric power forecast from wind power plants (WPP) based on new wind pattern recognition techniques and the correlation of reference wind pile data (RWM) with numerical weather prediction (NWPs) to localize wind data to the given WPP site [5].

The other researchers investigated wind energy was Merabet et al., studied the implementation of shear mode control systems for generator control and wind energy conversion system side. The shear mode of the second-order control and lattice strategy of the experimental wind energy conversion system of variable speed was applied to control the generator [6]. Tani studied energy management in a decentralized generation system based on renewable energy - ultracapacitors and batteries to compensate for fluctuations in wind power/loads. The energy management for decentralized generation systems (DGS) was used for wind turbines with photovoltaic panels (PV) and energy storage devices [7]. Kou et al. researched coordinated predictive control of DFIG-based wind battery hybrid systems using a predictive distribution of non-gaussian wind power. The coordinated stochastic control schemes were used for wind energy hybrid battery-based dual generator systems [8]. Ngamroo improved low voltage performance and reduced power fluctuations in DFIG wind turbines on DC microgrids by optimal SMES



with the error current limiting function. The vital problems of dual induction generator wind turbines (DFIG) were power fluctuations and low-voltage driving performance [9]. Kamalinia investigated the stochastic medium-term coordination of the flexibility of hydro and natural gas for the integration of energy. She presented stochastic safety restricted unit commitment models (SCUC) for optimal and flexible medium-term allocation of hydro and natural gas systems when accommodating large integration of wind energy [10].

Karaagac investigated the coordinated control of the wind energy conversion system to reduce sub-synchronous interactions in DFIG-based wind farms. The method was used to reduce synchronous interaction (SSI) between dual generator-based wind generators (DFIG) and compensated capacitor series transmission systems [11]. Thomsen researched the heating of a microgrid wind-powered room using a 220-kW induction generator. In the Faroe Islands, available wind energy was a clear source for space heating [12]. Ganger studied the characterization of wind power ramp statistics through extreme value analysis. He examined extreme power fluctuations in wind farms that are rare but are high-impact events, so the precise characterization of those extreme fluctuations would assist in the planning of power system operations in power systems with high wind power penetration [13]. Zhou and Sun studied the optimization of supercapacitor hybrid energy storage stations in the wind/solar generating systems. The researchers built mathematical models of wind/solar generating systems, batteries, and supercapacitors, proposed the objective optimization function of the HESS, and considered various constraints [14]. Marinelli examined the wind and large scale photovoltaic regional models for hourly production evaluation. The work presented two large-scale regional models used for the evaluation of normalized power output from wind turbines and photovoltaic power plants on a European regional scale [15].

Huang, Li, and Jin studied the maximum power point tracking strategy for large scale wind generating systems given the dynamics of the wind turbine. A new control strategy was used for large-scale wind energy conversion systems to achieve a balance between maximizing power output and minimizing operating costs [16]. Guo et al. studied energy management systems for stand-alone microgrid consisting of wind turbine generators (WT), diesel generators, energy storage systems (ESS), and seawater desalination systems [17]. Zhao, Yan, and Zhang examined wind-wave farming systems with their energy storage and subtle power output. Fluctuating electrical power from waves was smoothed by utilizing the wind turbine rotor inertia as a short-term energy storage device so that without additional energy storage hardware, the investment and maintenance costs of wave energy conversion were reduced [18]. Bitaraf and Rahman explored the reducing wind energy retained through energy storage and demand response. Curtailed wind energy was a challenge in utilities with high wind energy penetration [19]. Moghaddam, Chowdhury, and Mohajeryami investigated predictive operation and optimal size of battery energy storage with high wind energy penetration. High penetration of wind energy requires fast-

acting resources sent to manage energy imbalances in the electricity grid [20].

Wind energy is a potential renewable energy source to be developed in Indonesia. Wind energy can produce electrical and mechanical energy through the process of converting kinetic to mechanical energy, which will be converted into electrical energy. Wind energy has been developed to be used as electricity generation.

Based on the problems, the authors are interested in researching DC electrical data logger, which later the device will be used to store measurement data and monitor the amount of electrical energy generated by wind turbines.

## II. METHODS

The method used in conducting the research was heuristic analysis [21]–[23], instrument calibration, and system testing. The research included a literature review, preparation of device and materials, design, manufacturing of hardware, programming, testing, and data analysis.

Figure 1 shows the block diagram of the DC electrical voltage-current datalogger device implemented on the wind turbine control system [24]–[26] based on Arduino Uno [12], [27] in the Pandansimo Wind Turbine Control System.

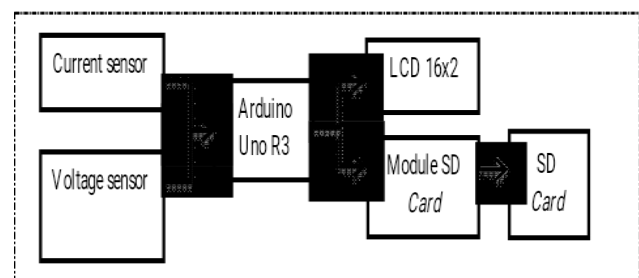


Fig. 1. System block diagram

The system block diagram shown in figure 1 explains the parts of the system. The system consists of a current sensor to measure the amount of current generated by wind turbines. Voltage sensor to measure the amount of voltage generated by wind turbines. Arduino Uno R3 as a circuit controller for the system using the Atmega 328 microcontroller [28]–[30]. 16x2 LCD as a display that displays the results of measurements in the form of characters. SD Card Module as a controller in the process of storing measured data. SD Card as a storage place for measurement data.

### A. System workflow

Figure 2 illustrates the process of the working system of the device, starting from the conditioning of the SD card module to regulate the RTC (Real Time Clock) and detect the presence of an SD card. The RTC aimed to set the timing during the data retrieval. When the RTC was active, the SD card module would detect the SD card inside the module and open the file in the SD card, according to the file name in the Arduino program. When the SD card was undetected, the Arduino would conduct the SD card module until detected. When the file opened, the Arduino would read the data in the file and start to conditioning the current and the voltage sensors so that they could read the measurement results. The

results would be processed by the Arduino, displayed on the LCD, and stored in the SD card.

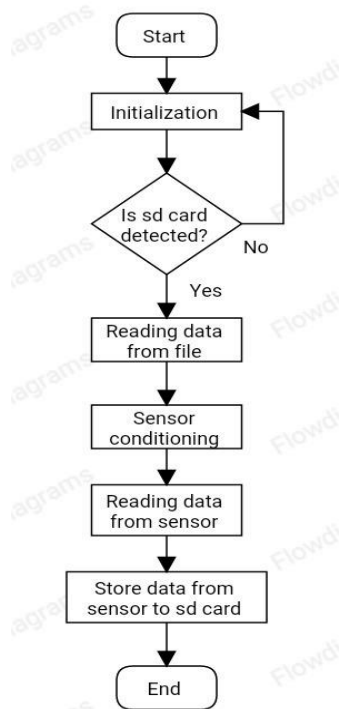


Fig. 2. System workflow diagram

### B. Hardware design

The hardware design of the device began with testing each component to be used, designing the device, and creating the working system of the device. The sensor used was WCS1800 as the current sensor and CR5310-300 as the voltage sensor, as inputs which would be processed by the Arduino Uno microcontroller. The results of the readings from sensors were analog signals so that the output of the current sensor was on pin A1, and the output of the input voltage sensor was on pin A0. Pins A0-A5 were the ADC pins or input pins to convert analog signals into digital signals in the form of binary numbers. The binary numbers were then being processed by the Arduino to be converted to volts for the voltage sensor output and amperes for the current sensor output. The results of the conversion were displayed on the 16x2 LCD and stored in the SD card.

### C. Firmware design

The analog signal or ADC from the sensors read by the Arduino would be stored in an array. The reading was done 20 times. When the data read was less than 20 times, it would be re-read by the ADC, otherwise, the process would continue using the average calculation of the data, processed by the conversion formula into a voltage. The voltage would be processed by equations that had been entered into the program. The results of the equations would be displayed on the LCD and stored in the SD card, and the process had completed.

### D. Matlab program design

The measurement data processing from analog into digital signal data used a Matlab design. The data processing served

to determine the characteristics of the sensors used. The characteristics of the sensors were essential to identify because the values of the sensor output were strongly influenced by them. Besides, each sensor had different characteristics, even though it had the same type. A linear regression equation of the relationship between the standard device and the designed device identified the characteristics of the sensor. The final step was to enter the value of the equation into the Arduino program.

## III. IMPLEMENTATION

### A. Characteristic of the current sensor

Testing the characteristics of the current sensor was carried out to determine the zero point of the current sensor reading. The sensor obtained an input voltage from a 5-volt power supply. The mechanism of testing was: the sensor input pin was connected to the positive PIN on the power supply, the ground pin on the sensor was connected to the negative pin on the power supply, and the current sensor output pin was connected to the red probe on the multimeter. Furthermore, the cable line was connected to the power supply, and the load was passed on the coil with the Hall effect principle. The test result of these characteristics showed 2.4952 V at 0.010A, or when all loads were off. Figure 3 shows the current sensor test.

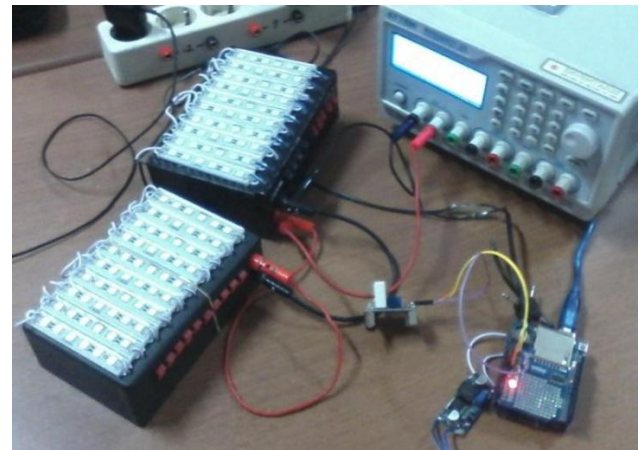


Fig. 3. Current sensor test

### B. Characteristic of the voltage sensor

Testing the characteristics of the voltage sensor was performed to determine the zero point of the voltage sensor reading. The sensor obtained an input voltage from a 12-volt power supply and increased it by using a DC-DC step-up converter to 24 volts. The mechanism of testing the voltage sensor characteristics: Pin 1 sensor was connected to the positive input voltage on the power supply, pin 3 to the negative input voltage on the power supply, pin 5 to the positive output voltage on the converter, pin 6 to the negative output voltage on the converter, and pin 8 to the red probe on the multi-meter. The test results of these characteristics showed -17mV at 0 volts. Figure 4 shows the voltage sensor test.

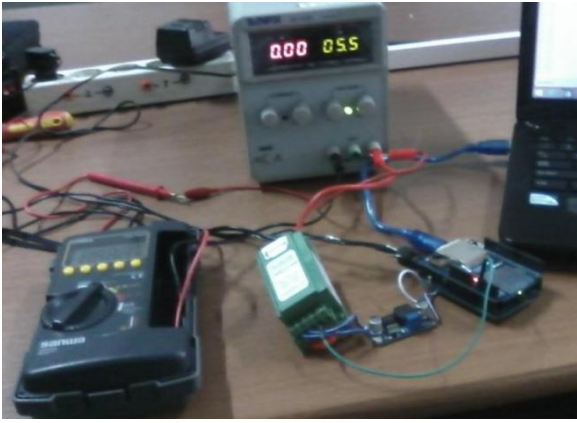


Fig. 4. Voltage sensor test

C. Datalogger test

The data logger test was performed to determine whether it worked properly or not.

IV. RESULT AND DISCUSSION

This chapter discusses the results of testing current and voltage sensors using a standard clamp meter. In the test, the sensor output was still in the form of voltages ranging from 0-5 volts. The test results would be compared to the standard device to determine the characteristics of the sensor using linear regression equations so that the results of the sensor readings would be more accurate.

A. Current sensor calibration

Table 1 presents the results of the calibration of the sensor measuring device with the standard clamp meter. The following are the results of the calibration of the device using Matlab. Standard Uncertainty = 0.155 A. Uncertainty in Readability = 0.028868 A. Coverage Factor = 2. Accuracy = 99.9816%.

TABLE I. CURRENT SENSOR CALIBRATION RESULT

No.	Standard (A)	Tested (A)	Standard Deviation (A)	Error (A)
1	0.00	-0.02	0.05	0.02
2	1.20	1.24	0.03	-0.04
3	2.50	2.42	0.05	0.08
4	3.40	3.51	0.04	-0.11
5	4.50	4.53	0.06	-0.03
6	5.30	5.39	0.05	-0.09
7	6.50	6.43	0.05	0.07
8	7.50	7.40	0.04	0.10
9	8.30	8.16	0.04	0.14
10	9.00	8.96	0.06	0.04
11	9.70	9.53	0.09	0.17

Based on the results of the calibration presented in the table, the measurement results of the device using the WCS 1800 sensor and the standard clamp meter, the uncertainty of the current measuring instrument was 0.316 amperes, at the standard current 0 - 9 amperes, and 0.317 amperes, at the standard current of 9.7 amperes with an accuracy of 99.98%.

Figure 5 shows the comparison of the calibration results between the current measuring device (A) to the standard current (A).

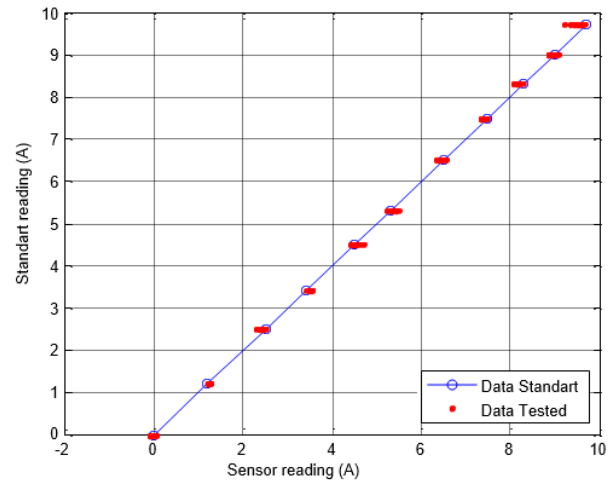


Fig. 5. Calibration graph of the current sensor

B. Voltage sensor calibration

Table 2 presents the results of the calibration of the voltage measuring device with the standard clamp meter. The following are the results of the calibration of the device using Matlab. Standard Uncertainty = 0.05 V. Uncertainty in Readability = 0.028868 A. Coverage Factor = 2. Accuracy = 99.992%.

TABLE II. VOLTAGE SENSOR CALIBRATION RESULT

No.	Standard (V)	Tested (V)	Standard Deviation	Error (V)
1	2.00	2.02	0.34	-0.02
2	4.00	4.02	0.41	-0.02
3	6.00	5.94	0.33	0.06
4	8.00	7.92	0.37	0.08
5	10.00	10.01	0.26	-0.01
6	12.00	11.99	0.35	0.01
7	14.00	13.82	0.29	0.18
8	16.00	15.84	0.40	0.16
9	18.00	18.00	0.39	0.00
10	20.00	19.81	0.32	0.19
11	22.00	21.77	0.37	0.23

Based on the results of the voltage sensor calibration presented in Table 2, the measurement results of the device using the CR5310 sensor and the standard clamp showed expanded uncertainty (U95) of 0.333, 0.341, 0.332, 0.336, 0.326, 0.334, 0.328, 0.340, 0.338, 0.331, 0.337 volts on the standard voltage of 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22. Figure 6 shows the comparison between the calibration results of the voltage gauge (V) and the standard voltage (V).

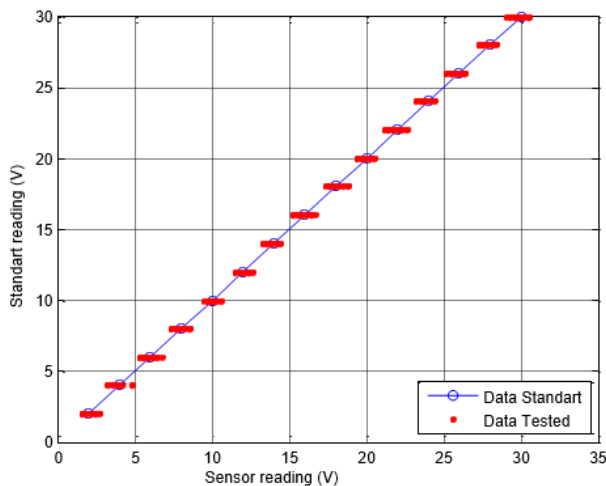


Fig. 6. Calibration graph of the voltage sensor

The characteristics of the current sensor (WCS1800) and the voltage sensor (CR5310) are 0.99966 for the current sensor and 0.99951 for voltage sensors. The WCS1800 current sensor and CR5310 voltage sensor provide almost all the information needed to predict a good variation of the dependent variable because of the determination of the current sensor. The sensitivity of the current sensor (WCS1800) is 0.29253 A/ADC, and the voltage sensor (CR5310) is 0.072978 V/ADC. The sensitivity values of the sensors greatly affect the accuracy of the device. The values of the accuracy level of the sensor in characterization testing are 99.9816% for the current sensor and 99.992% for the voltage sensor.

## V. CONCLUSION

Based on the results of research using the heuristic method in the manufacture of DC and voltage measuring device conducted by the author, it can be concluded that the results of the sensor characteristics are very influential on the measurement and will certainly affect the calibration results of the device because the sensitivity of the sensor will affect the accuracy of device. The results of this study have found that the accuracy rate for the voltage measuring is 99.992%. The uncertainty of the current measuring instrument was 0.316 amperes, at the standard current 0 - 9 amperes, and 0.317 amperes, at the standard current of 9.7 amperes with an accuracy of 99.98%. Based on the research results, the current and voltage measuring instrument maintain a good accuracy level.

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