Effect of Economic in Factory Installing Voltage Regulator

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ABSTRACT

There are many factors contributing to a problem of voltage drop in electricity distribution system such as a proximity to large electricity demand during the peak hours, a long distance between the industries/end users and the electricity substations, load factors and etc. To solve the problem, the electric utility normally compensates this drop by increasing the input voltage level in the transmission line. To avoid these consequences, in this research, the tap – switching voltage regulator is introduced to a sample of manufacturers located in Mahasarakham industrial estate, its conventional input voltage level is approximately 229 volts which is higher than the nominal voltage level. After the regulator installation, the input voltage is lower to 220 volts. It leads to 4.36 % electricity saving per month. Since the electricity consumption is reduced around 21,144.51 kWh per month or 61,319.08 Baht/month. The investment will break even within only 1.32 years.

Keywords: Economic return, Voltage regulator

Introduction

In the production and distribution of electrical power, it is started from the electrical generator which can generate electrical power that can have a voltage level at about 10 kV to 20 kV. After which this voltage will be sent through a main transformer station and high-voltage power lines to the power distribution station. This power is then transformed into a voltage level that is sufficient to the needs of electrical appliance and then supplied to the general consumers. The amount of voltage sent out to the power line at this point is in the range of 220 V to 240 V. The level of voltage at the source of the power line or at the area of the power distribution substation will be highest. The level of voltage will be reduced subsequently when it reaches the end of the power line. The purpose of this was to prevent the voltage drop incident at the end of the power line.

The voltage drop incident is a situation which the electrical power is insufficient to the needs causing electrical appliances to stop functioning. The incident may cause damage to electrical machines to have a voltage drop incident in the industrial factory which is running an active production and can affect the production system. The damaged machines can create loss in terms of many million baht.

This study will start to consider the problems which the factory found. The potentiality to reduce the power usage by reducing the level of electrical voltage including the suitability and the worthiness of investments in installing the voltage regulator device in order to save electrical power. To consider the worthiness of investment, the Economy Index will be used. Since the installation process and usage of the voltage regulator device is used to save electrical power and has involved a lot of investment, therefore as a result if the return values from the investments are too little, a different method which is more efficient and suitable should be chosen instead.

Materials and Methods

Theory and Operational Process

1) Electrical power in AC circuit 1 phase

Electrical power is power energy which electrical equipment uses within one second or is equivalent to the multiplication of electrical voltage at one point which falls on the load and the ampere at one point to the load in the unit of ampere. If the load terminal is *a* and *n*, the relationship of voltage and current can be written as the following equations [1]:

$$V_{an} = V_{\max} \cos \omega t \qquad (1)$$

$$I_{an} = I_{\max} \cos(\omega t - \theta) \qquad (2)$$

and electrical power at one point is

$$P = |V||I| \cos \theta \qquad (3)$$

where P is an electrical power in AC circuit (kilovolts), V_{max} is the highest voltage in AC circuit (volts), I_{max} is the highest current in AC circuit (ampere), V_{an} is an electrical voltage between terminals of loads, I_{an} is an electrical current between terminals of loads and $\cos\theta$ is a power factor of AC circuit

After considering Equation 3 , it can be seen that the manufacturer—which has the level of voltage higher than the standard—must carry the burden of high costs which pays to the unknown accelerated energy. Therefore, the reduction of the high-voltage level to the standard level can help the manufacturer save the monthly energy expense.

2) The analysis of the net present value

To analyze the worthiness economically, we used the economic principle to calculate the value of investment and the expense each year by converting that to the net present value. Then we used it to find the time for the return of investment which can be chosen through the following suitable analyses [2].

$$NPV = \sum_{t=1}^{n} \frac{F_t}{(1+i)^n} \qquad (4)$$

where *NPV* is a net value which is adjusted to time of present year (baht), F_t is an expense in year *n* (baht), *i* is an interest and n is years of ending project (year)

To compare the worthiness of a project from NPV, it is better to choose a project that has a higher NPV. This is done by comparing projects based on the consideration of money value according to times. However, if wanting to analyze and compare the economics worthiness value in detail, it is better to use an actual value of return investment ratio for comparison.

3) Internal rate of return: IRR

Internal rate of return (IRR) means the internal rate the investor will receive from investing into the project. After considering the average annual of the entire investment as a ratio, the total results of the entire projects net cash present value was equaled to zero. For the decision of using this method, if the return rate of the project is higher than the return rate needed or the cost of investments, then an investment should be chosen by comparing the worthiness of the project from the IRR. A project with an IRR that is higher should be chosen to be invested in [3-4].

$$-I_0 + \sum_{t=1}^{n} \frac{ES_t}{(1+IRR)^t} = 0 \qquad (5)$$

Where N is a life of the project (years), ES_t is an annual savings of energy costs since the ending of year 1 to *n* and I_0 is an investment paid at the beginning of the project (total investment).

4) Procedures

For the study and the analysis of the efficiency of saving power by decreasing voltage, we studied from an industrial factory within the zone of

Mahasarakham province. By which this factory is one of the factories that was experiencing the problem of voltage level being higher than the standard. The steps of the study procedures are listed in the following.

a) The potential and sensibility in decreasing voltage for saving electrical power: We studied the potential of the process of saving electrical power by decreasing the voltage of the industrial factory. We did this by using information of the use of electrical power collected by measuring and considering the suitability from the information of the electric machines within the factory.

b) The suitability in decreasing voltage with various methods: In this case which the industrial factory has the ability to decrease the voltage in order to save electrical power, the next title is the study to find the best way to reduce the voltage that is most suitable with the industrial factory. This is done by taking the data of the installation process of the voltage regulator device to compare and see if there is any other methods that can be used and how suitable each method is.

c) Efficiency in saving electrical power by reducing voltage: From reducing voltage that is higher than standard to be equivalent to the standard of industrial factories, the next objective is to analyze how much power could be saved by reducing voltage. This was done by measuring the power usage with a data logger with a chance of error of 0.1% to measure both cases where voltage is reduced as well as when voltage is not reduced. This was done by taking the data collected from measurements to find the relationship and difference in power usage and then to find the efficiency in saving electrical power.

Results and Discussion

The Factories Average Use of Electricity After Adjustment

"The factories average use of electricity after adjustment" is the state of the industrial factory which had installed and used the voltage regulator device which made the lowest average of voltage reduce from 227 V to 220 V. Which from the idea and theory that saving electrical power will make the average usage of electrical power of the factory in this case reduce, based from the information of the average usage of electrical power. The production in Figure 1 can be used to create a relationship graph between the usage of electrical power and the production.

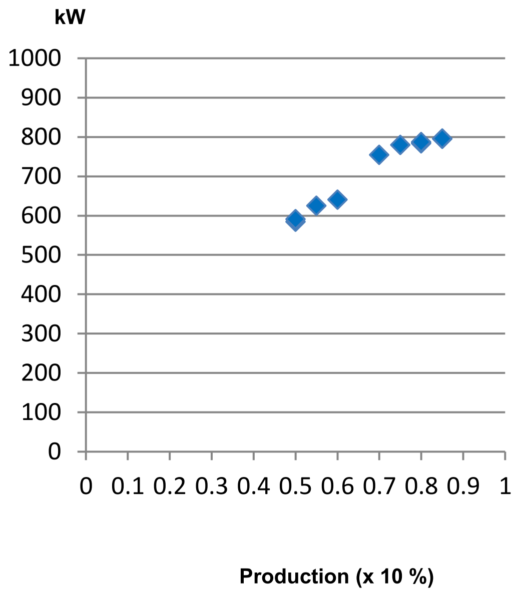

Figure 1 The relationship of the usage of electrical power and the production of the factory after adjustment.

The graph shows the relationship received after measuring the average usage of electrical power and the factories production after adjustment. An equation of its relationship can be made as Equation (6). Average usage of electrical power after adjustment is:

$$Y_S = 418.13 \ln (X_S) + 877.35 \qquad (6)$$

where Y_S is an average usage of electrical power after adjustment (kW) and X_S is factories amount of production (%). All of this, the given equation has a coefficient in decision (R2) equal to 0.96.

The Percentage of the Results of Saving Electrical Power from Using the Voltage Regulator Device

The installation and usage of the voltage regulator device for saving electrical energy helped the industrial factory to reduce the lowest average level of voltage from 227 V to 220 V. From the reduction of voltage this helped the factory to save electrical power monthly as Equation (7):

$$PS = [(kW_{avg}\,Normal - kW_{avg}\,Save)/kW_{avg}\,Normal] \times 100 \quad (7)$$

where kW_{avg} *Normal* is calculated from Equation (8):

$$Y_N = 333.77 \ln (X_N) + 899.26 \quad (8)$$

and kW_{avg} *Save* is calculated Equation (9):

$$Y_S = 418.13 \ln (X_S) + 877.35 \quad (9)$$

where kW_{avg} *Normal* is an average usage of electrical power before adjustment and kW_{avg} *Save* is an average usage of electrical power after adjustment.

In finding the percentage of the results of saving electrical power, it is necessary to consider the average usage of electrical power of the industrial factory equivalent to its production. Therefore, the value of X_N is equivalent to X_S

Therefore,

$$PS = \left[\frac{(333.77 \ln X + 899.26) - (418.13 \ln X + 877.35)}{333.77 \ln X + 899.26}\right] \times 100\%$$

$$PS = \left[\frac{\ln X^{-25} + 6.5}{\ln X + 2.69}\right] \quad (10)$$

where *PS* is a percentage of the results of saving electrical power of the industrial factory and *X* is an amount of production of the factory at that point (%).

From the given equation of the relationship, after distribution of the production from 40%-90, which is the normal production rate of the factory, a relationship graph can be made between the usage of electrical power and the production as the following.

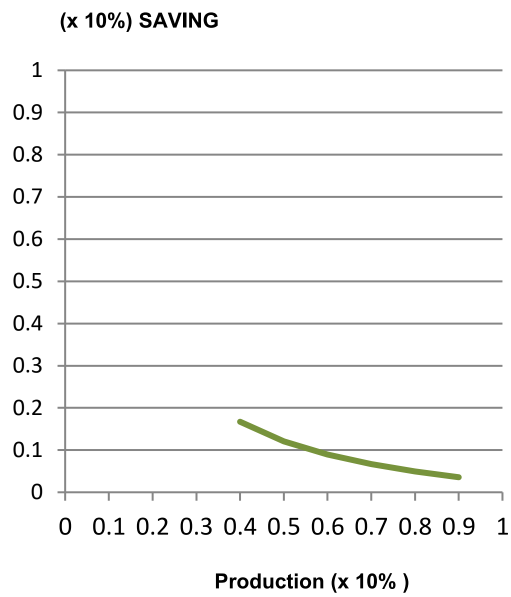

Figure 2 The percentage of the results of saving power in various points during production that was received from reducing voltage of the industrial factory.

From Figure 2, relationship between the percentage of saving power and the production, it has been found that if the industrial factories production rate increases, the value of the percentage of saving power decreases. From all of this, because most of the types of electrical machine loads are Alternating Current Motors (AC motors) which the behavior of power usage of AC motors can be divided into the following 2 operating conditions.

- in a full load operating condition, if voltage is reduced it will not affect the power usage of the motor

-in a non-full load operating condition, if voltage is reduced it will affect by helping the AC motor reduce power usage.

Conclusions

From studying the usage of the voltage regulator device of an industrial factory within in Mahasarakham industrial estate, after adjusting average level of voltage from 229 V to 220 V which the production of the industrial factory has as a normal value will be able to save electrical power monthly by 4.36% which can be considered as 21,144.51 kWh/month or 61,319.08 baht/month and has the amount of time for return investment of 1.32 years.

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