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APPLICATION OF WIRELESS SYSTEM FOR PROTECTION SYSTEM DEVELOPMENT BASED ON FUZZY LOGIC

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Abstract. *Consumption of electrical energy on user sites will be affected by the number of the risks caused by disturbances; therefore, it is very important to control disturbances that occur and potentially cause disasters. In general, the electricity distribution management has provided a standard protection for users or energy consumers, but it still needs an improvement to provide a good protection from disasters due to early interruption, because the protection is given specifically for one type of disturbance, and the cause of the disturbance cannot be recognized easily through the protection devices. Moreover, these conditions require smarter electrical protection devices, as reviewed in this work by applying fuzzy logic to being protection devices. Technically, the use of fuzzy protection devices is intended for a decision support system that serves to show the condition of the electricity network. The parameters used include voltage, current, and temperature of the cable. In this study, the results of this work have stated in fuzzy logic that reflects the level of dangers in the status range, and it is stated in safe, alert and dangerous warnings. Regarding, these results, operating conditions are used as instructions for protective devices to cut off electricity in order to avoid damaged devices. In addition, the disturbance and its effects can be measured by considering the parameters in the fuzzification process.*
Keywords: Development, Disturbances, Electricity, Fault, Fuzzy, Protection

1. **Introduction.** Numerically, the data of electricity users have reported a significant increase with significant growth in demand. This is triggered by the use of electricity in daily activities, such as, industrial sector, the household sector, and the commercial sector [1-5]. Moreover, conditions for the growth of electricity consumers (EC) are also similar to other countries, which have experienced significant changes [1,6,10]. Operationally, the use of electrical energy must be careful, because there are quite a variety of users and it can be technically damages when having experience disturbances. Disturbances can be caused by various factors, both coming from internal or from outside parts of the system. It means that it is very important to continue and to monitor the condition of the use of electrical energy. Monitoring and control must continue to be done for electrical energy services where they are able to guarantee safe and reliable conditions for consumers who are the final users as the EC, where energy is utilized. Technically, the electric power system (EPS) complements the sub-system developed with protective facilities to anticipate the disturbances that arise. This development is expected to prevent disasters or damage when disturbances occur. In particular, electric service providers serve an electrical protection (EP) to keep each customer and existing equipment.

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Along with the expansion of the EPS network to cover all services to the load, the EP is not enough to protect users from disturbances, but also must provide a guarantee of high service continuity for the ongoing delivery of electrical power [11-16]. Therefore, changes and modifications continue to be made for all existing protective system equipment, in order to continue being able to respond to various types of disturbances that will occur and be more sensitive to the various types of disturbances. Protection systems used today are generally based on magnetic and mechanical parts. Although it can work normally, it needs to be continuously updated considering the increasingly complex function that is encountered in the operation of the EPS. On the other hand, the EP has also begun to shift its technology toward more responsive and adaptive, so that the potential use of an intelligent system is a new opportunity for development in the EPS. In addition, discussion and study of its implementation are increasingly being discussed on evolutionary computation, intelligent systems, smart systems, or others. In this work, the development of protection systems will focus on the application of a fuzzy combination to optimize decision support data considering wireless systems. Fuzzy implementation will be directed at optimizing the status of conditions so that it is faster to make decisions and be more selective about the types of disturbances. It will make easier for the operator to analyze the disturbances and take the necessary technical action.

Furthermore, this study also developed an intelligent protection device (IPD) that can be used to monitor an operational status, not just to be used to protect the whole system, but also to provide information when the system is operating to send the power output to the load. The development of this work increasingly provides more applicative advantages and it can provide information about normal or abnormal conditions due to disturbances. Normal condition status will have an impact on the system operation being on the alert step to always monitor the performance of the system, so it does not collapse when they are being disturbances. Conversely, abnormal conditions will provide information to immediately take actions stated in various levels of danger. Technically, the IPD is developed using fuzzy logic (FL) as a part of a decision support system (DSS) for making final decisions. The parameters used in fuzzy are based on the performance of the EPS, where the device is installed, which includes input voltage, current and conductor temperature. The output of the FL is the danger level after an optimization process for delivering instruction to the actuator relay system.

2. **Protective Development.** Focusing on the EPS, this system is constructed using various interrelated infrastructures, to carry out the process of generating energy, sending energy, and utilizing energy. Therefore, the EPS has the main components of the generation system, transmission and distribution systems, and the load system. One part of these systems, the protection system will be installed at various points where the installation will function to localize the effects of disturbances and occur. In relation to the effect of the disturbance, operationally all interconnection sub-systems must run well to meet all existing technical conditions and environmental stresses when operating [12,13,17]. The protection system must be able to work well and have a high response to various types of disturbances that occur. So, the effects of disturbances that occur are not widespread and the damage will be localized [18-21].

In this section, this work develops the IPD that can be used to monitor an operational status with various levels of conditioned outcomes to make decisions. Basically, the development of this device is not only used to protect the entire system but also to provide information when the system operates to deliver power outputs to the load [18,22-24]. So, as the whole process, electric power transactions can be monitored on an ongoing basis in the operating period. The development of this work is expected to improve the overall performances of the system, including in responding to disturbances that will occur.

Technically, disturbances can be defined as a physical condition caused by a failure of a device, component or element to work in accordance with its function. The disturbances can be caused by various factors during the system work or operation, such as internal or external disturbances as detailed in Figure 1. Generally, internal disturbances originate from the condition of the system and devices used, while external disturbances are generally caused by environmental conditions around the system and weather situations that have implications for the system [25-31]. Therefore, disturbances that occur must be addressed immediately which is given the effect of the occurrence of electrical disturbances. It can cause damage to electrical equipment and cause all systems to be in an abnormal condition. Some disturbances effects on the system performance that need to be watched out are overloads that reflect increasing load requirements, short circuit interruptions in the electricity network, power supply outages, power instability, and others.

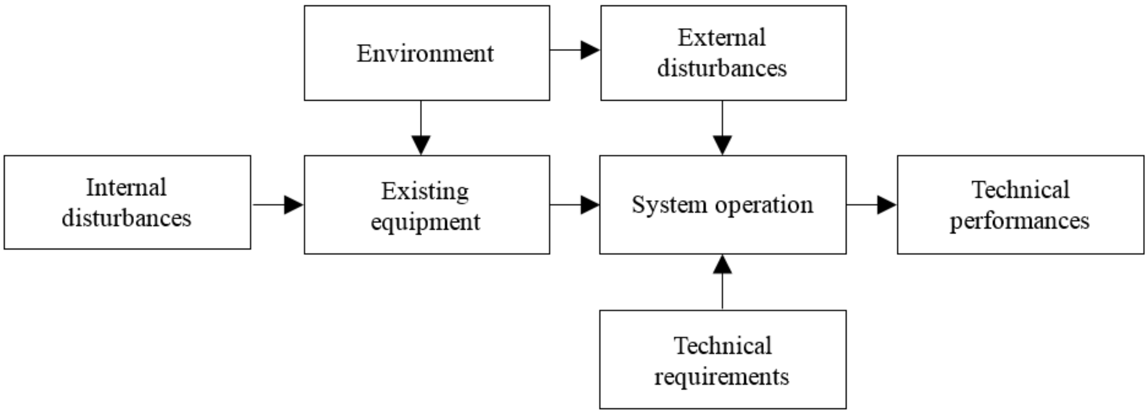

FIGURE 1. Disturbance contribution to the operating system

Recently, the EP is very necessary to deal with various disturbances that occur on the system and it will affect the EPS in all interconnected sub-systems [25,26]. As explained earlier, the EPS is facilitated with a protection system that is installed on electrical equipment or electrical systems to anticipate abnormal conditions. So, this device is also used to prevent damage to electrical equipment due to disturbances. Technically, the IPD must be able to function properly to avoid or reduce damage to electrical equipment due to disturbances. It is able to respond quickly by localizing the area of disturbances to become smaller, have high reliability, able to protect humans from electrical hazards, it can respond quickly, and it has an economic value. In addition, Figure 2 shows the covered protection for each area on the EPS.

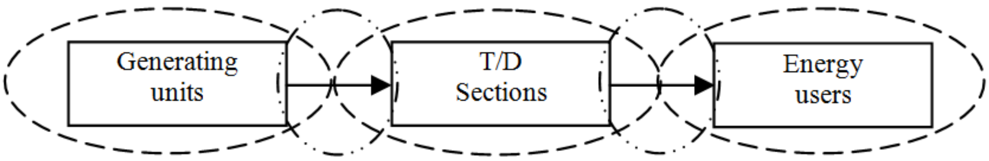

FIGURE 2. Protective area of the power system

In this work, the development of a protection system presented in the IPD is carried out by integrating wireless and fuzzy systems, both of which have different functions in their application. The IPD includes the data processing and status optimization. In general, the FL integrates a decision-making process based on the rule that has been created and has several ambiguous and gray parameters, while, wireless communication is a data transmiting system that is used to send and receive data packets from device systems [32-35]. This data presents a working condition for the information system where the data is processed. Moreover, the FL is determined based on the arrangement of logical problems that reflect complex differential statements. This problem is derived from the idea used to identify and take advantage of the gray between two extremes or two statuses that will give doubt in making decisions. In detail, the FL is built from fuzzy sets and fuzzy rules as given in Figure 3.

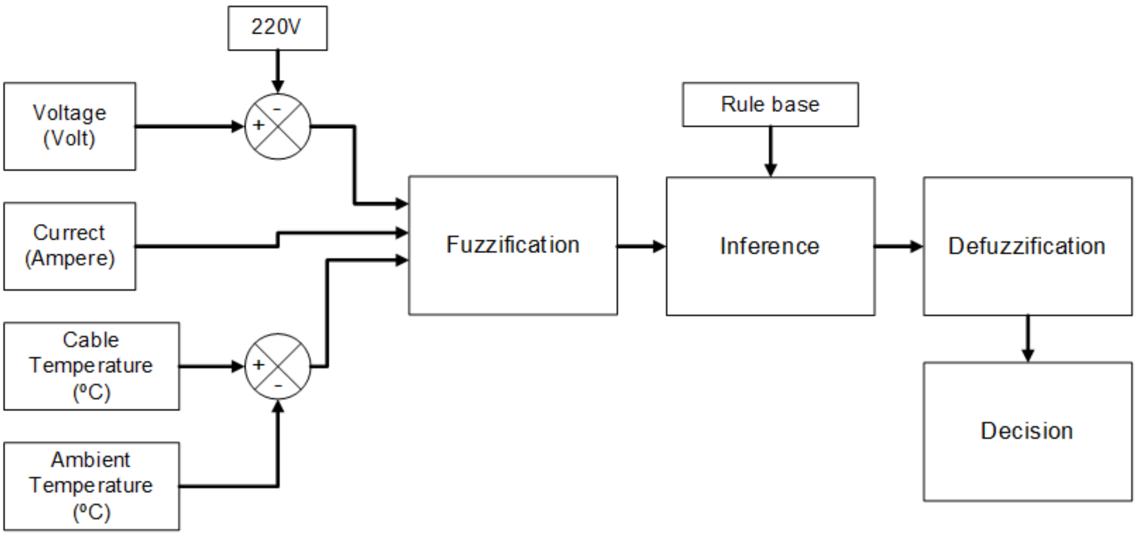

Figure 3. Fuzzy logic sequencing

Some fuzzy methods known today are Mamdani, Sugeno, and Tsukamoto. Specifically, the composition of each fuzzy logic method consists of fuzzification, rule evaluation, and defuzzification [32,34]. In this IPD, fuzzy logic components are developed based on technical functions. The membership function is the stage of changing the input parameter to the value of the membership degree. Membership levels can be expressed in the form of certain mathematical equations. In this work, the fuzzification process is used to change data entered explicitly in the form of membership degrees. The knowledge base is used to connect the input set with the output set. Decision-making logic is used to combine rules contained in a rule base into a set of fuzzy outputs. Furthermore, defuzzification is a step to change the results of the inference engine expressed in the form of fuzzy sets to real numbers. The logic of decision making or commonly called fuzzy inference is the application of fuzzy rules to the input which then evaluates each rule.

As discussed earlier, the IPD is also used to support the decision making process or actions during the operating system, so the DSS will be used as a the first step to determine the final results. This concept is given in Figure 4 coming from data acquisition on the EPS. The DSS is a system used to provide information, guide, and predictions for users to make appropriate decisions by considering various existing criteria [36-39]. In addition, the browsing process is processing that combines analytical models with conventional data entry techniques and information retrieval or checking functions, thus guiding towards valid decisions. As part of operational procedures, it is expected to be used or operated easily. By considering Figure 4, the IPD is designed based on the sequencing process referring to aspects of flexibility and high adaptability, so that it is easily adapted to change in the environment that occurs and according to user needs. The process of protective equipment will become more potential to face both internal and external disturbances, and make it easy to determine the final decision to take the necessary action.

3. **Technical Approach.** In this work, the application of FL as part of the IPD system is carried out in several stages. These stages are combined together in an integrated

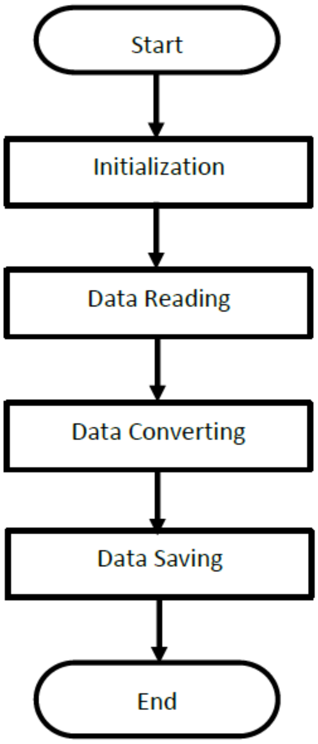

FIGURE 4. Data acquisition process

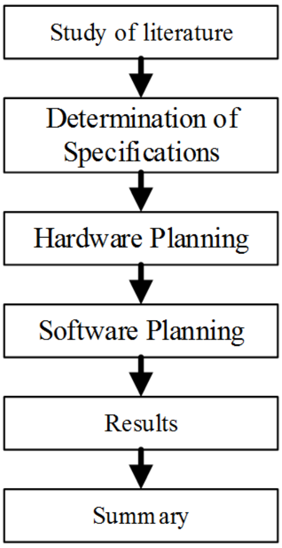

FIGURE 5. Sequencing process of protective design

process as illustrated in Figure 5. Technically, all devices development must meet the conditions stipulated in the operation, so it must meet the situation where the system works. The determination of device specifications is defined based on system requirements in hardware or software. As the parameter of the IPD, the operating conditions are referred to select several parameters including voltage, current, and temperature of the cable [25,33,39]. Thus, the process of detecting all these parameters requires a sensor for measuring accurately. The operating performances used in this work include a voltage sensor, where the sensor module consists of a current transformer and signal conditioner. In addition, the current sensor is also used to measure the amount of current that passes by referring to the mechanism of measuring the hall effect represented in the analog signal.

Furthermore, the temperature sensor is also used to detect temperature with the ability to measure an ambient temperature and to determine the non-contact temperature which is also able to measure the temperature at the cable surface.

In particular, sensors are integrated to the system required by a processing device that is able to execute quickly and it has sufficient storage and good reliability [23]. Moreover, Figure 6 covers sensor connections to the IPD which runs the FL and provides an action on each condition as the optimal and fast action. Furthermore, to provide information to users, the system is equipped with a display device based on the FL in associated with Figure 6. Moreover, this device can be programmed to give information according to the operation for outputs and it displays the parameter information, system conditions and protection conditions based on the FL.

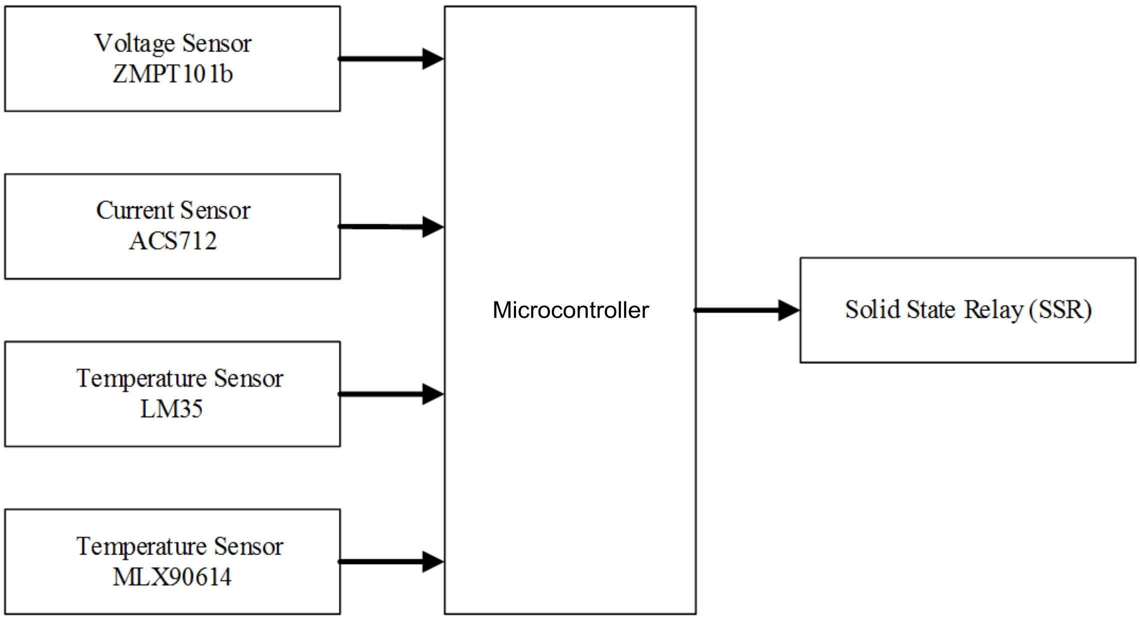

FIGURE 6. Diagram block hardware

In detail, the final action is decided based on the data acquisition referred to the IPD as given in Figure 7. The data acquisition process is subjected to system collection. In this work, the system will acquire data based on the measured amount of voltage and current measurements periodically. From Figure 7, it is known that the DSS is developed based on the results of the FL. Moreover, the system will perform a calculation process in the micro controller into units of measurement according to the parameters measured. In addition, the DSS needs to be designed well in order to be able to give a decision that is in accordance with the conditions that occur [27,37]. Moreover, the system will give an action to meet a current termination during operation.

4. **Results.** In this work, the application of the FL as part of the IPD system is carried out in several stages. These stages are combined together in an integrated process as illustrated in Figure 3. Technically, all devices developed must meet the conditions in the operation. By considering all processes and procedures as detailed in the previous section, the results are performed in several indicators to inform the status. Physically, the output is displayed on a monitor to inform the results of the process as presented in Figure 8. In this section, the system is tested to measure parameters in real terms and compared to measuring devices that have been calibrated to determine the accuracy of the sensor. The testing calibration results are detailed in Table 1 where the fluctuated conditions are illustrated in Figure 9.

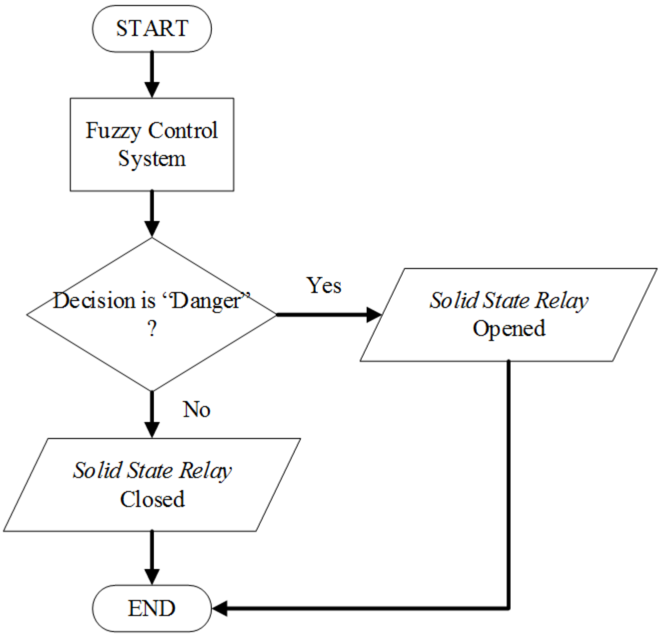

Figure 7. Control action flowchart

Figure 8. Tool design looks outside

Table 1. Testing calibration results

Data	Voltage (V)		Temperature (°C)		Data	Voltage (V)		Temperature (°C)	
	Source	Device	Device	Tool		Source	Device	Device	Tool
1	244	247.85	27.79	28.00	16	197	197.48	29.05	29.00
2	256	262.5	30.25	29.00	17	256	262.5	30.25	30.00
3	240	242.97	29.3	29.00	18	272	272.03	33.2	33.00
4	272	282.03	30.2	30.00	19	272	271.03	32.2	32.00
5	256	242.5	31.25	31.00	20	210	210.35	29.63	31.00
6	302	300.65	31.87	32.00	21	256	256.5	30.25	30.00
7	240	242.97	29.3	30.00	22	257	253.72	31.37	31.00
8	224	233.44	27.34	28.00	23	292	296.45	32.64	33.00
9	246	256.29	30.03	30.00	24	272	272.03	33.2	32.00
10	256	262.5	29.25	30.00	25	277	278.13	32.81	32.00
11	176	164.84	28.48	28.00	26	288	288.56	34.16	34.00
12	218	215.11	29.61	30.00	27	256	255.5	33.25	33.00
13	248	252.73	30.27	30.00	28	248	248.73	30.27	31.00
14	236	228.09	29.81	30.00	29	208	207.91	29.39	29.00
15	211	213.57	28.76	28.00	30	240	239.97	29.3	29.00

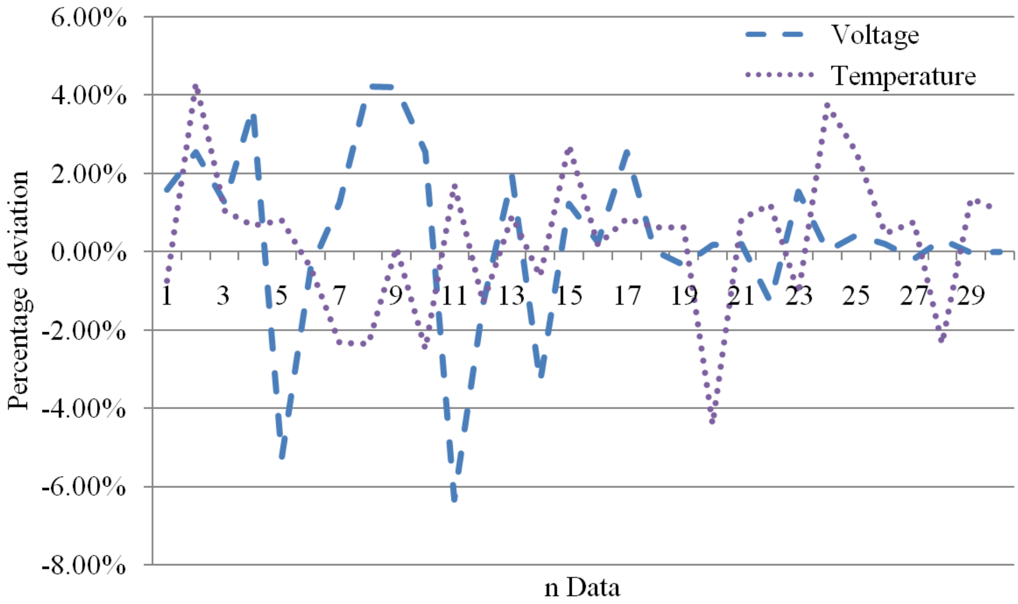

Figure 9. Fluctuated deviation of percentage calibration

Table 2. Operating performances

No	Voltage (V)	Current (A)	Temperature (°C)		No	Voltage (V)	Current (A)	Temperature (°C)	
			Environment	Cable				Environment	Cable
1	218.182	0.14264	24.4141	27.17	16	211.833	0.04498	23.4375	27.21
2	218.182	0.24029	23.9258	27.21	17	218.182	0.24029	24.9023	27.21
3	216.066	0.24029	23.9258	27.25	18	203.367	0.04498	22.9492	27.17
4	218.182	0.24029	23.9258	27.21	19	220.298	0.14264	23.4375	27.21
5	218.182	0.24029	23.4375	27.21	20	207.6	0.04498	23.4375	27.23
6	220.298	0.14264	24.4141	27.21	21	220.298	0.24029	23.9258	27.17
7	216.066	0.24029	23.9258	27.21	22	220.298	0.24029	23.9258	27.17
8	218.182	0.14264	24.4141	27.17	23	216.066	0.53326	24.9023	27.21
9	218.182	0.43561	24.4141	27.21	24	218.182	0.04498	23.9258	27.17
10	205.484	0.04498	23.9258	27.21	25	218.182	0.24029	23.4375	27.17
11	213.949	0.24029	24.9023	27.21	26	207.6	0.24029	24.4141	27.21
12	216.066	0.14264	22.9492	27.21	27	216.066	0.14264	23.9258	27.17
13	218.182	0.24029	24.4141	27.21	28	220.298	0.24029	23.4375	27.17
14	218.182	0.24029	23.4375	27.17	29	205.484	0.04498	24.4141	27.21
15	216.066	0.24029	24.4141	27.21	30	209.716	0.14264	23.9258	27.17

Regarding system operation, Table 2 shows the operating performance for the IPD, where this result is captured on various loads. These results are presented under voltage and current conditions where the temperature indicator is measured on the cable under environmental penetration. In detail, this system has been run in a fluctuating load as illustrated in Figure 13. Furthermore, the test has been also carried out separately, although the test has carried out impacts. The individual parts tested are given in Figure 10, Figure 11, and Figure 12. Figure 10 and Figure 11 show the operating performance covered for voltage and current data related to the sensor. Based on this figure, it can be seen that the EPS has been running at a relatively stable voltage between the device designed and the device calibrated to maintain the voltage condition. These results show, the voltage deviation is relatively small. In contrast to other results, current performances, the IPD has worked at fluctuating loads as shown in Figure 13 with an increase in current

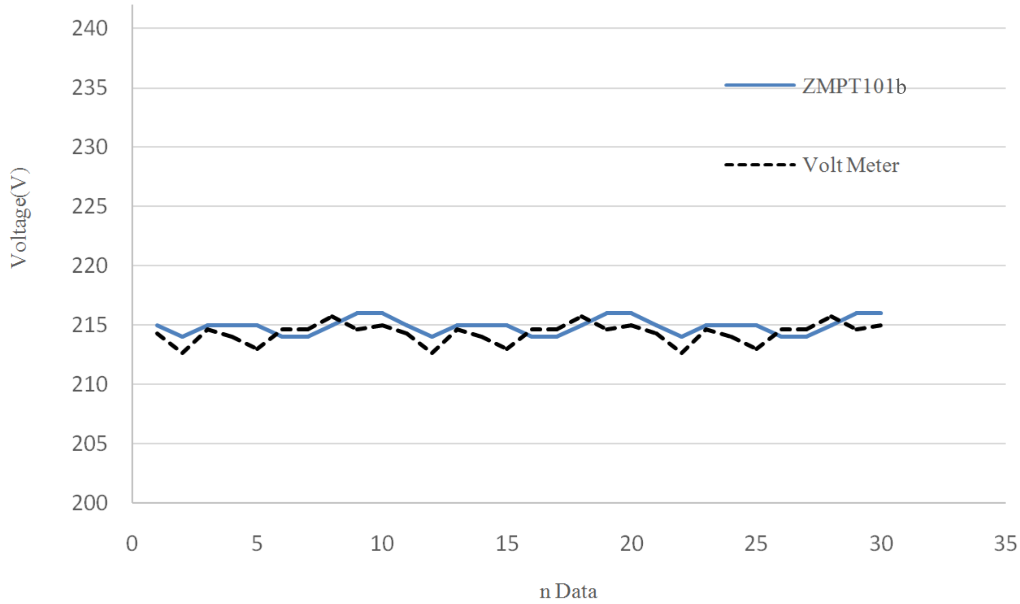

Figure 10. Voltage performances

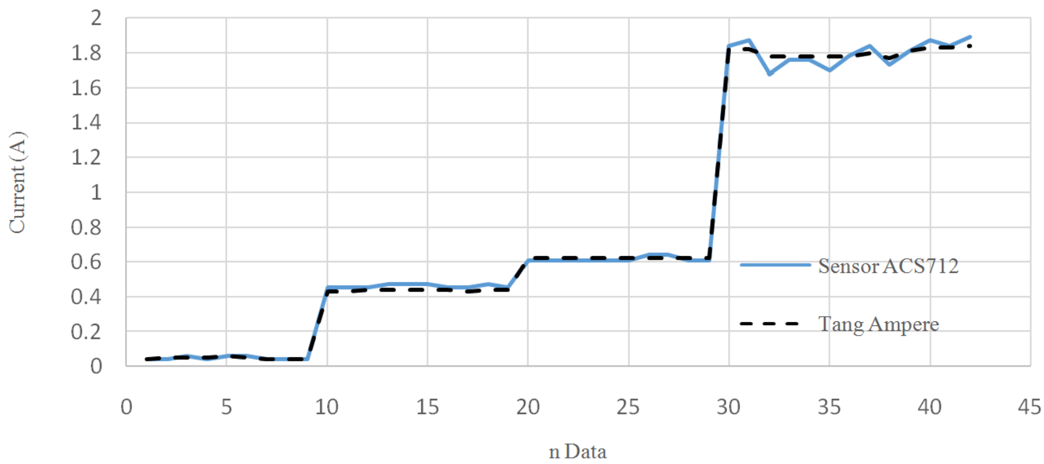

Figure 11. Current performances

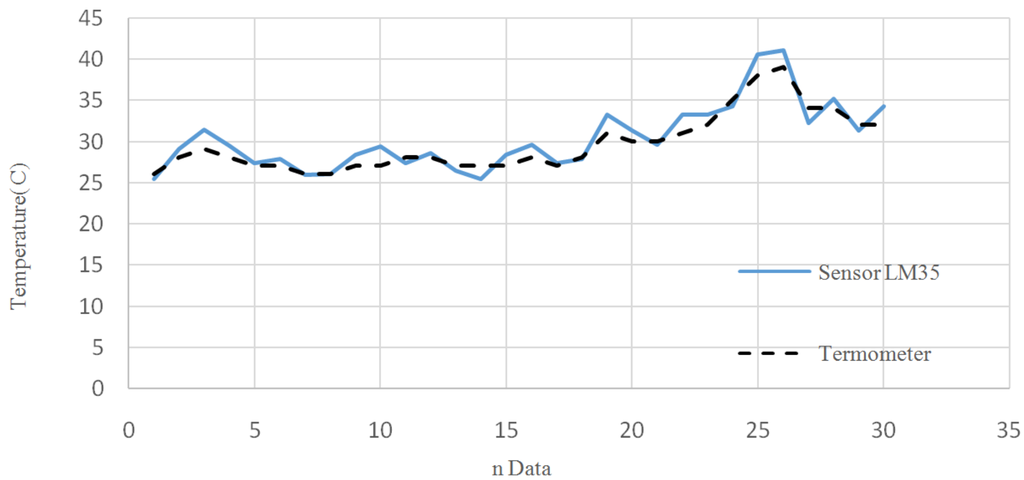

Figure 12. Temperature performances

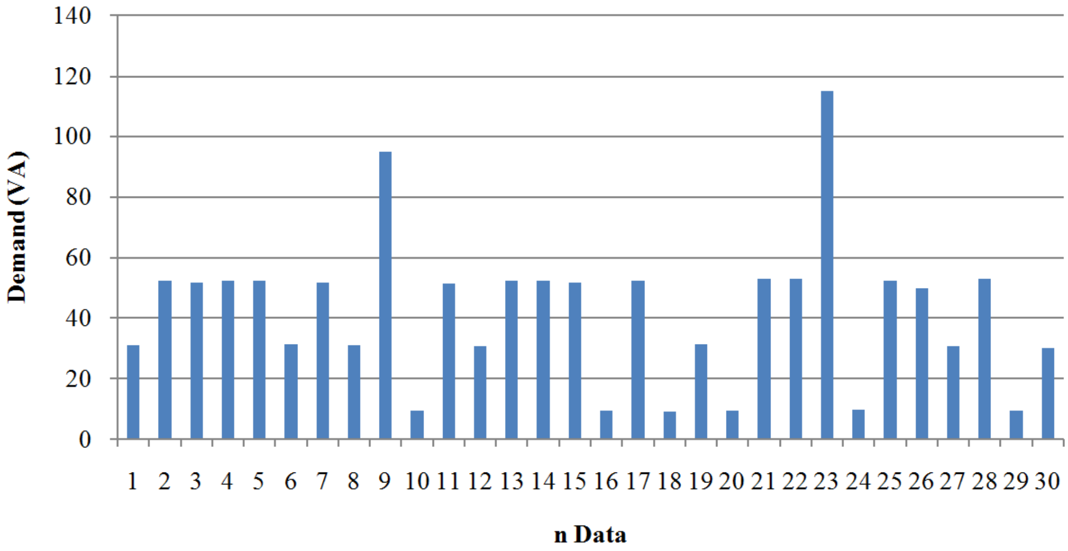

Figure 13. Power demand condition

capacity during all data collection periods, thus impacting the most current delivery. Specifically, temperature performance is given in Figure 12. This figure illustrates the current power flow during the EPS operation, where the flow will cause heat to the conductor. On the other hand, the temperature contribution is also very dependent on the environment around the conductor installed. Based on the EPS, the temperature increases gradually in line with current performance as described in Figure 11. From the above performance, it is known that conditions can measure parameters with different values under the permissible deviations in the optimization process. This system is also tested to ensure that the FL application runs well.

5. **Conclusion.** Operationally, the electric power system will work for 24 hours, where the existing system must be stood for faults. Electrical disturbances that occur in the electric power system can cause problems and can also cause damage; therefore, protective devices are needed. This is very important to note, because protection devices need to be upgraded from conventional systems, so that the intelligent protection device (IPD) becomes an interesting study, as discussed in this work. This IPD can measure parameters and provide information about conditions for safe, alert or dangerous status. In addition, the developed device is also able to catch the electrical parameter mesurement and it provides operating data from the fuzzy algorithm. Therefore, for further research, it can be developed in fuzzy input variations and focused on reducing the achievement of iteration.

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