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Life Cycle Cost Assessment of Replacing Standard Induction Motor with High Efficiency Induction Motor Used in Salt Industry

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Abstract. Energy conservation and energy management, which is important thing that must be done by industrial players in Indonesia, has a purpose for optimizing energy usage. it becomes important in electricity, because rising of the electricity cost makes electricity itself not being a cheap thing anymore. For decreasing the electricity cost that should be paid, it is necessary to do energy conservation on electrical energy. Electric motor is one of the core parts of industrial sector that has the biggest electricity consumption. In other words, if the energy conservation needs to be done in industrial area, so that means it can be focused in electric motors. In that case of pressing electricity cost, suitable strategy can be reached by not only considering to the technical aspect but also economical aspect. Life cycle cost and payback period are some of the economic assessment tools which can be helped for assesing strategy in many cases. By using those tools, it can be reached the assessment of replacing strategy that is used in induction motors in salt industry, which is used as a one of the tools to make a decision. This paper will explain about how to use life cycle cost and payback period in induction motors replacement case.

INTRODUCTION

Industrial sector in Indonesia is one of the significant sectors that has large contribution in total electricity usage. The continuous production activities, that is undertaken by industrial sector, certainly require a lot of electricity consumption, and it is noted that 49,8% of total electricity sales in Indonesia is used by that sector[1]. On the other hand, in the internal industrial sector, electric motors use around 30%-80% of total electricity usage which makes it become one of the biggest contributors [2]. Electric motors themselves have a premier function in industrial process, particularly production process that makes electricity consumption of the electric motors cannot be avoided. As time goes on, the electricity cost increased gradually and is not as cheap today as before, Therefore, almost all of the industrial players think that improvements are required for pressing electricity consumptions which are used for operational. It also drives them to carry out the energy conservation and management.

Energy conservation is one of the vital tools that should be done for increasing optimization in industrial process. It is also predicted that it can reduce the energy consumption (in this case electricity) by approximately 11% to 18% [3]. Moreover, if the aim is to reduce the electricity usage, the conservation should be focused to the electric motors. In addition, the best way to decide the proper strategy that can be used for bringing electricity cost of electric motors operational down begins with analyzing the life cycle cost of electric motor itself [4]. Afterwards, savings, investment value and payback period also can be calculated for supporting data.

Salt industries, which most operational electricity usage is used by induction motors, is a one of the important industrial part in Indonesia. Based on the survey data, almost 77% of the total electricity consumption is used by electric motors operational [5].

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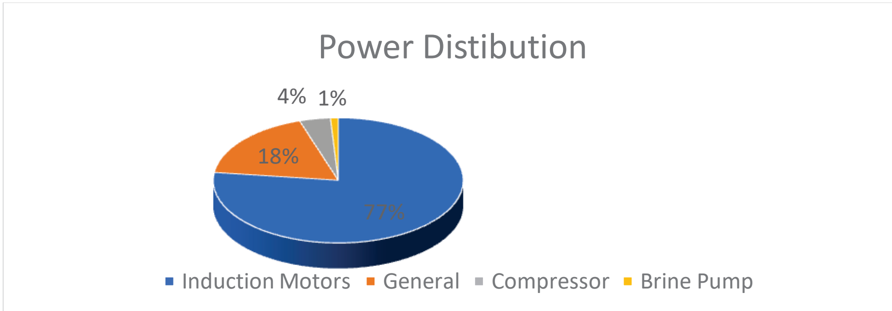

FIGURE 1. Electricity distribution.[5]

One reason of this, because electric motors is one of the important parts in salt operational industry that has the biggest effect to the production goal whether it can be achieved or not. Hence, to reach the production targets without wasting too much energy, the condition of electric motors which can be operated in effective conditions are required and this leads to effective evaluation conditions of electric motors that should be done. In the end, by doing life cycle cost assessment towards the electric motors, the escalation of the electric motors operational effectiveness, cost savings, and also the decision whether this replacement strategy is feasible to implement can be expected as a result.

METHODS

Data Collections

In this research, there are two ways to collect the data that will be used. Firstly, the premier data is collected by doing measurements directly in the factory, and also interviewing person who is responsible in each area of researches. Secondly, the supporting data is collected from some literature on the internet and books. In this research, the number of induction motors that is used are 70 induction motors. All of the premier data that will be collected directly in the factory are induction motors condition (such as RPM, voltage and current), historical maintenance data, historical inspection data, historical life cycle of induction motors, historical of electricity bills. Whereas, supporting data that will be collected from the internet and books are inflation, economic growth of the country, labour standardization salary in the city where the factory located.

Processing Data of the Induction Motors

Processing data of the induction motors has a purpose to know the actual/current conditions of the induction motors whether it has already had to change or not. From 3 measurement data that has been collected (RPM, voltage, current), the processing data can be done and will be gotten some results, such as actual load, power input actual, estimation of the efficiency based on actual loading, power output actual/current (kilowatt and horsepower) based on actual loading.

Actual Load

Actual load is a value that is calculated for representing actual load in operating condition which is obtained by induction motors. Actual load can be calculated by using this formula :

$$\text{Actual Load} = \left(\frac{\text{Iavg}}{\text{Inameplate}} \times \frac{\text{Vavg}}{\text{Voltage standard(380 V)}}\right) \times 100\%$$

Where :

$I_{nameplate}$ = The current that is written in nameplate or catalogue of the induction motors.

Actual Power Output Based on Loading (in Horsepower) ($P_{out\ based\ on\ the\ load(in\ HP)}$)

Actual power output based on loading in horsepower (HP) is a value that represent how many horsepower that should be released by induction motors in the specific loading conditions. Actual power output based on loading in horsepower (HP) can be calculated by using this formula :

$$P_{\text{out based on load in HP}} = \text{Induction Motor Load} \times \text{HP}_{\text{nameplate}}$$

Where :
HP nameplate = The horsepower value that is written in nameplate or catalogue of the induction motors.

Actual Power Output Based on Loading (in Kilowatt) ($P_{out\ based\ on\ load\ (in\ kilowatt)}$)

Actual power output based on loading in kilowatt (Kw) is a value that represent how many kilowatt that should be released by induction motors in the specific loading conditions, that means, this value is same with actual power output based on loading in horsepower. However, they have different unit. To convert horsepower unit to kilowatt unit, this formula can be used :

$$P_{\text{out based on load in kilowatt}} = P_{\text{out based on load in HP}} \times 0{,}746$$

Estimation of Efficiency Actual Based on Load (η_{act}).

Actual efficiency can only be obtained by performance test in test lab area, in other words, it cannot be calculated by using a theoretical. However, doing the performance test to the induction motors will disturb the production process. Therefore, theoretical formula will be used for estimating the value of actual efficiency by using power losses (Q_{Loss}) approach and assume that the power output does not change against the load ($\cos\theta = \cos\theta_{rated}$). The assumption should be done because power factor cannot be measured correctly in the survey field.

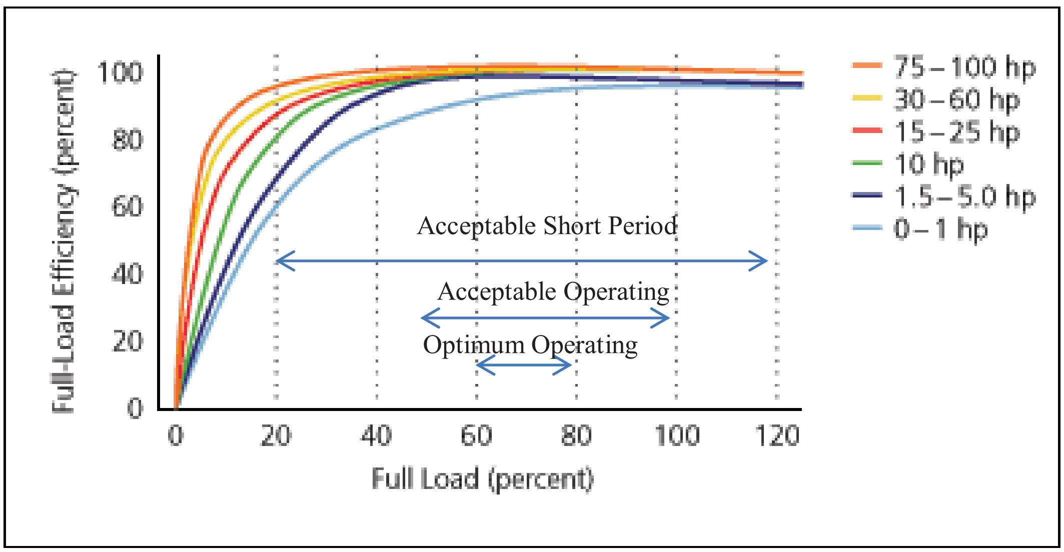

FIGURE 2. Efficiency vs Load [8]

Because of that the graphics in the figure 2 will be used. Based on figure 2, it shows that increasing load will be followed by increasing efficiency as well. One reason of this is electric motors manufacturer has designed that the acceptable operational efficiency of induction motors will appear in load between 50%-100%[6]. Furthermore, the maximum efficiency of induction motor will be gotten in 75% load and will drastically decrease below 50% load [6], whereas to know actual efficiency, induction motors have to follow several test outside the operational place and comparing to the original standard graphics that has been made by the maker. Therefore, because doing test will disturb production activities, the efficiency value can be estimated by using this formula :

$$\eta_{act} = \frac{\left(1-\left(\frac{1}{\eta_m}-1\right) P_{out\ nameplate}(0{,}3(\frac{V}{Vrated})^2 + 0{,}7\left(\frac{V \times I}{Vrated \times Irated}\right)^2\right)}{(\frac{1.732 \times \cos\theta \times V \times I}{1000})} \times 100\%$$

Power Input Actual (P_i)

Power input actual is a value that represent how many electricity which should be input to the electric motors from the electricity sources for operating the induction motors in specific loading. Power input can be calculated by using this formula :

$$\eta = \frac{P_{out}}{P_{in}} \times 100\%$$

$$P_{in} = \frac{P_{out}}{\eta} \times 100\%$$

Estimation of Induction Motors Condition after Replacement

After existing induction motors condition, which has been calculated before, has been known after comparing to the graphic, the induction motors which is not in good condition will be prioritized to change with energy efficient motors and more appropriate horsepower. One reason of this, owing to optimize use of the induction motors which has optimum condition in 75% load [6]. Furthermore, The condition of induction motors can be estimated by using the data(HP, RPM, efficiency nameplate) that can be collected from nameplate and catalogue, also calculating load, power output and power input. As a results, power savings can be known.

Estimation of Load after Replacement (%)

Estimation of load after replacement can be calculated by using this formula :

$$Load = \frac{P_{\text{out based on load in HP}}\ (existing\ motor)}{HP_{\text{nameplate recommendation motor}}}$$

Power output existing motor is used because to operate in similar load, the recommendation induction motors should have same power output with existing motors.

Power Output (in Kilowatt) ($P_{out\ (in\ kilowatt)}$)

Power output in kilowatt can be calculated by using this formula :

$$P_{\text{out based on load in kilowatt}} = P_{\text{out based on load in HP}} \times 0{,}746$$

Estimation of Power Input ($P_{in\ aktual}$)

Power input can be calculated by using this formula (The efficiency value ,that will be used in this formula, can be collected from nameplate of induction motors) :

$$\eta = \frac{P_{out\ aktual}}{P_{in\ aktual}} \times 100\%$$

$$P_{in\ aktual} = \frac{P_{out\ aktual}}{\eta} \times 100\%$$

Power Savings (in kilowatt)

Based on power input calculations, the value of power savings can be known by using this formula :

$$Power\ Savings = P_{input\ existing\ motors} - P_{input\ recommendation\ motors}$$

Power savings value will be used in annual savings costs calculations in further step.

Life Cycle Cost

In the life cycle cost calculation, there are some supporting factors that will be used such as inflation, economic growth of the country, Standardization salary. However, in this case, the inflation and economic growth historical data that will be used is only 2 years (2014-2015), because it is based on president change in 2014 until this project started. Therefore, to ease the calculation, both of those value will be averaged instead of doing forecast to the data.

Life cycle cost calculation will be assumed to start in March 2016 and it will take 4 years for life cycle of the induction motors (based on historical data in the factory). Moreover, there are some aspects that will be used in this calculation, which are :

Initial Cost

Initial cost in this case is a cost that should be spent for buying new energy efficient motors including installation and commission cost. Additionally, initial cost does not affected by the inflation and the economic growth, because intial cost is a cost which is only paid in the beginning of the projects.

Installation and commission cost

In this case, installation and commission cost will be put in the initial cost to ease the calculation, because both of the cost will also be spent in the beginning of the projects.

Maintenance cost

The value of maintenance cost that will be used in this case are the cost which should be spent for employee salary during maintenance activities and spare parts cost. Maintenance cost will be affected by the inflation and economic growth, owing to calculate salary increase for employee each year, the inflation and economic growth value will be used in the calculation. In addition, maintenance costs will be calculated in 4 years (during life cycle cost of the induction motors).

Operational cost

The value of operational cost that will be used in this case is the electricity cost which should be paid during the operational time. To calculate operational cost in a year, this formula can be used :

$$Operational\ cost = (KWh\ \ each\ months\ LWBP\ \times\ price\ of\ LWBP) + (KWh\ each\ months\ WBP\ \times\ price\ of\ WBP) \text{ x 12 month.}$$

Where :
LWBP = the electricities that is used between 10 pm until 5 pm.
WBP = the electricities that is used between 5 pm until 10 pm.

Inspection cost

In this case, the value of inspection costs is a cost that should be spent for employee salary during the inspection activities. Inspection cost will be affected by the inflation and economic growth, because to calculate salary increase for employee each year, the inflation and economic growth value will be used in the calculation. In addition, inspection costs will be calculated in 4 years (during life cycle cost of the induction motors). In general, inspection process is one of the preventive maintenance parts. Nevertheless, the inspection process that is done in this case is only visual inspection (temperature and sounds motors check). hence, the inspection costs will be separated from maintenance costs.

Environment cost

In this case, environment cost will not be used in the calculation due to the data ,which has been gotten, is not enough.

Down time cost

In this case, down time cost will be ignored from the calculation due to unpredictable time when down time will happen. Whereas collecting historical data is not possible because the historical data, which has been collected for down time cost, is not enough.

Disposal cost (salvage value).

Salvage value is a value that will gotten from scrapping motors or selling the motors. Meaning, salvage value can be an income or outcome for the company. It depends to the company policy. Furthermore in this case, salvage value will be an income for the company due to the company policy which chooses to sell the used motors. Salvage value is only put into the calculation one time which is in the end of life cycle cost of the induction motors.

Based on all of the aspects above, life cycle cost can be calculated by using this formula:

$$LCC = CP_p + CP_i + CP_L + CP_o + CP_d + CP_{Env} + CP_{dec}$$

Where :

CP_p= Initial cost (Purchase), CP_i = Installation and commission cost, CP_L= Maintenance and labour cost, CP_o= Operational cost, CP_d= Down time cost, CP_{Env}= Environment cost, CP_{dec}= Disposal cost

Then, after adjustment has been done, the formula of life cycle cost in this case will be :

$$LCC = CP_p + CP_{insp} + CP_L + CP_o + CP_{dec}$$

Annual Savings and Payback Period

Annual savings is a value that represents how much cost savings each years. In other words, annual savings can be gotten from the gap between cost of the old induction motors with cost of the new induction motors. Annual savings can be calculated by using this formula:

$$Annual\ saving\ = (Operatinal\ Cost + Maintenance\ Cost)_{Existing} - (Operational\ Cost + Maintenance\ Cost)_{recommendation}$$

Whereas payback period is a economic method that has a function for estimating and calculating how long the money that has been invested will come back. In addition, simple payback period has also another function for assessing the investment whether is feasible or not. Payback period can be calculated by using this formula :

$$Payback\ periods = \frac{Investment\ Cost}{Annual\ Savings}$$

Then, after adjustment has been done, the formula of payback period in this case will be :

$$Payback\ periods = \frac{Initial\ Cost - Salvage\ Value}{Annual\ savings\ Averaged}$$

RESULTS AND DISCUSSION

Existing motors

Based on the data that has been processed, some of motor conditions can be gotten by classifying into some classes (50%-100% *acceptable operational*, 60%-80% *optimum operational*, and outside of both classes will be classified into *non-acceptable operational*, (it is showed in figure 2) for 70 motor samples that has been used in collecting data. Furthermore, the results is shown in figure 3, where 46 existing motors have been classified into non acceptable operational conditions, 13 existing motors have been classified into acceptable operational conditions and 11 existing motors have been classified into optimal operational conditions.

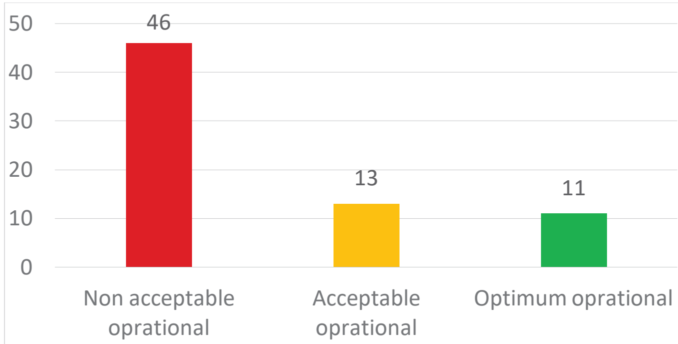

FIGURE 3. Existing motors classification results based on conditions.

Estimation of Induction Motors Condition after Replacement

After replacement of induction motors has been done based on figure 2 (Load vs Efficiency), the condition of induction motors can be estimated. The results is shown in the figure 4, where the conditions after replacement is 59 motors can be operated in the optimal conditions, 11 motors can be operated in acceptable conditions, and no one of the induction motors is still operated in non acceptable conditions. Replacement of the induction motors is not recommended for the motors which is classified into acceptable conditions, because referring to the recommendations when applying energy efficient motor [3, 7], it is not recommended to replace before the conditions which requires replacement. Besides of that, Doing replacement to the induction motors which still in good conditions will give the company losses.

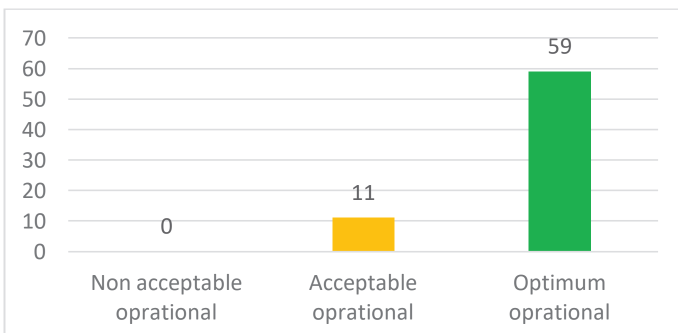

FIGURE 4. Estimation of induction motors condition after replacement

Life cycle cost

In this case, life cycle cost is used to know how much costs that should be spent during the life cycle of induction motors (in this case, life cycle will be in 4 years, because it based on the historical data of life cycle induction motors in salt industries which is we got in the field survey). After life cycle cost has been calculated, the results is obtained and is shown in figure 5. Where from the figure 5, it can be known that there are 5 aspects in life cycle cost calculations which is initial cost, maintenance cost, inspection cost, operational cost, and disposal cost (salvage value). Furthermore, It also can be known that initial cost and maintenance cost is not the highest cost which should be spent, because they onlv need IDR 909.802.4773,00 and IDR 1.394.579.047,87. On the other hand, operational cost is the highest cost that should be spent which has value IDR 12.234.307.210,95. Moreover, inspection cost only has IDR 29.135.166,08 that should be spent, while disposal cost (salvage value) is in contrast condition, because of company policy, they sell all of the used induction motors which is need to be replaced. In other words, it becomes an income for the company which has a value IDR 8.751.600,00.

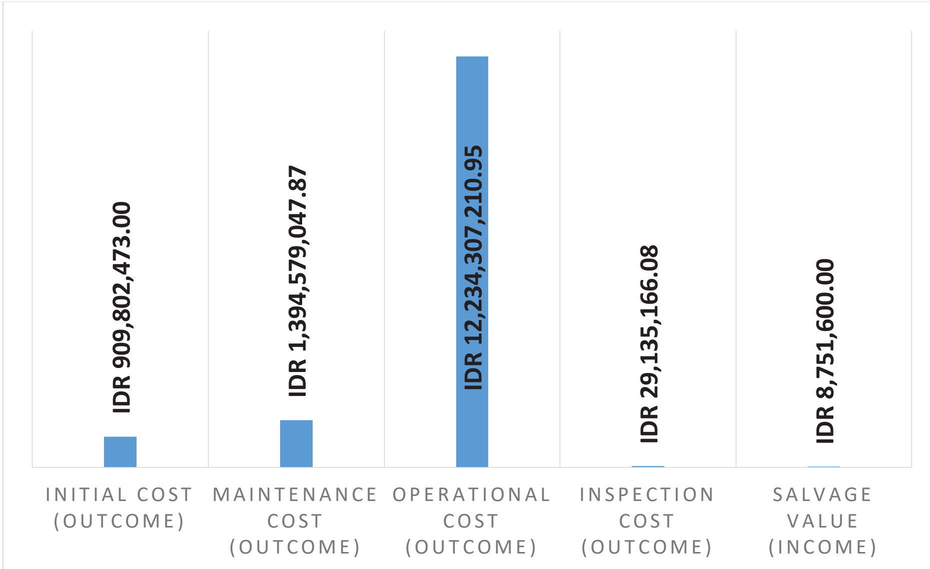

FIGURE 5. Life cycle cost results

Annual savings dan payback period

TABLE 1. Annual savings and Payback period results

Existing Motor		New Motor					
Operational Cost	Maintenance Cost	Operational Cost	Maintenance Cost	Annual Savings	Initial Cost	Salvage Value (Existing Motor)	Payback Period (years)
IDR 3.244.363.935	IDR 442.552.612	IDR 3.058.576.802	IDR 355.767.518	IDR 272.572.226	IDR 909.802.473	IDR 8.751.600	3.3

Based on calculation process of payback period, it can be known that annual savings total is IDR 272.572.226,70, where the component that is used for calculating the annual savings are only maintenance cost and operational cost, while inspection cost does not need to be calculated because each motor has a same inspection cost. Furthermore, after the value of annual savings has been known, payback period can be calculated by dividing intial cost minus salvage value with annual savings. In this case, the value of initial cost is IDR 909.802.473,00 and the value of salvage value is 8.751.600,00, as a result, the value of payback periods is 3,3 years.

CONCLUSION

In conclusion, based on 70 induction motors that has been used for research object, there are 46 induction motors in non-acceptable conditions, that means, the replacement of induction motors should be done. Because as we know that operational and maintenance cost are the highest costs, so if we do not replace the motors which are not in the acceptable conditions, there will be a lot of losses that company get. On the other hand, replacement of the induction motors is not recommended for motors which is still in good conditions, meaning all of the motors which is in acceptable and optimum conditions are not need to be replaced. In addition, calculating life cycle cost in replacement induction motors cases has an aim to know cost estimation that should be spent during life cycle of induction motors and also for supporting the calculations of payback period and annual savings which is used for considering tools in decision-making. In this case, we can see that due to the replacement toward non acceptable motors, we can operated 59 motors which are in the optimum conditions, that means, there are also cost savings that will be able to get as a result of eliminating some energy losses. In addition, regarding to the payback period, this replacement strategy is feasible to implement. Because based on historical data, the average of life cycle of the induction motors in salt industry is around 4 years. However this strategy is only need 3,3 years to return the investment value in total.

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