Indonesian Journal of Electronics, Electromedical Engineering, and Medical Informatics
Multidisciplinary : Rapid Review : Open Access Journal Vol. 4, No. 4, November 2022, pp.192-198 e-ISSN: 2656-8624

RESEARCH ARTICLE OPEN ACCESS

Manuscript received June 03, 2022; revised September 01, 2022; accepted September 01, 2022; date of publication November 28, 2022
Digital Object Identifier (**DOI**): https://doi.org/10.35882/ijeeemi.v4i4.251

How to cite: Sindy Yurisma Sheila, Nur Wakhidatur Rochamwati, Faris Riyadi, Reza Fardiyan As'ad, Anggara Trisna Nugraha, "Desain and Build a Medium Voltage Cubicles Temperature and Humidity Optimization Tool to Minimize the Occurrence of Corona Disease with the PLC-Based Fuzzy Method", Indonesian Journal of Electronics, Electromedical Engineering, and Medical Informatics, vol. 4, no. 4, pp. 192–198, November. 2022.

Desain and Build a Medium Voltage Cubicles Temperature and Humidity Optimization Tool to Minimize the Occurrence of Corona Disease with the PLC-Based Fuzzy Method

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ABSTRACT Cubicle is an electrical device that functions as a breaker, protector, connector, controller, and divides the electric power system from an electric power source and reduces sparks when connecting. One of the problems that occur in medium voltage cubicles is the presence of corona. Corona phenomena at cubicle terminations can trigger disturbances such as a decrease in insulation quality, power loss and a significant increase in harmonic distortion. In this study, raised a problem regarding the optimization of temperature and humidity in cubicles using the fuzzy method to stabilize the performance of medium voltage cells. The purpose of this research is to control the temperature and humidity in the medium voltage cubicle so that it is optimal so as to minimize the occurrence of corona discharge. In addition, in this study there is a fuzzy method for controlling the fan and has been equipped with SCADA for monitoring and controlling the center of several parameters such as temperature, humidity, voltage, current and power. In this study, it was found that the fuzzy method in this prototype was able to stabilize the panel humidity at 55% RH and stabilize the panel room temperature at 31.5oC. Thus, it is hoped that a stable and optimal temperature and humidity can minimize the occurrence of corona. The use of HMI/SCADA based applications can facilitate the ability of the user (operator) to monitor several available parameters and manually control the operation of the panel (on/off).

INDEX TERMS Cubicel, Fuzzy, Humidity, Temperature.

I. Introduction

Medium Voltage is an electric voltage with a capacity of 3 kV to 36 kV[1]. Medium voltage cubicle is one of the electrical equipment that functions as a controller, connector, breaker, protector and divides the electric power system from an electric power source and is useful for reducing sparks that occur when connecting[2]. Cubicles are usually installed on distribution substations or connecting substations in the form of concrete or kiosks[3]. Blackout in medium voltage distribution network can occur due to internal or external failures. Internal disruptions can occur due to connection errors between underground cables, corona, cubicle termination faults, underground cable faults, cubicle faults, transformer faults, and CT faults[4]. However, one of the problems that often occurs in medium voltage cubicles is corona[5]. Corona is a phenomenon that occurs when the air around a conductor or conductor is ionized. From this process, there is a discharge that can result in the failure of the insulation in the air[6]. According to research data, it was found that the T-241 cubicle of the Menteng Command Post experienced power losses of 3.88 kW. Meanwhile, in the K-245 cubicle, the Menteng post experienced power losses of 3.45 kW. However, corona can be minimized by optimizing the temperature and humidity in the cubicle[7].

Based on research[8] one way to optimize the temperature and humidity values in the cubicle is to use a fan and heater. Fan and heater control is carried out based on the temperature and humidity values on the panel that are read on the sensor[9]. When the temperature value in the cubicle is high, the fan will operate to circulate air in the cubicle space. So that the temperature in the cubicle can decrease. Then, when the humidity value in the cubicle is high, the heater will operate to lower the humidity value. However, the weakness of this research is that there is no fan control method, so the temperature in the cubicle cannot be optimal.

The next problem is that according to a field survey conducted by researchers, it can be seen that the distance between one High Voltage Substation and another is at least ±500 meters and the maximum is ±2 kilometers. So that monitoring and maintenance takes a long time due to the long distance. Currently, monitoring data on cubicles for each Medium Voltage Substation at the Port of Tanjung Perak Surabaya is only carried out once a month to collect data on electricity consumption (kWh) for the last 1 month or when a disturbance occurs in the cubicle. In fact, if routine monitoring is carried out, it can minimize disturbances that occur in the cubicle. Therefore, in the opinion of[10] there is a need for a real time monitoring system for several parameters in the cubicle to facilitate cubicle monitoring.

Based on the existing problems, the researcher wants to design a medium voltage cubicle temperature and humidity optimization tool to minimize the occurrence of corona disease using a PLC-based fuzzy method. The system can control temperature and humidity, so that the temperature and humidity in the cubicle can be optimal. Optimizing the temperature and humidity will minimize the occurrence of corona. So that the losses caused by the corona such as power losses, sparks can be minimized and the performance of medium voltage cubicles can be stable. The contribution of this paper are in this study there has been a fuzzy control method for controlling the fan in order to stabilize the room temperature and controlling the heater to stabilize the humidity on the connection panel for maximum low voltage. In this study, SCADA has been equipped for monitoring and controlling the parameters on the prototype such as temperature, humidity, voltage, current and power.

II. Material And Method

A. Material

1. Medium Voltage Cubicle

Medium Voltage Cubicle is a set of electrical equipment installed at the Substation and Distribution Substation / Substation that serves as a divider, breaker, connector, controller and safety medium voltage power distribution system [11] (FIGURE 1 (a)). Medium voltage cubicles are usually found in substations or distribution substations[12]. Cubicles are often defined as switching equipment and combinations thereof, equipped with measurement, control and protection equipment, while according to[13] Medium-voltage cubicle is an electrical component that is connected to a 20kV medium-voltage power grid.

2. PLC M211 Scneider

Programmable logic controllers (PLC) are special-purpose embedded devices used in various industries for automatic control of physical processes[14]. PLC M221 is a digital electronic device with memory produced by Scheneider and can be programmed to store instructions that perform functions such as: logic, sequences, timing, arithmetic and counting (FIGURE 1 (b). The process of removing the output in the PLC M221 process in issuing data to be issued which is added to the PLC M221 [15]. With a working system using a PLC, the production process will be easier because the machine's performance can be controlled using a computer system[16].

(a) (b)

FIGURE 1. (a) Medium Voltage Cubicles, (b) PLC Schneider

3. SHT20 Sensor

The SHT20 sensor contains a capacitive-type humidity sensor, a bandgap-type temperature sensor, and dedicated analog and digital integrated circuits – all on a single CMOSens (FIGURE 2 (a). The reading of the SHT20 sensor in the humidity level reading is in the range of 0 – 100 %RH with an accuracy rate of ±3.0 %RH. While the reading of the temperature value is in the range of -40 – 125 ^{0}C with an accuracy level of ±0.3 ^{0}C [17] . SHT20 with a double-column flat and no pin DFN for reflow welding Package, operating power is very low, even in high humidity environments, can be more stable operation. It is characterized by the following: using standard I2C digital signal communication; Humidity accuracy resolution 12-bit, temperature resolution 14-bit; In the 8-bit measurement; In the 1 second/time case, Power consumption:1.5uw[18]. In addition, SHT20 is small in size, fast in response, low in energy consumption, immersible, strong in anti-interference ability, integrated in temperature and humidity, and has dew point measurement[19].

(a) (b) (c)

FIGURE 2. (a) Temperature and Humidity Sensor, (b) Digital temperature sensor, (c) Dry heater

4. MLX90614 Sensor

The MLX90614 temperature sensor is an infrared thermometer for temperature measurement without touching objects (FIGURE 2 (b)). As PWM 10 bits will show temperature changes which will be measured continuously with the temperature range on the sensor -40°C to 120°C and the object range from -70°C to -380°C [20]. The thermometer comes factory calibrated with a digital PWM and SMBus (System Management Bus) output. As a standard, the 10-bit PWM is configured to continuously transmit the measured temperature in the range of -20-120˚C, with an output resolution of 0.14˚C[21].

5. Heater

The heating element used is divided into two, namely the initial form heating element and the advanced form heating element (FIGURE 2 (c). Advanced form heating elements have been developed, such as adding a metal pipe or sheet plate to the heating element body[22].

6. Cooling Fan

Cooling fan is a component that functions to remove heat and replace it with fresh air into the interior of the room, the shape of the device is like a fan in general but is so small with dimensions of 12 cm x 12 cm[23].

B. Methode

Fuzzy logic control belongs to the class of "intelligent control", "knowl-edge-based control", or "expert control". Even though it is incorrect to claim that fuzzy logic control is always better than the conven- tional types of "crisp" ("hard" or "inflexible") control, it has several advantages [24]. Fuzzy logic is an extension of Boolean logic by Lotfi Zadeh in 1965 based on the mathematical theory of fuzzy sets, which is a generalization of the classical set theory. By introducing the notion of degree in the verification of a condition, thus enabling a condition to be in a state other than true or false, fuzzy logic provides a very valuable flexibility for reasoning, which makes it possible to take into account inaccuracies and uncertainties. One advantage of fuzzy logic in order to formalize human reasoning is that the rules are set in natural language [25].

Fuzzy system consists of 4 components, namely Fuzzy rule base, Fuzzy inference engine, Fuzzy generator (fuzzifier), and confirmation (defuzzifier) [26] . Fuzzy logic has 3 methods, namely fuzzy Tsukamoto, Sugeno, and Mamdani. In this study using fuzzy logic with the Sugeno method. The Fuzzy Sugeno method is often called the Max-Min method. This fuzzy has an output (consequent) system not in the form of fuzzy sets, but in the form of constants or linear equations. The Sugeno fuzzy inference system method is also called the TSK fuzzy inference system method which was introduced by Takagi, Sugeno and Kang [27] .

1. Fuzzification

Fuzzification is a process that aims to change a non-fuzzi variable or numerical variable into a fuzzy variable or linguistic variable. The input value which is still a numerical variable that has been quantified before being processed by the fuzzy controller must first be converted into a fuzzy variable. Through the inverse member function, the input value is converted into fuzzy information, which is also useful for later fuzzy processing. The fuzzy input parameters at the panel room temperature are divided into 4, namely low, normal, high, and very high with the function of each membership as shown in Figure 3.

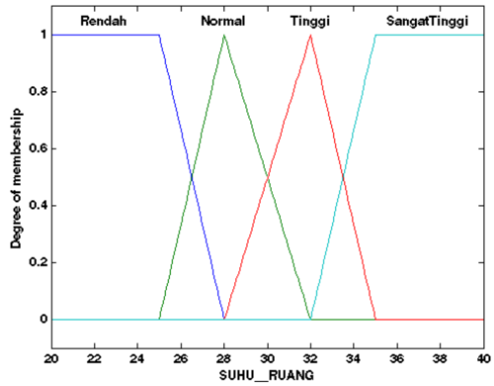


FIGURE 3. Panel room temperature input

Based on the Membership Function in Figure 3, the formula for each Membership Function is as follows:

a. Low Temperature (x)

<25
$(;20,20,25,28) = \{ \frac{1\ 28}{28\ 25\ 0}$ 25 28
>28 (1)

b. Normal Temperature (x)

<25
$(;25,28,32) = \{ \frac{1\ 28}{28\ 25\ 0}$ 25 28
$\frac{32}{32\ 28\ 0}$ 28 32
>32 (2)

c. High Temperature (x)

<28
$(;28,32,35) = \{ \frac{0\ 28}{32\ 28}$ 28 32
$\frac{35}{35\ 32\ 0}$ 32 35
>35 (3)

d. Very High Temperature (x)

<28
$(;28,32,35) = \{ \frac{0\ 28}{32\ 28}$ 28 32
$\frac{35}{35\ 32\ 0}$ 32 35
>35 (4)

2. Inference

Fuzzy rules are used to map several possible outputs from a combination of input parameters. There are 16 fuzzy rules used to design this FIS, as shown in Table 1.

TABLE 1
16 Rule Fuzzy

No	Input Panel Room Temperature	Output fan RPM
1.	Low	Slow
2.	Low	Slow
3.	Low	Normal
4.	Low	Normal
5.	Normal	Normal
6.	Normal	Normal
7.	Normal	Normal

8.	Normal	Fast
9.	Tall	Fast
10.	Tall	Fast
11.	Tall	Fast
12.	Tall	Very fast
13.	Very high	Very fast
14.	Very high	Very fast
15.	Very high	Very fast
16	Very high	Very fast

3. Defuzzification

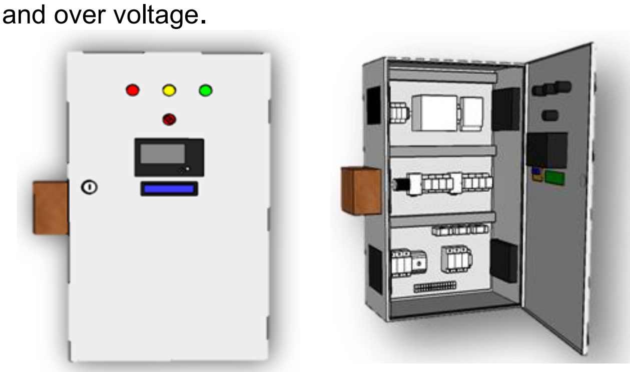
The processing results from the fuzzy algorithm will be read by the controller which is used as a reference to control the intake and exhaust fans. The results of the membership function are listed in TABLE 2.

TABLE 2
Output Rpm Intake and Exhaust Fan

RPM Intake fan		RPM Exhaust Fan	
RPM	Category	RPM	Category
575	Slow	575	Slow
1150	Normal	1150	Normal
1725	Fast	1725	Fast
2300	Very fast	2300	Very fast

C. Desain Concept

Figure 4 (a) is a prototype design concept that will be designed. In which the panel design planning process uses the SketchUp software [28] . This tool is equipped with a heater located on the outside of the panel which is used to stabilize the humidity on the panel; there are 5 fans on the right and left sides of the panel where 4 fans are used to stabilize the temperature on the panel and 1 fan is used to channel the temperature from the heater to maintain humidity on the panel; 3 pilot lamps that function as phase failure indicators; 1 buzzer that functions as an indicator when there is under voltage and over voltage.



(a) (b)

FIGURE 4. **(a) Prototype Design Front View, (b) Prototype model**

In the prototype, there are several hardware used to support the performance of the system to be made (FIGURE 4(b)). In hardware design there are three main components [29], namely the input in the form of the PM1200 Power Meter, Arduino which has read the MLX90614 sensor, and the SHT20 sensor. Controller consisting of PLC M221 and Arduino Nano. As well as outputs consisting of incoming and outgoing relays (aux relays), heater control relay, L298N module as fan control [30]. FIGURE 5 and FIGURE 6 is an illustration of the hardware design that will be made.

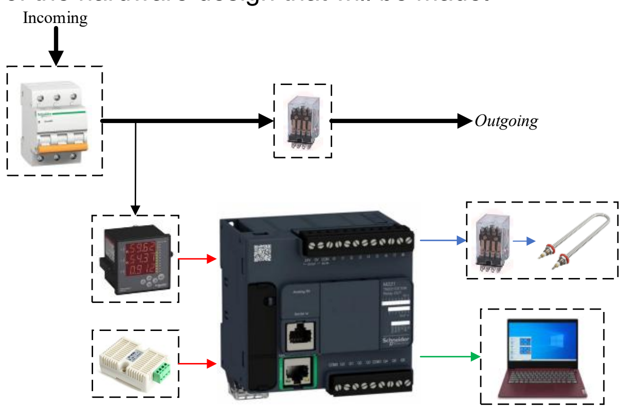


FIGURE 5. **PLC System**

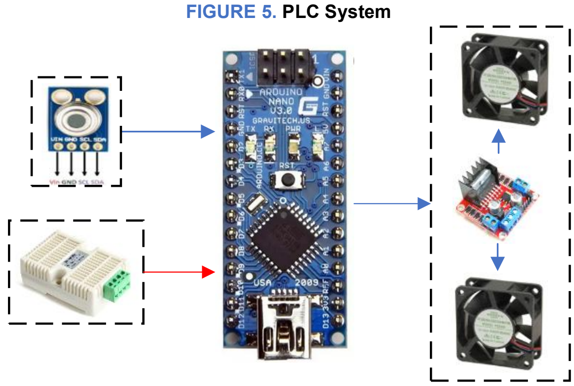


FIGURE 6. **Microcontroller System**

III. Result

In this study, testing was carried out for the success rate of the medium voltage cubicle temperature and humidity optimization tool. The tests were carried out at the Instrumentation Laboratory and the Electrical Machinery Laboratory of the Surabaya State Shipping Polytechnic. The test was carried out into 2 parts, namely, humidity control testing and temperature control testing.

A. Humidity Control Test

The humidity control test aims to determine the effectiveness of using the heater control to reduce the humidity level in the panel so that the humidity level on the panel can be controlled according to a predetermined set point. The test is carried out by increasing the humidity in the panel until it reaches 95% RH, when the humidity level reaches 95% RH, the heater will turn on automatically and will work until the humidity level decreases according to a predetermined set point of 55%RH. The data from this test is in accordance with the one attached in table 3.

TABLE 3
Moisture Control Test Data

Time(s)	Final Humidity (%RH)	Time(s)	Final Humidity (%RH)	Time(s)	Final Humidity (%RH)
0	95.14	110	61.00	220	55.35

Time(s)	Final Humidity (%RH)	Time(s)	Final Humidity (%RH)	Time(s)	Final Humidity (%RH)
10	91.23	120	59.79	230	55.25
20	87.37	130	58.78	240	55.15
30	83.18	140	57.77	250	55.07
40	79.41	150	57.37	260	54.99
50	76.25	160	56.86	270	55.09
60	73.38	170	56.36	280	55.18
70	70.14	180	56.16	290	55.29
80	67.06	190	55.95	300	55.38
90	65.12	200	55.65	-	-
100	63.13	210	55.45	-	-

The test results data in table 3 can be illustrated according to the graph attached in FIGURE 7. The purpose of this graph is to determine the heater's performance in reducing humidity on the panel and it is proven that the heater can reduce the humidity level from 95.14% RH to 55.38 % within 300 seconds.

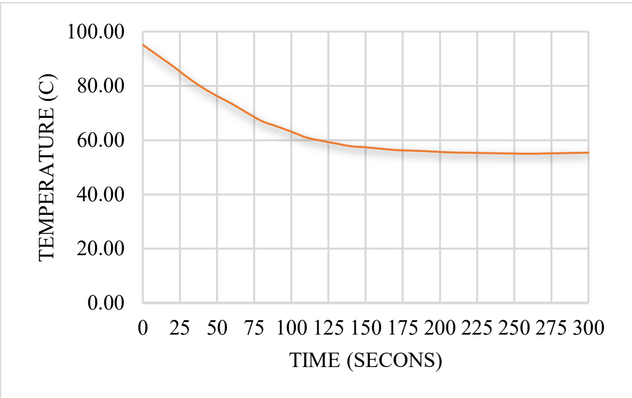


FIGURE 7. **Moisture Control Chart on Panel**

B. Temperature Control Test

The temperature control test aims to determine the effectiveness of the fan control in maintaining the stability of the room temperature on the panel so that the room temperature level on the panel can be in accordance with the predetermined set point.

TABLE 4
Temperature Control Test Data

Time (s)	Room Temperature (C)	Time (s)	Room Temperature (C
0	29.28	640	31.21
20	29.37	660	31.26
40	29.46	680	31.31
60	29.54	700	31.35
80	29.63	720	31.39
100	29.71	740	31.43
120	29.79	760	31.46
140	29.88	780	31.49
160	29.95	800	31.52
180	30.02	820	31.54
200	30.09	840	31.57
220	30.17	860	31.59
240	30.25	880	31.57
260	30.33	900	31.55
280	30.41	920	31.54
300	30.49	940	31.55
320	30.56	960	31.57
340	30.64	980	31.55
360	30.71	1000	31.56
380	30.79	1020	31.58
400	30.85	1040	31.57
420	30.91	1060	31.55
440	30.99	1080	31.54
460	31.04	1100	31.56
480	31.08	1120	31.59
500	31.13	1140	31.57
520	31.17	1160	31.56
540	30.56	1180	31.54
560	30.64	1200	31.55
580	30.71	-	-
600	30.79	-	-
620	30.85	-	-

The test is carried out by increasing the temperature of the panel room with the initial temperature of 29.28 ° C and then the panel will be heated for 1200 seconds. When the room temperature reaches 31.59 ° C, the fan will work automatically to stabilize the room temperature so that the room temperature will be stable at around 31.55 ° C. The data from this test is in accordance with the attached table 4. The data from the test results in table 4 can be illustrated according to the graph attached in FIGURE 8. The purpose of this graph is to determine the fan performance in stabilizing the room temperature on the panel, and it is proven that the fan can stabilize the room temperature when it reaches a value of 31.59 ° C.

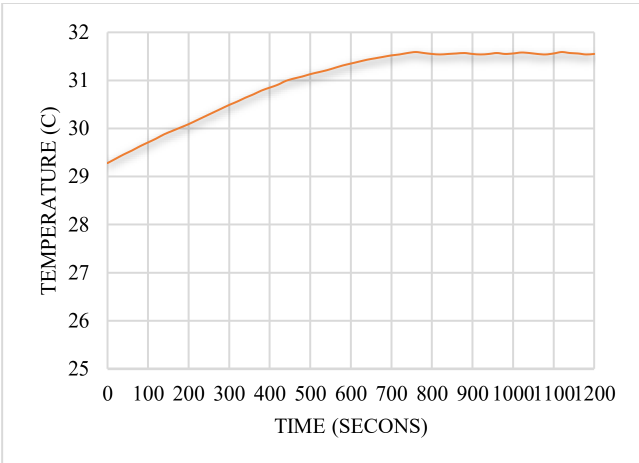


FIGURE 8. **Temperature Control Chart on Panel**

IV. Discussion

From the research that has been done, it is known that by using the Fuzzy method, optimizing the temperature and humidity in the cubicle can stabilize the performance of the medium-voltage cubicle panel. Corona is one of the problems that occur in medium cubicles. Corona causes insulation failure in the air because the air around the conductor or conductor is ionized. Many previous studies have examined controlling temperature and humidity in cubicles using fans and heaters, but the temperature and humidity have not yet reached a stable and optimal point [8]. The corona effect on cubicle terminations that can trigger disturbances such as a decrease in insulation quality, power losses, and a large increase in harmonic distortion can be stabilized and optimized with this research. In this study, it was found that the Fuzzy method in this prototype was able to stabilize the humidity of the panel at a value of 55%RH and stabilize the temperature of the panel room at a value of 31.5°C.

Based on table 3 data, it is known that when the humidity in the panel room is < 95%RH, the heater relay will be ON. So that when the heater operates, the humidity level will decrease over time. This is also evidenced by the data in table 3 where the humidity of the panel which was originally 95.14%RH becomes 55.38%RH within 300 seconds. The temperature controller chart has also proven that the fan control line using the fuzzy method makes the panel room temperature stable and optimal. Then based on the data in table 4, it is known that when the initial room temperature is 29° C, it is heated for 1200 seconds and reaches a temperature of 31.59° C, the fan relay will be ON and the fan will turn on. So that when the fan is on, the room temperature on the panel will decrease and stabilize according to the specified set point. The room temperature reaches a stable state at a value of 31.57° C. This is evidenced by the fan control line using the fuzzy method in Figure 12 which is stable and sloping.

To achieve optimal results, researchers use an HMI/SCADA-based application that is connected to the system on the cubicle panel prototype. This application can make it easier for operators to monitor several available parameters and control the operation (on/off) of the panel manually. In addition, the researcher also uses the SHT20 Sensor and the MLX90614 Temperature Sensor which functions as humidity level readings and temperature measurements without touching objects, so that the tools used will work optimally.

V. Conclusion

From the research above, it can be concluded that the results of the fuzzy method on this prototype are able to stabilize the panel humidity at 55%RH and stabilize the panel room temperature at a value of 31.5C. This research is carried out with the results or outputs in the form of prototypes and monitoring applications. This monitoring application is to achieve optimal results, researchers use an HMI/SCADA-based application that is connected to the system on the cubicle panel prototype. In this research using PLC M221 Schneider, Sensor SHT20, and Sensor MLX90614. PLC functions as a digital device and can be used to store instructions for carrying out functions. Both sensors are used for humidity level readings and temperature measurements without touching objects, so the tools used will work optimally.

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