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Protection System for Electrical Loads of Administration Building in Controlling Voltage Variations Due to Over-Voltage and Under-Voltage

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ABSTRACT

The purpose of this study is to focus on producing a protection system design for the electrical loads of administration buildings from over and under voltage. An on-site voltage reading has been initiated and continued for several days to determine whether voltage variation is occurring in the location. The building's load schedule has served as a point of reference in calculating the appropriate size of wire and Molded Case Circuit Breaker ampere rating. For the proponents to understand the design standards, the Philippine Electrical Code is used as a reference. Consequently. The design that has been made and proposed is for controlling over and under voltages. The power supply at the Administration building can be transferred over to the other power supply coming from a generator set. The voltage readings in the Admin Office MDP range from 218.55 to 231.03 V. The other one on the General Office MDP is from 219 to 230.48 V, showing that no over-voltage and under-voltage is happening in the building and normal working voltages are delivered on the electrical loads. Thus, the electrical loads in the building are safe from voltage variations.

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1. INTRODUCTION

The distribution system is among the most essential components of a country's power system (Bhosale *et al*., 2018; Fadaeenejad *et al*., 2014). This system is operated by distribution utilities that have an exclusive franchise area, such as private corporations, electric cooperatives, government-owned utilities, or existing local government units (ERC Sec. 4 q, RA 9136). Consequently, these utilities have end-users to provide reliable power like those in residential, commercial, and industrial settings (Energy Regulatory Commission).

While delivering reliable and efficient energy, power quality problems arise as well. According to Johnson & Hassan (2016), long-duration voltage variation is one of the issues concerning the quality of power. It is called "long duration" when a variation of the voltage's RMS value from its nominal value lasts more than one minute. Moreover, there are two conditions for this variation: over and under-voltage. If the RMS value of the voltage is less than or equal to 90% of the nominal voltage, it is considered an under-voltage (Mousavi *et al*., 2018). On the other hand, there is an over-voltage when the RMS value of the voltage is more than or equal to 110% of the nominal value.

Over-voltage is often caused by two factors: internal and external. Internal ones are power system surges, insulation failure, arcing ground, and resonance. Meanwhile, external forces come due to lightning strikes. On the other hand, under-voltage conditions are somehow produced by electric providers. To meet the higher demand of consumers, leading to overloading, utilities are forced to lower their delivered power, which is divided between end-users. This results in exceeding the power capacity of certain transformers, where a voltage drop usually transpires. Consequently, these occurrences have some sort of negative impact on electrical equipment. When over-voltage takes place, the insulation on electrical equipment is severely stressed, which can cause harm if repeated. Also, electric surges normally result in transformer failure and damage to motor machines. However, under-voltage can lead to irrelevant exposure that leads to premature failure, malfunction, overheating, and shutdown (i.e., dryers, air conditioning units, and refrigerators).

With human intervention, to solve this problem, protection systems are invented and innovated to alleviate the damaging effects of over-voltage and under-voltage on electrical loads.

Protection systems have various approaches but certainly share one objective, which is to protect electrical loads from the drastic effects of over-voltage and under-voltage. These systems care for the safety of electrical equipment, avoiding serious damage.

In India, the group Thamiz Thentral has successfully produced a tripping mechanism or a system to protect the loads and circuit by having an upper triggering point and a lower triggering point. The project works at 195 to 215 V. When the voltage is below 195, it is considered to be under-voltage, and if it is above 215, over-voltage is detected.

The voltage delivered by the utilities to consumers is constant, but at a certain point, an abnormality occurs. Most consumers have electrical loads, and others are operated by motors. Moreover, these apparatuses are used daily. Over-voltage and under-voltage happen at the most unexpected times. Most end-users may be unaware of the consequences of this situation for their appliances. By the time it is recognized, it is probably too late and appliances are left to be seriously damaged to the point that they are no longer fit to be used.

Nowadays, people have or use Smart TVs, inverter air-conditioning systems, laptops, and desktops that have electronic devices inside that can be sensitive to sudden changes in voltage. In older designs of over and under-voltage protection, diodes and transistors were widely used to manipulate the voltage in the circuit. One good example is the Silicon-

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Controlled Rectifier (SCR) Crowbar. When an over-voltage problem occurs, the crowbar circuit creates a short circuit across the output of the power supply, as the name indicates. Thermistors or SCR, are commonly employed for this since they can switch enormous currents and stay on until the charge has dissipated. The thermistor can be connected to a fuse that blows when a higher voltage is applied to it, thus isolating the regulator from additional voltage. The next one is voltage limiting: When over-voltage protection is required for switch-mode power supplies, SMPS, the clamp, and crowbar techniques are less widely used because of the power dissipation requirements and the possible size and cost of the components. Fortunately, most switch-mode regulators fail in a low voltage condition. However, it is often prudent to put in place voltage limiting capabilities in case of an over-voltage condition.

Because of these limits, we become aware of these issues and think about how to get a normal operating voltage that can be regulated for these electrical appliances to be safe to use. Furthermore, unlike other older designs of over or under-voltage protection that only use the 555-timer integrated circuit (IC), it has limitations, such as the inability to hold an opposite contact that can be used to switch another electrical power source if necessary. Furthermore, the design in this study can be flexible and can adapt to its client's needs.

2. METHODS

Figure 1 explains how the workflow of this study. The step-by-step process is used as a guide to creating a design based on the present situation of the locality. This includes data gathering, formulation of design specifications, and simulation of the program for its evaluation.

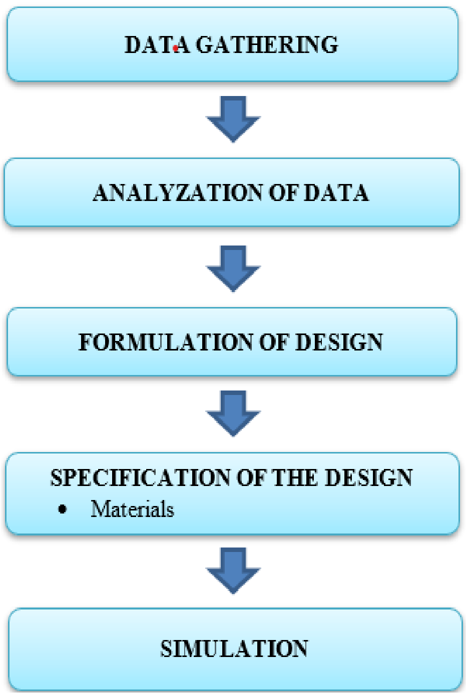

Figure 1. Research design.

2.1. Data gathering

The first aspect to do in developing a design for over-voltage and under-voltage protection systems is data gathering. The data includes the load schedule of the administration building at DHVSU. Also, we conducted an on-site voltage reading to record the voltage supply in the building for 5 days.

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2.2. Data analysis

In this part, data analysis is done where we rigorously evaluated each piece of information from the university building. In this manner, the loads that are critical to over-voltage and under-voltage are determined. Moreover, the cases of these events were identified.

Consequently, voltage readings were assessed following the guidelines of the Philippine Distribution Code and Philippine Electrical Code on voltage variations. Over-voltage was considered when the value of the voltage is greater than or equal to 105% of the nominal voltage, while under-voltage if it is less than or equal to 95%, otherwise it was treated as a normal working voltage.

2.3. Formulation

The load schedule was considered in this part to compute the size of the wire and the motorized molded case circuit breaker to be used in the design. Furthermore, we proposed a design on which to control the over-voltage and under-voltage within a specified time, where when voltage variation is present, the power source of the Administration building was transferred to another power source. Utilization of the Philippine Electrical Code was also present in the design for the proponents to understand and know the design standards that need to be used.

2.4. Design specification

In this part, the materials needed and the function in the design took place.

2.5. Simulation

We used Proteus and LOGOsoft for the simulation, which was performed to see its operation. Consequently, voltage drop calculation was used to assess the efficiency of the feeder in the building, which eventually determine the chance/s of voltage variation happening as per the PEC on Voltage Drop Calculation. Equation 1 is the Voltage Drop Calculation in the Panel Board.

$$\mathrm{VD_{PB}} = \mathrm{k(I)}\left(\sqrt{R^2 + X^2}\right)\left(\frac{L}{305}\right) \quad (1)$$

where VDPB is the Voltage drop at panel board (volts), I is the line current (amperes), D is the distance of the device from the source, k is the Constant (2 for 1-phase and 1.732 for 3-phase), R is the line ac resistance (oms), and X is the line reactance at 60 Hz (ohms).

Values of *R* and *X* were identified in the conductor table and used as a reference. Equation 2 is the Percent Voltage Drop Calculation.

$$\%VD = \frac{(VD_{PB}) \times 100\%}{V_S} \quad (2)$$

where $\%VD$ is the Percent Voltage Drop, and VD_{PB} is the Voltage Drop at Panelboard, volts.

To determine the sizes of the wire to be used in the feeders, full load current (IFL) will be calculated and considered on equation 3 based on PEC standards. Equation 3 is the Wire Size Computation.

$$IFL = 1.732(IT) + 0.25(HML) \quad (3)$$

where IFL is the Full-Load Current, IT is the Total Current, and HML is the Highest Motor Load.

After getting the full-load current, table 3.10.2.6(B)(16) will be used as a reference for wire sizing.

To know the ampere rating of the Molded Case Circuit Breaker (MCCB), equation 4 will be used based on PEC standards. Equation 4 is the Ampere Rating Calculation.

$$IMCCB = 1.732(IT) + 150\%(HML) \quad (4)$$

where *IMCCB* is the Molded Case Circuit Breaker Current *I*, *T* is the Total Current, and *HML* is the Highest Motor Load.

After getting the current on the circuit breaker, Table 2.40.1.6(A) will be used as a reference for the size of the MCCB.

3. RESULTS AND DISCUSSION

The proponents have gathered data from the Office of the Physical Plants and Facilities (OPPF) containing the electrical plan and electrical loads of the Administration building of the university. According to the layouts, the building is connected on a 3-phase system and has 2 Main Distribution Panels (MDP), one consisting of the admin offices and the other one from the general offices. Furthermore, actual voltage readings are performed under the supervision of an authorized OPPF technical staff member to determine if there is voltage variation. Furthermore, computations are made using Microsoft Excel.

We used the Philippine Electrical Code 2017 Edition (PEC) as a reference in classifying voltage readings in the Administration building. According to the Philippine Distribution Code 2016 Edition (PDC), voltage is qualified as over-voltage when it is greater than or equal to 11% of the nominal voltage. It is under-voltage if the voltage becomes less than or equal to 90% of the nominal voltage. However, in the PEC, which is considered for end-users, the voltage tolerance is +/-5% of the nominal voltage. Therefore, when the voltage becomes less than or equal to 105% of the nominal voltage, it is under-voltage; it is over-voltage if it is greater than or equal to 95% of the nominal voltage. Thus, the PEC guidelines are used as a reference for evaluating voltage variations since the DHVSU's Administration Building is counted as a consumer.

Table 1 shows the equivalent voltage based on the 2017 edition of the Philippine Electrical Code (PEC).

Table 1. Voltage equivalent according to PEC 2017.

Voltage Equivalent According to Pec 2017	
Over-Voltage	241.50
Normal	218.51 - 241.49
Under-Voltage	218.50

In voltage testing, we recorded line-to-line readings at a 30-minute interval.

Table 2 shows the Average Line-to-Line Voltage Readings in the circuit breaker of the Admin Office.

Based on the recorded data and from **Table 2** shown above, from day 1 to day 4 of voltage readings. It is obtained by adding the line-to-line voltages individually and then dividing them by 4. In this regard, the voltage varies from 218.55 V to 231.03 V, which falls within normal working voltage and indicates that there is/are no over-voltage or under-voltage scenarios occurring in the Admin offices MDP's line-to-line voltage (Vab, Vbc, and Vca).

On the other hand, the average line-to-line voltage reading in the MDP of the general offices is depicted in **Table 3**. The average is attained through the sum of individual line-to-line voltages, divided by 4. Consequently, the voltage varies from 219 V to 230.48 V, indicating that line voltages are at normal operating voltages.

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Table 2. Average line-to-line voltage reading in admin office (MDP).

Average Line-to-Line Voltage Reading in Admin Office (MDP)			
Time	**Vab (V)**	**Vbc (V)**	**Vca (V)**
9:00 AM	226.03	225.58	223.10
9:30 AM	225.90	225.75	224.03
10:00 AM	226.05	226.40	223.00
10:30 AM	224.70	224.73	221.25
11:00 AM	224.93	225.43	221.75
11:30 AM	224.93	225.38	221.95
12:00 PM	226.18	227.20	223.63
12:30 PM	226.40	227.33	224.48
1:00 PM	223.83	224.65	220.03
1:30 PM	222.20	222.83	218.55
2:00 PM	223.33	223.55	219.35
2:30 PM	224.23	224.18	219.55
3:00 PM	226.05	226.70	222.88
3:30 PM	228.03	230.10	225.60
4:00 PM	231.03	229.70	228.33

Table 3. Average Line-to-Line Voltage Reading in General Office (MDP).

Average Line-to-Line Voltage Reading in General Office (MDP)			
Time	**Vab (V)**	**Vbc (V)**	**Vca (V)**
9:00 AM	223.98	225.00	223.25
9:30 AM	223.08	224.83	222.28
10:00 AM	224.63	225.45	223.33
10:30 AM	224.30	225.25	222.20
11:00 AM	225.05	225.45	222.00
11:30 AM	225.10	225.38	222.30
12:00 PM	226.25	226.75	223.98
12:30 PM	226.55	226.25	223.55
1:00 PM	223.60	223.68	219.78
1:30 PM	222.30	222.95	219.00
2:00 PM	223.38	223.90	219.90
2:30 PM	223.88	224.23	221.13
3:00 PM	225.83	226.38	223.00
3:30 PM	226.95	228.00	225.23
4:00 PM	229.43	230.48	227.98

As the voltage resulted in normal operating voltage, illustrating no over-voltage and under-voltage cases, we calculated the voltage drop in the Admin and General Office Main Circuit Breakers (MCB), denoted by the formula, $\mathrm{VD_{PB}} = \mathrm{k(I)}\ (\sqrt{R^2 + X^2})\ (\frac{L}{305})$, computed a value of 2.5543 and 2.7809, respectively. More so, a percent voltage drop is calculated as well through the formula $\%VD = \frac{(VD_{PB})\times 100\%}{V_S}$, getting value 1.2091% for the Admin and General office MCB, respectively. Hence, the outcome says that there are no over-voltage and under-

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voltage conditions, providing efficient operation becomes reasonable based on Article 2.15.1.2 Minimum Rating and Size (Feeders), FPN No. 2 of the PEC.

To explain the design, the proponents make the Single Line, Power, and Control Circuit Diagrams.

Figure 2 shows the Single Line Diagram of the design. The 2 transformer banks are connected to the 2 main distribution panels, the Admin and General Offices MDPs. The 225-kVA transformer is connected to the Admin Offices MDP, while the 150 kVA is connected to the General Offices MDP. Furthermore, the proposed generator set of 250 kVA, as per the OPPF, is tapped to the offices, where the original disconnecting means and motorized molded circuit breaker are connected from the source to the load.

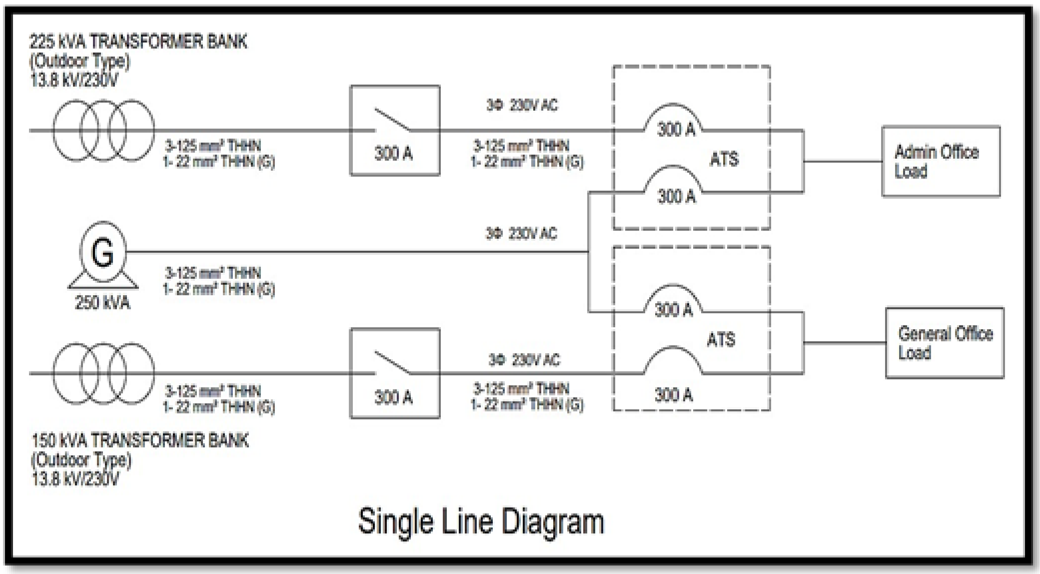

Figure 2. Single line diagram.

On the other hand, **Figure 3** presents the power circuit diagram of the design. It shows where the components of the protection system integrate with the existing electrical system. Where voltage sensors are connected to each phase and where the fuse of each voltage sensor is added for protection. Numbered connectors are also used in the illustration for easier understanding and designation of circuits. The use of an uninterruptible power supply (UPS) is also proposed by the proponents to give a constant power supply to the logic control circuit and also to the Arduino Uno. In case of power interruption, the microcontroller and control circuit will work continuously and independently. Moreover, the data reading that is being read by the voltage sensors is being fed and processed by the commanding unit, which is the microcontroller. The microcontroller is programmed to command the relay to close the normally open contacts of the Arduino actuated relay when the sensed voltage coming from the microcontroller is within the range of the considered normal operating voltage of the offices or in the range of voltage regulation of 5% of 230V AC. However, when the sensed voltage is above or below the considered normal operating voltage, which means over-voltage and under-voltage, the microcontroller will stop to command the Arduino actuated relay, which results in bringing back the actuated relay to its normal position, which is normally closed. A delay timer is also connected to each contact of the Arduino-actuated relay, on in the normally closed contacts and off in the normally open contacts.

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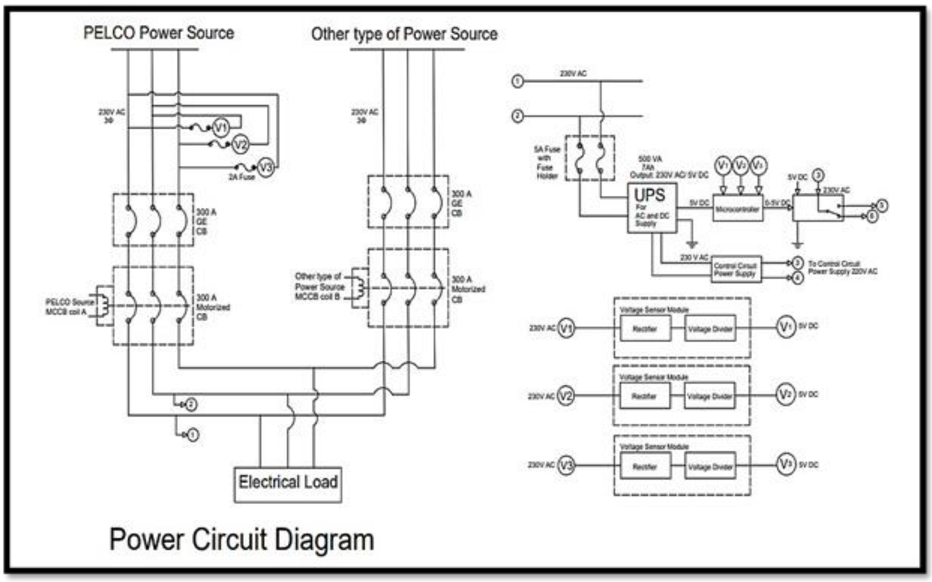

Figure 3. Power circuit diagram.

Figure 4 thoroughly explains the workings of the on-delay timers. In the control circuit, the actuated Arduino relay is connected to the timer. As stated, when the normal operating voltage is sensed and processed by the microcontroller, the actuated relay will close the normally open contact of the relay and turn on the on-delay timer of the utility power source control circuit. If the voltage exceeds above or below the considered normal voltage, the relay will bring the Arduino actuated relay back to its normal position, which will turn on the on-delay timer of the proposed generator control circuit. More so, the on-delay timers are used in the control circuit of the utility power source and proposed generator to prevent the instance of turning the switching on of two incoming power sources. To surely avoid this scenario, a normally close contact that is interlocked in the coils of each power source is present. Hence, when a source is already supplying power, which means the MCCB of this source is already engaged, the secondary source will not connect because the series of a normal contact in the coil of the other MCCB is already open.

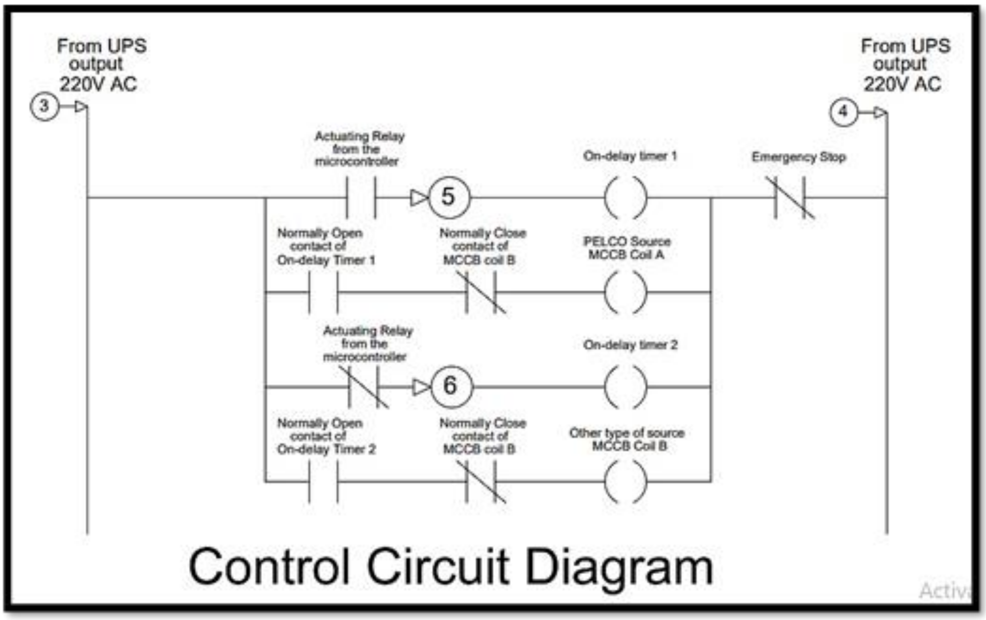

Figure 4. Control circuit diagram.

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The electrical loads on the Main Distribution Panels (MDP) in the proposed design of the protection device are connected to two power sources. The first one comes from the utility. The other one is the 250-kVA generator set proposed by the Office of Physical Plants and Facilities (OPPF). The model is to protect the electrical system of the administration building from over-voltage and under-voltage coming from the electrical utility. The protection device switches the MDPs from which power source they are connected to.

The design uses a microcontroller as the main command center of the system. It uses 3 voltage sensors. One is connected to each phase to sense the alternating current voltage per phase in the three-phase supply from the utility. These voltage sensor modules use a bridge rectifier and a voltage divider circuit. The use of those components is to convert alternating current (AC) to direct current (DC) and reduce the voltage in the range of 0V-5V, as the microcontroller only accepts a voltage range of 0V-5V DC analog input signal. The command center only actuates the relay when the analog DC voltage signal that is being sensed by the voltage sensor module is ranging from 2.16 V DC to 2.38 V DC, which correlates with 2.38 V DC to 241.49 V AC and 2.16 V DC to 218.51 V AC.

We set a range of 218.51 V AC to two of 241.49 V AC using a voltage tolerance of 5% (PEC 2017). When the voltage sensor modules sense the signal is within the acceptable voltage range, they will feed an actuating 5 V signal to the microcontroller actuated relay. But when the sensed voltage exceeds the range, which is considered an unsafe working voltage, the command center stops feeding a 5 V signal to the actuating relay.

The actuating relay is connected to a logic control circuit. This logic control circuit controls the switching of the motorized circuit breakers where the power circuit is connected. The interchanging of supply power happens when the command center releases the actuation in the relay due to the fault being seen. When the 5 V DC actuating action is stopped by the command center, the actuating relay from the microcontroller will also release the actuating action of the motorized circuit breaker where the utility power source is connected to the load, then cut out the supply from the utility to the electrical load. Afterward, a countdown timer will start, which is set to 3 sec. After 3 sec, the normally open contact of the timer will close where the actuating coil of the second motorized circuit breaker is connected, on which the second power source is connected to the electrical loads of the admin building as well. This second power source will come from the generator set that is being proposed by the OPPF. Furthermore, it depicts the function of an Automatic Transfer Switch, as the power sources are interchanging with one another concerning the operation.

Consequently, the usual operation where the utility supplies power to the building will repeat if the command center receives data coming from the 3 voltage sensor modules per line that is within the safe range for the electrical load. The microcontroller actuates the relay again by giving a 5 V DC signal to the relay, which again actuates the on-delay timer and, after three seconds, will close the normally open contacts of the on-delay timer, which connects the electrical load back to the utility and cuts out the power supply coming from the 250-kVA Genset to the load.

The three-second on-delay timer is used to control the power circuit, avoiding turning on the two power supplies at the same time. We used an Uninterruptible Power Supply (UPS) to give a power supply to the microcontroller and the AC 230V control circuit, even when there is a power interruption. The proposed protection design is used to describe how the Automatic Transfer Switch (ATS) works but not the actual ATS component. When the microcontroller senses less than 218.51 V AC to zero and a voltage greater than 241.49 V AC coming from the utility, it automatically transfers the supply power to the alternate power

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sources or the generator set. Nevertheless, zero voltage implies there is no power or power interruption.

One of the specifications on the proposed design is Motorized Molded Case Circuit Breakers (MCCB), whereas considering the 2 MDPs, which are from the Admin and General offices, ampere ratings and wire sizes need to be computed.

The formulas used to calculate the size of wire and ampere ratings in the MCCBs of Admin and General Offices MDP are from equations 3 and 4.

The schedule of loads served as a reference used in the total current in the computation is the largest total phase current among the 3 phase currents for the reason that even when electrical loads consumed unintended higher value from the total phase currents of the other phases, the wire and the circuit breaker can sustain the current that will pass on it. Moreover, HML is considered through the highest current consuming motor load. **Table 4** shows the total current and highest motor load of the Admin offices MDP.

Table 4. IT and HML of admin offices MDP.

Admin Offices (MDP)	
IT(A)	146.96
HML(A)	12.00

Wire Size:
$IFL = 1.732(IT) + 0.25(HML)$
$IFL = 1.732(146.96) + 0.25(12)$
$IFL = 257.53$ A

According to the PEC, with a full load current of 257.53 A, the wire size to be used for the circuit breaker is 3-125 sq.mm THHN Cu wire + 1-22 sq.mm in 65 mm RSC, as shown in Table 3.10.2.6(B)(16).

Ampere Rating:
$IMCCB = 1.732(IT) + 1.5(HML)$
$IMCCB = 1.732(146.96) + 1.5(HML)$
$IMCCB = 272.53$ A

According to **Table 2**, the standard ampere rating of the MCCB based on the measured value of 272.53 A is 300 A. Hence, use 300 AT, Bolt-on, 3-Pole. On the other hand, **Table 5** illustrates the total current and highest motor load of the General offices MDP.

Table 5. IT and HML of general offices MDP.

General Offices (MDP)	
IT(A)	139.22
HML(A)	12.00

Wire Size:
$IFL = 1.732(IT) + 0.25(HML)$
$IFL = 1.732(139.22) + 0.25(12)$
$IFL = 244.13$ A

The wire size of 244.13 A full load current, with Table 2.40.1.6(A) of the PEC as a basis, is, 3-125 sq.mm THHN Cu wire + 1-22 sq.mm in 65 mm RSC.

Ampere Rating:
$IMCCB = 1.732(IT) + 1.5(HML)$
$IMCCB = 1.732(139.22) + 1.5(12)$

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IMCCB = 259.13 A

As 259.13 A is the calculated value for the Molded Case Circuit Breaker, its standard ampere rating is 300 A. Consequently, use a 300 AT, bolt-on, 3-pole.

We used two simulation software, Proteus and LOGOsoft, to operate the protection system. However, the other components are not available in the application, like the motorized molded case circuit breaker. The Arduino Uno (microcontroller) function is handled by Proteus, while the relay control circuit is handled by LOGOsoft. Consequently, by observation and assessment, when the normal operating voltage is inputted, the power is from the utility; but, when over-voltage and under-voltage values are inputted, the power source is automatically transferred to the generator set.

4. CONCLUSION

As per the Philippine Electrical Code 2017th Edition, "the voltage tolerance is +/-5% of the nominal voltage." Then, when the voltage becomes less than or equal to 105% of the nominal voltage, it is under-voltage; thus, it is over-voltage if it is greater than or equal to 95% of the nominal voltage. Based on the findings of the study, the voltage readings in the Admin Office MDO range from 218.55 V to 231.03 V, and the ones on the General Office MDP are 219 V to 230.48 V on average. Hence, no over-voltage and under-voltage are happening in the building and normal working voltages are delivered on the electrical loads, which states that the electrical loads in the building are safe from voltage variations. Therefore, we further conclude that a protection system design for the electrical loads of DHVSU's Administration building from over-voltage and under-voltage is not needed or necessary. However, it can still be considered to be implemented since it has the function of transferring the power source from the utility to the generator set, which is a future project on the building. More so, this can be handy or helpful as it will not just serve as a power transferring device in cased of power interruption but a protection system as well from voltage variations. Moreover, it can also be useful in the other facilities of the school that need to install such a device. Furthermore, other sectors can also benefit from this study since it is an important protection system, especially in areas that have a high voltage drop.

The proponents recommend a thorough study of over-voltage and under-voltage protection systems on possible innovations too, from which end-users will benefit as it protects critical electrical loads from voltage variations. More so, gathered data can serve as a basis or tool for the university's OPPF for maintenance as well as for the electric cooperative or utility in providing reliable power.

In the design, the voltage readings sensed by the voltage sensors that are directed to the Arduino are not stored in a specific place. In line with this, for future studies, data loggers can be integrated into the design to store the data, which can be utilized as a reference for maintenance. This data logger can be programmed to automatically save the readings on a daily, weekly, or even annual basis.

Other approaches can be taken in this study, where future researchers can use the findings as a reference for conducting further research similar to this one. A Solar Photovoltaic System can be considered to be applied instead of a generator set, and a cost-benefit can be integrated into the study as well.

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6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

7. REFERENCES

Bhosale, G., Vakhare, A., Kaystha, A., Aher, A., and Pansare, V. (2018). Over voltage, under voltage protection of electrical equipment. *International Research Journal of Engineering and Technology (IRJET), 5*(2), 29-32.

Fadaeenejad, M., Saberian, A. M., Fadaee, M., Radzi, M. A. M., Hizam, H., and AbKadir, M. Z. A. (2014). The present and future of smart power grid in developing countries. *Renewable and Sustainable Energy Reviews, 29*, 828-834.

Johnson, D. O., and Hassan, K. A. (2016). Issues of power quality in electrical systems. *International Journal of Energy and Power Engineering, 5*(4), 148-154.

Mousavi, S. Y. M., Jalilian, A., Savaghebi, M., and Guerrero, J. M. (2018). Coordinated control of multifunctional inverters for voltage support and harmonic compensation in a grid-connected microgrid. *Electric Power Systems Research, 155*, 254-264.

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