# Proposed 5MVA 69 / 13.2 kV Substation for The State University in Bacolor, Pampanga.

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***Abstract— The study of a proposed 5MVA 69/13.2 kV substation for the state university in Bacolor, Pampanga. The distribution system is very essential to the community. It is the consumer's major source of energy. The state university is subordinate to the community's local electric utility. The institution will be self-sufficient and able to significantly reduce power outages at the state university by owning its own substation. This research study's goal is to proposed a substation for Don Honorio Ventura State University's (DHVSU) main campus. The researchers designed a radial type substation that has components of metering equipment, current transformer, potential transformer, lightning arrestor, disconnect switch, circuit breaker (SF6), 5MVA power transformer, recloser, feeder, and etc. The total cost of a 5 MVA 69/13.2 kV substation is Php.35,160,370.00. The researchers calculated that, the 5MVA 69/13.2 kV substation, will reach full load in 17 years, based on data collected on the state university electric usage from 2016 to 2019. Based on the first (1) comparison calculation of the researcher for the return of investment (ROI), it is shown that it will take 11 years to achieve the return of investment (ROI). For the second (2) comparison computation, the researchers consider the future 17 years of annual electric consumption, annual electric bills in PELCO II and the annual electric bills in NGCP. As a result, the DHVSU will begin to see a return on its investment (ROI) in the substation in 7 years' time, as well as lower electric bills and begin to make a profit on its investment.***

## I. INTRODUCTION

The distribution system is very essential to the community. It is the primary source of usable energy for consumers. It is composed of many different pieces of equipment and devices that are connected in sequence to supply power to end users. Substations are locations where voltages are increased to a high quality for transmission and then stepped down for distribution to be generated into usable source. Substations are critical in the power industry's support of the transmission grid in moving electricity from generation sources to customer loads. Substations create a strong connection between generation, transmission, and distribution.

Four types of distribution system: radial distribution system its main characteristic is that power flows are only one direction. It is the most basic system with the lowest initial investment. Parallel feeders' distribution in this system the number of feeders is increased, the initial cost of this system is much higher. When supply reliability is essential, or when load sharing is required, thus this system may be utilized. Ring main distribution system each of distribution system transformer is fed by two feeders, but in opposite directions. The feeders in this system from a loop that begins at the substation bus bars, travels across the load area feeding distribution transformer, and then returns to the bus bars at the substation. Interconnected distribution system is one in which a ring main feeder is energized by two or more substations or generating units. In the case of a transmission failure, this technology ensures reliability. During peak load hours, any area fed from one producing station or substation can be fed from the other generating station or substation to satisfy higher load power requirements.

The university has been renovating and constructing buildings continuously over the last few years. Another factor to consider when renovating and expanding existing buildings is upgrading the electrical system to ensure the buildings safety. According to Gagarin (January, 2002) the university's electrical demand has expanded considerably in recent years, and continues to grow in relation to the university's ongoing expansion of campus utilities and related infrastructures. This new substation is certainly an excellent illustration of modern technology. The university's electrical distribution upgrade will assist in providing reliable power that can meet the university's needs during peak season. According to E. K. M. (2013) upgrading equipment, particularly power transformers, in a substation is necessary to guarantee the system's reliability and meet the customer's needs on a consistent basis.

The State University is being affected by the electrical failure of the local utilities which is not necessary because of an important class that cannot be stopped immediately such as laboratory works, programming class, designing in Auto-cad, major exams, and etc. Furthermore, students are impacted by power outages, which can cause delays in their classwork. The unexpected interruption of electricity supply causes discomfort in everyone's life, as electricity is considered one of the economy's basic needs. Moreover, with the growing demand for electricity, any substation failure that results in power interruption is intolerable for the consumer, as electricity is a primary need in their way of life. Manalo, P.C. (2010) A five-minute interruption is generally considered a reliability issue. As defined by the Philippine Grid Code (PGC), reliability refers to the likelihood that a system or component will perform a required task or mission for a specified period of time in a specified environment. It is a power system's capacity to provide uninterrupted service to its customers.

The state university is subordinate to the community's electric utility. Having its own substation, the university will be self-sufficient and able to significantly reduce power outages at the state university. When a university decides to upgrade its electrical design, it is generally because the university's electric load has increased due to its development. Another reason for redesigning is that the previous design was out of date. According to Kokorus et al., (2018) increased power demand on aging infrastructure produces an increasing number of problems, right up to blackouts.

Roquios, (2007) Iloilo II Electric Cooperative, Inc. (ILECO II) is an electric distribution utility that serves the province of Iloilo's central region. ILECO II cannot simply supply power to its member consumers following the enactment of RA 9136, often known as the Electric Power Industry Reform Act of 2011 (EPIRA). EPIRA requires all electric utilities to ensure the delivery of electric power is of high quality, efficient, secure, and affordable. It modifies the energy industry's rules. It modifies the energy industry's rules. It modifies the energy industry's rules. It authorizes reforms and establishes a framework for reorganizing the energy industries. Additionally, the law adopted and issued the Philippine Grid Code (PGC) and the Philippine Distribution Code (PDC), which establish the rules requirements, processes, and standards for the effective operation and maintenance of the country's transmission and distribution networks. The law intended for the generation, transmission, and distribution sectors to be efficient in all aspects of operation in order to safeguard the public interest as it related to the rates and services of electric utilities and power suppliers.

The researchers came up with the idea of proposing a substation in response to the university's continued growth and development. Simultaneously, the electrical load increases. Besides that, the electrical design must improve.

This study will be limited into design of the substation that will consider the cost analysis and economic analysis. This research study aims to proposed a substation design for Don Honorio Ventura State University's (DHVSU) main campus. The researchers will determine what type of substation, the capacity of the substation, the size of the potential and current transformers, the following equipment or components of the substation (metering, current transformer, potential transformer, lightning arrestor, disconnect switch, circuit breaker (SF6), power transformer, recloser, feeder, and etc.), the location of the substation, the cost of the materials and economic analysis.

The proposed substation design is the first research study that will be conducted at the State University. In the future, the State University can use this research study as a basis to conduct another research study to explore more of this topic and to build on an existing study about designing substations.

This research that the researchers conducted can be of great help to the future development of the State University in considerate to invest in implementation in this substation design. It can be used as a stepping stone and as a foundation for building the project. The future researchers of the Don Honorio Ventura State University campus and outside campus can use this thesis paper as a reference to guide the future researchers in conducting research about designing substation.

## II. METHODS OF THE STUDY

### *A. Planning*

In this procedure, the researchers planned what data will be consider to obtain in this research study to use as a reference for designing the substation. The researchers decided to design a radial type of distribution system, because it is the most basic system with the lowest initial investment. The researchers also considered the 69 kV line from NGCP is the available source for the local utility. The NGCP transmission line located in Sta. Barbara, Bacolor with a distance of 1500 meters away from the location of the proposed substation, will be the 69kV source of the substation. DHVSU can request to NGCP to provide 69 kV line to supply the substation.

When locating the substation, it should be close to where the load comes from, but not in an area with a lot of people. Other factors to be considered in locating a substation are listed: Access Road to the site, Historical data of worst flood, (forest land, sanctuaries, and parks) should be avoided, the local should be aware of the upcoming substation, and should be away from the airport and defense establishment. The researchers proposed to locate the substation at Brgy. Sta Ines, Bacolor, Pampanga at the back of DHVSU. The lot area that required is $675m^2$.

### *B. Data Gathering*

The proponents gathered the following data from PELCO II located at BRGY. San Roque, Guagua, Pampanga, namely: DHVSU's electrical consumption, monthly bill, and electrical demand from 2016 to 2021.

### *C. Designing the Proposed Substation*

The researchers used AUTOCAD in preparing a single line diagram which shows in simplified form of the switching and protection arrangement required, as well as the incoming supply lines and outgoing feeders. Preparing a single line diagram with principal elements (lines, switches, circuit breakers, transformer, feeders) is usually practice by a designer of a substation it will arranged similarly to the way equipment's would be laid out in the actual station. A benefit of adopting a single line diagram is that it allows for more non-electrical information, such as economic data.

The researcher determined the intended capacity of the substation by interviewing an electrical engineer who has experience in the field of designing a substation. The researchers used the power formula for determining the current ratings of the equipment especially current and potential transformer in the 69 kV line and 13.2 kV line. The researchers also figured out the size of the wire of the high voltage and low voltage of the substation by the use of PEC 2017 to properly size the wire and it will depend on the current ratings of the substation/equipment. Power Formula: $P = IV$ (1)

The researchers use voltage drop formula based on PEC 2017 to compute the percent voltage drop of the wire that been use in 69 kV line and 13.2 kV line. Formula for Voltage Drop:

$$\text{Percent Voltage Drop} = \frac{(VD_{PB} + VD_m)x100\%}{Voltage\ supply\ (V)} \quad (2)$$

### *D. Cost Analysis and Economic Analysis*

The consulted Engineer gave the researchers an updated cost of the proposed substation design to calculate the benefits outweigh of the cost of the investment. A cost analysis helped to determine whether to go forward with the proposal.

The formula of growth and decay was used to know when the load of the university will reach the intended capacity of the substation designed by the researchers. Formula for Growth and Decay: $X = Ce^{kt}$(3)

The researcher considers economic analysis to study the effectiveness of substation in reducing the electric bill of the university by computing the Return of

Investment (ROI) of this study to be calculated how much years will return the cost of this study. Formula for Return of Investment (ROI): =

$$\frac{initial\ cost\ of\ the\ substation}{avg.\ annual\ bill\ before\ installation\ -\ avg.\ annual\ bill\ after\ installation\ -\ avg.\ annual\ worker's\ wage} \quad (4)$$

## III. RESULT AND DISCUSSION

### *A. Capacity of the substation*

According to Engr. Ryan David of PELCO II who is specialized in designing substations that the researchers interviewed, 5MVA is the smallest power transformer that can be designed at the university that is why the researchers decided to design a 5MVA substation for Don Honorio Ventura State University based on the interview that was conducted. The researcher also decided to design 5MVA substation for longer used of the university.

### *B. Components of the substation*

Components that have been used into the 5MVA substation; metering, current transformers, potential transformers, lightning arrester, disconnection switch, circuit breaker, power transformer, recloser, feeders, and etc. The components that mention are all be needed to create a radial substation. Current and potential transformer are to be used in metering and protection. Lightning arrester, disconnection switch, and circuit breaker are the protection of the system of the substation. Power transformer is the most important equipment in the substation that must be protected because, it is the one that step down the 69kV into 13.2kV. Recloser is the component that is automatically shuts off the electric power when trouble occurs. Feeders is the distribution point of the substation that deliver the electrical power.

### *C. Size of wire of the substation*

In computing the current ratings of equipment 69 kV and 13.2 kV voltage ratings the researchers used 5MVA as the total power. The researchers came up with a current rating of 41.8370A for 69kV and 218.6933A for 13.2 kV by using the power formula P = IV. The size of wire to use in 69kV equipment is ACSR #4/0, Conductor, Bare, AWG 6/1 (Meters), while in 13.2kV equipment is ACSR #336.4, Conductor, Bare, MCM 26/7 STD (Meters), while in 13.2kV equipment is ACSR #336.4, Conductor, Bare, MCM 26/7 STD (Meters). Based on the voltage drop calculation from NGCP 69kV line going to the substation the researchers calculated 0.2686 percent voltage drop and from the substation going to the farthest building of the university the researchers calculated 0.8320 percent voltage drop.

### *D. Single-line diagram of the substation*

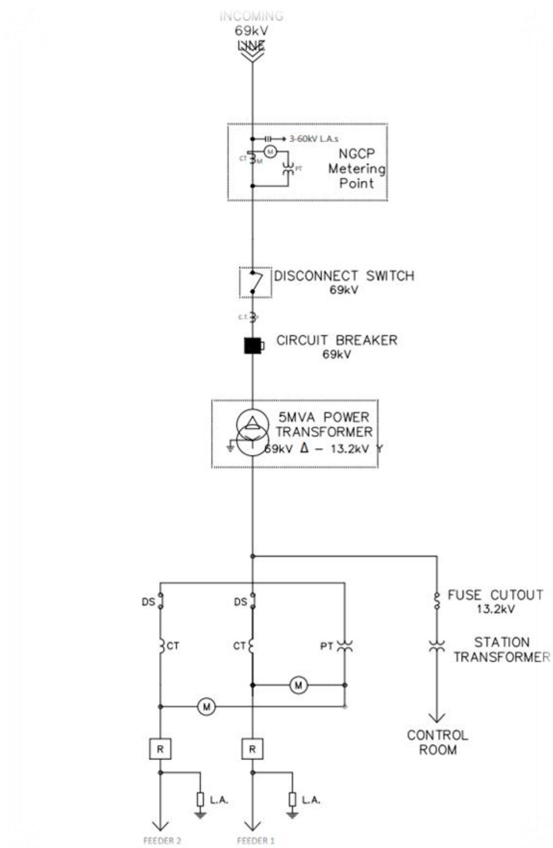


*Figure 1: Single Line Diagram of the Substation*

This single-line diagram is divided into four (5) section: the first section is the incoming 69 kV line going to the NGCP net metering point where you can see here is the potential and current transformer for metering, and also lighting arrester for protection, and the metering from NGCP. The second (2) section is for the protection of the power transformer, it consists of a disconnection switch used to provide isolation; the current transformer can detect a big current fault flowing through a circuit breaker. The current transformer output can be used to trigger the circuit breaker, causing the load to be disconnected and a circuit breaker used as a protection device to interrupt fault currents automatically, and can be used to turn on and off loads. The third (3) section is the main power transformer that allows to step down the high voltage from 69 kV to 13.2 kV. And the fourth (4) section is the recloser it is also protection that used beyond the power transformer it senses when there is trouble occurs and automatically shuts off the power, it has potential and current transformer and also a metering. Lastly the fifth (5) section are the feeders for the feeder one (1) will supply the following buildings: University wellness center, multi-purpose cover court, senior high school building, student center motor pool, IRTPC building, IRTPC extension building, college of business studies building 2, MDRTC building, University hostel, guest lounge, guest house, MP hall, three story IT building, university auditorium, CBS building 3, prince 2 story building, three story girls trade building, CIT extension building, industrial technology building, motor pool, electrical technology building, supply & procurement office, general shop room building, arts and science building, lab building, graduate school building, graduate school extension building, college building, museum, library and period park. The feeder two (2) will supply the following buildings: College of business studies building 1, medical and dental clinic, ECE building, engineering building 2, Eng'g Lab. Building, Civil engineering and mechanical engineering laboratory building, CE lab., accreditation room, faculty office building, computer studies building, student service building, E.A. extension, engineering & architecture building, university food center, library, administration building, and teachers education building. These 2 feeders had a load transfer point in case of trouble.

*E. Cost of the substation*

This is a simplified example that is based on the interviewed that the researchers conducted with Engr. David that is an expert in the field of designing substations to give an overview of full economic costing and is not meant to reflect accurate cost. The equipment's price is based on current market prices, and the equipment's used in the proposed design are based on market availability. The total material cost is Php.19,918,100.00. The total electrical accessories are 10% of the total material cost, civil works also 10% of the total material cost, for the total labor cost is 30% of the total material cost. The total initial cost of the proposed design is simply adding the total material cost, total electrical accessories cost, total civil works cost, total labor cost, and lot area price. Php.33,252,150.00 is total cost of the proposed substation design.

*F. Forecasting the load consumption of DHVSU*

The researcher considered the total average electric demand of Don Honorio Ventura State University. The total average of electric demand in the year 2016 came up to 439.41kW. In year 2017, the electric consumption was 489.23kW. It increased by 49.82kW in the previous year of electric consumption. In year 2018, the amount of electricity that the university consumes is 544.18kW. It increased by up to 54.95kW compared to the consumption of year 2017. In the year 2019, the university consumed a 738.93kW. In that year, the electric consumption increased by 194.75kW compared to the year 2018. In year 2020 the electrical consumption of the university is 411.74kW. It decreases into 327.25kW in the previous electric consumption of year 2019 the reason why the electric consumption decreases by huge amount of 327.19kW is because this year is under the 2020 lockdown during the COVID-19 pandemic. The university consumes 489.06kW of electricity in the year 2021. It is less than the electric consumption in the year 2019. It is also under the COVID-19 pandemic, that's why the electric consumption is still a huge difference in the year 2019.

The researchers used the formula of growth and decay to calculate the increasing electric demand of year 2016 to 2019 of DHVSU. Based on the calculation of the researchers the total average of years is 17.24243 or 17 years to meet the full load of the 5MVA capacity of the substation.

*G. Year 2016 to 2019 comparison of PELCO II and NGCP*

- *Annual PHP/kWh of PELCO II and NGCP*

To compute the annual PHP/kWh of DHVSU is simply the total annual bill divided by total annual electric consumption (kWh) of DHVSU. At the year 2016, 8,999,682.67 divided by 849,487.80 equals 10.59 PHP/kWh. At the year 2017, 9,081,581.45 divided by 934,143.10 equals to 9.72 PHP/kWh. At the year 2018, 9,804,390.75 divided by1,047,326.00 equals to 9.36 PHP/kWh. At the year 2019, 11,666,696.99 divided by 1,191,498.80 equals to 9.79 PHP/kWh. For computing the average PHP/kWh is simply the summation of PHP/kWh of year 2016 to

2019 divided by four (4), the average PHP/kWh of DHVSU is Php.9.87.

Due to the lack of the data that will be needed in this process the researchers came up with a solution that can be used to compute the local distribution of the percentage charge in the electricity distributed by the PELCO II. December 2021 total bill of DHVSU is equal to Php.600,091.12, December 2021 total kWh of DHVSU is equal to 55,295.70 kWh and the December 2021 NGCP PHP/kW is equal to Php.7.34 will be considered as a given reference to determine the percentage charge between NGCP and PELCO II. The researchers calculated 32% charge between PELCO II and NGCP. For the NGCP PHP/kWh at year 2016 is equal to 7.20 PHP/kWh, 2017 is equal to 6.61 PHP/kWh, 2018 is equal to 6.36 PHP/kWh, 2019 is equal to 6.66 PHP/kWh. The average PHP/kWh of NGCP is Php.6.71.

- *Annual bill of PELCO II and NGCP*

The researchers calculated the annual bill to determine how much is the difference between PELCO II and NGCP. The difference between PELCO II and NGCP at year 2016 is Php.2,882,351.18, at year 2017 is Php.2,907,269.12, at year 2018 is Php.3,138,369.97, and at year 2019 is Php.3,734,651.71.

- *Average annual bill of PELCO II and NGCP*

To compute the total average annual bill of PELCO II, it is simply the summation of the total bill of PELCO II per year in the year 2016 – 2019 divided by four (4). This will be used to determine the return of investment (ROI) of this research study. (8,999,682.67 + 9,081,581.45 + 9,804,390.75 + 11,666,696.99) divided by 4 equals to the total average annual bill of PELCO II is totally Php.9,888,087.97.

To compute the total average annual bill of NGCP, it is simply the summation of the total bill of NGCP per year in the year 2016 – 2019 divided by four (4). This will be used to determine the return of investment (ROI) of this research study. (6,117,331.55 + 6,174,312.23 + 6,666,020.52 + 7.932,045.81) divided by 4 equals to the total average annual bill of NGCP is totally Php.6,722,427.53.

- *Return of Investment (ROI)*

The researchers used the initial cost of the substation, average annual bill before installation, average annual bill after installation, and average annual worker's wage to compute the return of investment (ROI). Based on the researcher's computation for the proposed substation it will takes 11.28 years or 11 years to achieve the return of investment (ROI).

*H. Future comparison of PELCO II and NGCP*

- *Average growth of DHVSU electric consumption*

The total annual kWh consumption of DHVSU in the year of 2016 to 2019 will be considered as a given reference to determine the difference of consumption yearly to be used to calculate the average growth of kWh of DHVSU to assume the future kWh consumption: Year 2016 = 849,487.80 kWh, Year 2017 = 934,143.10 kWh, Year 2018 = 1,047,326.00 kWh, Year 2019 = 1,191,498.80 kWh. Based on the calculation the difference kWh at year 2016 to 2017 is 84,655.3 kWh, at year 2017 to 2018 is 113,182.9 kWh, at year 2018 to 2019 is 144,172.8 kWh. The average difference kWh is 114,003.67 kWh. *Average PHP/kWh of PELCO II and NGCP*

The total annual PHP/kWh of DHVSU in the year of 2016 to 2019 will be considered as a given reference to determine the average of PHP/kWh yearly to be used to assume the future PHP/kWh: Year 2016 is equal to 10.59 PHP/kWh, Year 2017 is equal to 9.72 PHP/kWh, Year 2018 is equal to 9.36 PHP/kWh, Year 2019 is equal to 9.79 PHP/kWh. The average PHP/kWh of PELCO II is Php.9.87.

For the NGCP PHP/kWh at year 2016 is equal to 7.20 PHP/kWh, 2017 is equal to 6.61 PHP/kWh, 2018 is equal to 6.36 PHP/kWh, 2019 is equal to 6.66 PHP/kWh. The average PHP/kWh of NGCP is Php.6.71.

- *Return of Investment (ROI)*

Considering the 2016- 2019 electric consumption of DHVSU in determining the future 17 years; annual electric consumption of DHVSU, annual electric bill in PELCO II, and annual electric bill in NGCP. The researchers consider the price of electricity for PELCO II and NGCP to multiply into the annual consumption of DHVSU to compute the annual electric bill of DHVSU in PELCO II and NGCP. It shows that the electricity consumption of DHVSU is continuously growing per year. The researcher's observation to the results of this computation the higher the consumption of DHVSU, the lower the electric bill by having an own substation. The researcher considered the worker's wages in the substation and less it in the yearly saving of DHVSU. Based on the computation of the researcher it shows that in the year 2028 it has already returned on its investment (ROI) in the substation, and it is starting to lower the electric bill and it is starting to make a profit on its investment.

## CONCLUSION

The study entitled "Proposed 5 MVA 69 / 13.2 kV Substation for the State University in Bacolor, Pampanga" which tackles about the proposal of a substation to serve as an upgrade of the existing electrical system of a state university located in Bacolor, Pampanga. Its main purpose is to have an efficient and a sustainable energy that will help lessen the episodes of power interruption within the state university. This proposed substation can be used as an independent supply of power to the buildings and the facilities of Don Honorio Ventura State University.

The intended capacity of the substation is 5 MVA 69 / 13.2 kV. Upon reaching the end of this study, the researchers have determined the cost of this design to be Php.32,281,050.00. Also, based on the data gathered regarding the electric consumption of the state university from the year 2016 up to 2019, the researchers ascertained that given the designed capacity of the substation, it will reach its full load in 17 years.

Furthermore, based on the December 2021 data, the researchers calculated the percentage charge difference between the NGCP and PELCO II to be at 32%. Given the calculated percentage, the proposed project will reach its full return of investment (ROI) in no less than 11 years' time. For the future comparison the researchers computed that in 7 years' time the DHVSU will start to returned on its investment (ROI) in the substation, and it is starting to lower the electric bill and it is starting to make a profit on its investment. Hence, the researchers have concluded that the proposed 5 MVA 69 / 13.2 kV substation is profitable and feasible for DHVSU.

## V. RECOMMENDATION

During the past several months, the researchers have met their objectives in conducting the study and have reached their conclusions. Having said that, if this study shall be pursued in the near future, the following critiques, suggestions, and recommendations are intended to further improve the grounds and purpose of the study. Primarily, the researchers suggest utilizing the load schedule of the buildings located within the state university to forecast the full loading capacity of the 5MVA substation.

Furthermore, in terms of cost, the maintenance of the said project must be considered also when calculating the ROI. For a more accurate ROI computation, the researchers also propound to consider requesting updated and actual data of PHP/kWh from the NGCP.

For the complete design of the substation the grounding system of the substation must be considered in the design. The researchers recommended to consider to use two 2.5MVA power transformers in designing a substation to compare the reliability and sufficiently between the two 2.5MVA power transformers and one 5MVA power transformer. In addition, the consideration of the development plan for proper locating of the substation.

The researchers recommended to compute or request to NGCP for the billing price of the cost of 69kV line starts in Sta. Barbara, Bacolor, Pampanga going to DHVSU substation, Bacolor, Pampanga. Also, the proponents recommended to find a possible customer near in DHVSU for the substation to fasten the ROI of this study. To conclude, if considered that the research will be implemented, the researchers put forward that more intensive planning, and data gathering must be done prior to the execution of the 5 MVA 69 / 13.2 kV substation.

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