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SCADA-based Low-Cost Single Phase AC Generator Control Laboratory Kit

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Abstract. In the power plant, SCADA is used to monitor, control the generator, voltage, current, frequency, and rotation of the generator, in the form of variable values and graphs. One of the factors that become an obstacle in realizing a laboratory to support practicum-based learning is the problem of cost. The purpose of this laboratory kit is to simulate low-cost, affordable, and portable electric power generation. The power generation simulation equipment consists of a 1-phase AC generator with a capacity of 1000 watts of the Dongfeng ST3 brand with a load of 370 watts in the form of an induction motor and driven by a 3-phase 2000-watt Hitachi motor as the prime mover. Parameters of voltage and current values using current and voltage transducers connected to the MAD 42 analog input-output module, control of the system to be made using PLC (Programmable Logic Control) Omron 1CJ1M CPU12 32 I/O. 3 phase inverter is used as a 3 phase motor driver which will regulate the rotational speed of the generator to keep it constant at 1500 rpm. Control and monitoring equipment on the Dongfeng ST3 brand 1 phase AC generator with a capacity of 1000 watts is carried out through SCADA CX Supervisor 3.2. The results of the analysis of the cost of laboratory kit equipment are significantly cheaper than the commercial prices of similar laboratories so that the procurement burden is no longer burdensome to the institution. The simulation obtained is in the form of generator control at 1500 rpm rotation with the generator voltage remaining stable in the range of 210-230 V AC both on generator measurement and display on SCADA. While the generator frequency is constant at 50/60 Hz with the current value at the generator itself of 2.66 A, and 2.71 A on the SCADA display when there is a load. In the future, a low-cost, single-phase AC generator control laboratory kit based on SCADA can be applied to PLTMH applications and practical simulation tools for Electrical Power courses for students.

I. INTRODUCTION

The need for technical laboratory equipment becomes absolute when practicum-based learning is carried out in the classroom,[1]. The minimal budget for the procurement of laboratory kit equipment makes it difficult to realize obstacles in realizing practicum-based learning. [2]. This study provides an overview of a low-cost laboratory kit [2], [3] for undergraduate practicum. Low-cost laboratory kits are designed to reduce costs for component realization while still paying attention to functions and learning outcomes after learning is still achieved at the end of the practicum. This low-cost laboratory kit is applied to simulate the generation of electrical energy from a 1-phase AC generator based on Supervisory Control and Data Acquisition (SCADA), [4]. SCADA in this case is used to control the generator, frequency, voltage, current, and rotation of the generator, [5],[4] in the form of variable values and graphs. Monitoring and controlling with SCADA [6], [7.],[4] is easy This is done only by observing the display on the Human Interface (HMI) monitor screen [8] [9] in the form of generator rotation, voltage, current, and frequency). This low-cost laboratory kit equipment was proposed due to a large number of procured laboratory kits similar to the results of the manufacture. The components of this low-cost laboratory kit consist of a 1 phase AC generator with a capacity of 1000 watts, an induction motor as a load, a 3 phase motor as a prime mover, a MAD 42 transducer for current and voltage, PLC (Programmable Logic Control) Omron 1CJ1M CPU12 32 I/O for control [10], a 3-phase inverter is used as a motor rotation stabilizer [11], [12] and SCADA CX Supervisor 3.2. as a monitoring display [8], [9].

II. RESEARCH METHOD

The research methodology used includes the stages of data collection, component requirements analysis, software, and hardware design, and tool testing. At the component requirements analysis stage, the components needed are realized through 2 steps, namely first, using components that are in the laboratory to be reused as support for low-cost laboratory kits, secondly, procurement of laboratory kit components by procuring new components. In the realization of this inexpensive laboratory, the kit consists of; AC generator as a voltage generator that will be driven by a 3-phase induction motor as a prime mover. The rotation speed of a 3-phase induction motor is regulated by a 3-phase inverter via a computer using the CX Supervisor 3.2 software application. The value of generator rotation, current, and voltage on the generator will be displayed on the computer. Data in the form of voltage and current values , as well as rpm, will be recorded in real-time on the computer. In the designed SCADA [5] display, the data displayed is also in the form of a graph. The following diagrams and systems are made:

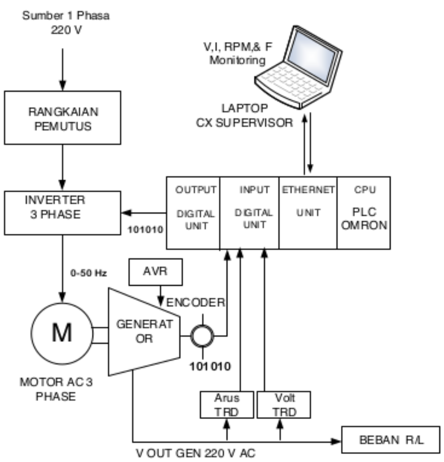

Figure 1 Scada Block Diagram For Generator Control and Monitor

From the block diagram above, the control system for the generator is controlled and monitored by SCADA CX Supervisor 3.2.[5]. The generator is rotated using a 3 phase motor as the prime mover, and the motor rotation is regulated by a 3 phase inverter. The input from the inverter setting is an analog voltage of 0-10 Volt DC from the PLC. The voltage generated by the generator is a voltage of 220 V AC after receiving a voltage amplifier from the outside, the value of the voltage and current is monitored by SCADA[13],[14]. Current transducers and voltage transducers function to convert from current and line voltage to a current of 4 – 20 mA. The output current from the transducer is then used as input to the analog input which is then processed and displayed in a computer instrumentation system, namely by CX Supervisor. The generator rotation speed is detected by the encoder, from the encoder data in the form of pulses it will be processed into an rpm display and at the same time as feedback to the motor rotation as the generator's prime mover.

A. *System Design, Control, and Power Installation*

The design is divided into 2 parts; namely hardware and software design. The hardware design includes the design and manufacture of actuators for generator coupling. The design and installation of power in this study use an inverter with one-phase input and three-phase output. The selection of one phase is expected to be easy and can be used for single-phase sources so that it can be used on single-phase sources at home or in installations with low power. The voltage source used in this case is a single phase 220 V AC voltage.

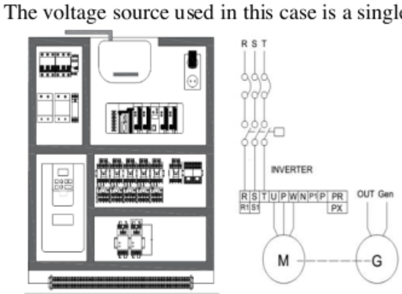

Figure 2 Power Circuit and Control Panel Wiring Diagram

B. *Perancangan Ladder dan Pembuatan Screen*

Pada perancangan ini untuk pemrograman PLC Omron menggunakan software CX Programmer versi 9.6. CX Programmer adalah aplikasi program dari Omron yang digunakan untuk pembuatan ladder khusus pada PLC Omron. Berikut Jendela tampilan CX Programmer.

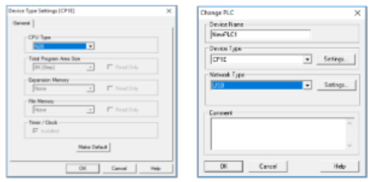

Figure 3 Jendela Tampilan CX Programmer

C. *Ladder Design and Screen Making*

In making this system, the PLC used is PLC OMRON CJ1M CPU 21. This PLC has an Input ID 211 module with 16 input points with the address 00.00 – 00.15. It has an OC211 output module with 16 outputs with an output address point of 1.00 – 1.15. The communication module has an ETN 21 module. The analog input and analog output modules use DAO21 and ADO41.

III. RESULTS AND ANALYSIS

A. *Low-cost analysis laboratory kit*

The components needed in the realization of low-cost laboratory kits go through two stages, namely, the use of old components (upgrades) that exist in the laboratory while still prioritizing functions and support with the laboratory kit design, secondly purchasing new components taking into account the price and specifications of needs. The result is that the cost of realizing a low-cost laboratory kit is cheaper than a similar factory-made laboratory kit.

B. *Device assembly*

In this study, a series of systems for control panel generator operation that can be controlled and monitored by a computer with a SCADA interface with CX Supervisor 3.2 is made. The results of the component assembly in the test are as shown in the image below:

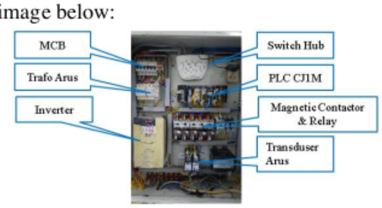

Figure 4 Generator Control Device and monitor

The assembled device consists of a control box, an actuator in the form of a motor coupled to a generator, and a network device in the form of a switching hub. Communication between PLC and SCADA is connected through a switching hub.

C. *Design of SCADA Interface with CX Supervisor*

The interface screen created consists of four pages. The first screen is the main menu as the operational plant page. The second page displays current values and graphs. The Third Page displays voltage values and graphs. The fourth page displays generator speed values and graphs. Below is the SCADA interface display screen with CX Supervisor 3.2.

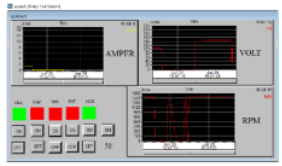

Figure 6 Tampilan Layar SCADA dengan CX Supervisor

The results and discussion include testing the readings of the voltage, current, and generator rotation values when no load and inductive load on the SCADA interface display and testing of current and voltage transducers.

IV. TESTING AND ANALYSIS

A. Testing of Voltage Value Readings in SCADA and Voltage Transducers

In this study, the generator is controlled and monitored using the SCADA interface. This test is done by reading the voltage value on the SCADA interface on the computer and testing the voltage transducer output and the data read in the PLC memory. The following is a table for testing the results of measurements carried out by adjusting the Field voltage on the Generator.

Table 1 Testing the Voltage value at SCADA and Voltage Transducer Output

Field Voltage (V)	Out Generator (V)	SCADA (V)	Output transducer mA	hex PLC
0	0	0	4	0
3	25	24	5.98	495
6.2	50	49	7.92	979
9.43	75	74	9.88	1468
13	100	98	11.96	1985
17.15	125	124	13.94	2480
22.26	150	148	15.85	2960
32.39	175	173	17.98	3487
50.2	200	198	19.5	3870
70	220	219	20	3950

From table 1 above, it can be seen that the voltage value displayed on SCADA has a value that is close to the voltage value on the generator by measuring using a voltmeter. The difference in the average measurement results is 1 volt.

B. Testing of Current Value Readings in SCADA and Current Transducers

In this study, the generator is controlled and monitored using the SCADA interface. This test is done by reading the current value on the SCADA interface on the computer and testing the current transducer output and the data read in the PLC memory. In this test, the generator is given an inductive load in the form of an induction motor. To get a varying current, the field voltage in the generator is set by changing the field voltage on the generator. The following is a table for testing the results of measurements carried out by adjusting the Field voltage on the Generator.

Table 2 Testing the Current Value in SCADA and Current Transducer Output

Out Generator (V)	Arus Generator A	Hex PLC	Out transducer mA	SCADA A
0	0	0	0	0
40	0.56	230	4.59	0.55
75	1.02	254	5.08	1.02
110	1.53	282	5.63	1.52
150	2.03	308	6.16	2
185	2.51	334	6.67	2.47
220	3.01	360	7.21	2.98

From table 2 above, it can be seen that the current value displayed on SCADA has a value that is close to the current value in the generator by measuring using an ammeter. The difference in the average measurement results is 0.03 Ampere

V. CONCLUSION

A low-cost laboratory kit designed to simulate the generation of electrical energy from a 1-phase AC generator based on Supervisory Control and Data Acquisition (SCADA) according to the initial plan. The designed SCADA system can control and monitor voltage, current, and rpm to function properly. . In the future, the SCADA-based low-cost single-phase AC generator control laboratory kit can be applied to PLTMH applications and practical simulation tools for electricity courses for students.

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GENERAL COMMENTS

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FOCUS

State a clear claim/topic sentence and stay focused on supporting it.

MEETS EXPECTATIONS	A precise claim/topic sentence based on the historical topic and/or source(s) is present. The response maintains a strong focus on developing the claim/topic sentence, thoroughly addressing the demands of the task.
APPROACHES EXPECTATIONS	A claim/topic sentence based on the historical topic and/or source(s) is present, but it may not completely address the demands of the task, or the response does not maintain focus on developing it.
DOESN'T MEET EXPECTATIONS	The claim/topic sentence is vague, unclear, or missing, and the response does not address the demands of the task.

EVIDENCE

Represent relevant historical information accurately.

MEETS EXPECTATIONS	The most appropriate evidence is presented to support the topic sentence, and all information is historically accurate.
APPROACHES EXPECTATIONS	Appropriate evidence may be presented to support the topic sentence, but it may be inadequate or contain some historical inaccuracies.
DOESN'T MEET EXPECTATIONS	Evidence is general, inappropriate, or inadequate in support of the topic sentence, or is largely inaccurate.

DEVELOPMENT

Explain how evidence supports the topic sentence.

MEETS EXPECTATIONS	The response demonstrates reasoning and understanding of the historical topic and/or source(s), and sufficiently explains the relationship between claims and support.
APPROACHES EXPECTATIONS	Some reasoning and understanding of the historical topic and/or source(s) are demonstrated. The response attempts to explain the relationship between claims and support.
DOESN'T MEET EXPECTATIONS	The response does not demonstrate reasoning and understanding of the historical topic and/or source(s), and explanation of the relationship between claims and support is minimal.

ORGANIZATION

Present ideas in a logical structure that shows the relationships between ideas.

MEETS EXPECTATIONS	An effective organizational structure enhances the reader's understanding of the information. The relationships between ideas are made clear with effective transitional phrases.

APPROACHES EXPECTATIONS	An organizational structure is evident, but may not be fully developed or appropriate. Transitional phrases may be used but the relationships between ideas are somewhat unclear.
DOESN'T MEET EXPECTATIONS	An organizational structure is largely absent and the relationships between ideas are unclear.

LANGUAGE

Communicate ideas clearly using vocabulary specific to the historical topic.

MEETS EXPECTATIONS	Ideas are presented clearly, using vocabulary specific to the historical topic. If errors in conventions are present, they do not interfere with meaning.
APPROACHES EXPECTATIONS	Ideas are mostly clear, using some vocabulary specific to the historical topic. Some errors in conventions are present that may interfere with meaning.
DOESN'T MEET EXPECTATIONS	Ideas are not clear, using little to no vocabulary specific to the historical topic. Several errors in conventions interfere with meaning.