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# Electrical Usage Reduction in UPHA Pharmaceutical MFG (M) Sdn Bhd for Electricity Bill Savings

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## Abstract

UPHA Pharmaceutical MFG (M) Sdn Bhd is a pharmaceutical company located in Bangi Industrial Estate and has more than 40 years of history. The electrical tariff has increased by 5% in June 2012. The maximum demand (highest power recorded) in the plant is 1763 kW and the annual electricity cost is RM 3.7M which was the highest recorded so far. The increase has reflected badly on the operation cost and eventually affected the company's profit at the end of the day. The objective of this research paper is to reduce the monthly electricity bill in the company. This paper presents a comprehensive discussion on industrial energy saving by conducting energy audit using six sigma methodology strategy tools and Minitab as a data processing tool. Finally, the study has identified the department that consumes the highest electricity and also the recommendations to reduce it.

***Keywords:*** **Energy Savings, Energy audit, Six Sigma, Electrical bill reduction, Energy management**

## 1. Introduction

UPHA Pharmaceutical MFG (M) Sdn Bhd is a pharmaceutical company located in Bangi Industrial Estate. It has more than 40 years of history in manufacturing pharmaceutical products. It is also the largest local producer of generic drugs with nearly 300 products across a wide therapeutic group which includes analgesics, antibacterial, antihistamines and many others. Its medications for gastrointestinal and cardiovascular conditions - Omesec and Vascor respectively are blockbusters in both the local and export markets.

In June 2012, the electrical tariff has increased by 5%. The maximum demand (highest power recorded) in the plant is 1763 kW. The electricity cost for 2012 is RM 3.7M.

## 2. Problem Statement

The highest electricity bill which has been recorded was in year 2012 where it has increased from RM 2.9 million to RM 3.7 million. The increase has reflected badly on the operation cost and eventually affected the company's profit.

## 3. Objective

The objectives of this study are to:

1) Reduce the monthly power usage.
2) Eliminate power wastage for production machines and supporting equipments.
3) Lower down the monthly electricity bill

## 4. Research Question

In order to achieve the objectives of the study, the research questions are as follows:

1) Can the electricity bill reduced?
2) How to measure the reduction?
3) How to measure the consumption?
4) How long it take to reduce once solution implemented?
5) Which machine to target?
6) How much cost is involved in implementing the solution?
7) Will it affect the production productivity?

## 5. Variables

In order to understand the issues addressed in the study in relation to electrical kilowatt analysis, several key terms are included.

Power = Voltage x Current

DV = Voltage

IV 1 = Current

IV 2 = Power

## 6. Significance of the study

From this study, we would be able to identify what are the methods and strategies to be implemented in reducing the electrical usage in UPHA Pharmaceutical MFG (M) Sdn Bhd. We would also be able to identify the machine that consumes high energy and come up with ways to reduce the energy used which assists in reducing the bill usage at the end of the day.

## 7. Literature Review

This section reviews the literature related to the present study and among others on the overview of the current energy usage in Malaysia, energy usage of electrical motors and high-efficiency motors. This section also reviews the energy usage of solar system, compressed air energy, air-conditioning and lighting. The relationship between current and voltage and the benefits of capacitor are also presented in this literature review. Finally, the energy saving strategies are also discussed.

### 7.1 Energy in Malaysia

In Malaysia, fuel consumption for the combination of absorption and compression cooling systems for residential and commercial sectors with the current compression systems will increase up to 6308 $Mm^3$ for natural gas, 4419 kton for coal, 115 and 59 $km^3$ for fuel oil and diesel in 2025, respectively. (Shekarchian et al., 2012). Therefore, the consumption for electricity of air condition systems is predicted to rise in the future due to popular demand. We need to find a solution on how to reduce the energy consumption on air-conditioning in industry. In this way, we could save on electricity bill and reduce fuel consumption as well.

In the present study energy audit has been done in 11 industrial sectors comprising of 91 factories of the east coast of Malaysia. After the energy audit data has been analyzed, it can be concluded that among a wide diversity of end-use electricity-consuming equipment, electric motors contributes the highest energy consumption followed by motor pumps and air compressors. Old equipment are still used in majority of the factories which are not efficient and waste huge amount of energy. The study also indicated that most of the audited factories have lack of knowledge and awareness about conservation of energy. The study shows that a huge amount of emissions can be reduced with the implementation of energy-efficient motors. It has proven that 64% of electrical energy is consumed in peak hours by the industries and the average power factor ranges from 0.88 to 0.93. (Saidur et al., 2009). It is clear that this study empirically investigated the breakdown of end-use equipment/ machineries energy use, the peak and off-peak usage behavior, power factor trend and specific energy use in industry sector. By doing this in our industry, we would be able to identify which are the areas that we should tackle to improve energy efficiency.

Saidur (2009) has identified major energy-using equipment in Malaysian office buildings and compared energy usage of office buildings' equipment with a number of selected countries. The study has discovered that emissions can be reduced together with huge amount of energy and costs can be saved by implementing various energy savings strategies in this area.

Analysis of multiple strategies were done and among them which are increasing the set point temperatures for thermostat, standby and housekeeping do not require any additional investment cost to implement. Therefore, as energy-saving strategies recommendations, the installation of CFL to replace with incandescent and the use of insulation, where the period the period of payback is very less compared to life span, are also found to be economical. Furthermore, the study has discovered that the usage of high-efficiency motors is energy efficient if the motors are operated at lower loads (e.g., load less than 50%) and that the use of Variable Speed Drive is more energy efficient for some motors with 10 and 15 kW, especially at 60% of speed reduction. It is clear that this study empirically examined the methodology to implement energy savings strategies in office buildings of an industry. Even though the overall savings percentage is small compared to the manufacturing side, it is still worth implementing this solution to reduce $CO_2$ emission.

### 7.2 Electrical Motors

Saidur (2009) has pointed out that energy audit is an adequate tool that assists to gather necessary data for estimating energy usage in motor. The tool allows easy identification of source of energy waste so that corrective action can be imposed. This study showed quantitatively different types of losses occurring in electric motors. It has been proven that highest amount of losses (e.g. 59%) is taking place at the rotor and stator parts of a motor [44,50,51] here are high potentials to avoid indirect emission and save energy by appropriate selection/determine the size of motors by stating the potential areas where loss can be reduced. Introducing Variable Speed Drives (VSDs) in such situations to match the required loads would contribute energy savings. It may also be noted that energy can be saved using high-efficient motors instead of standard-efficient motors. It is clear that this study empirically examined the saving technique for industrial motors in Malaysia. This methodology would be very useful to be implemented in industries because most of the industries are using motors for their machineries. This could help motor designers, operators, energy managers and motor manufacturers in the decision-making process during the initial planning and design stages. On the other hand, energy audit should be done regularly to identify the areas that consume high energy. By doing this, we could investigate what causes the energy consumption to be high and find a solution on how to solve the problem by using the available computer tools. Engineers should select a proper motor when designing a machine to reduce losses which resulting to energy savings. Plant/Machine maintenance personnel should ensure that the preventive maintenance for motors is performed according to the planned schedule.

The study conducted as shown that in the industrial sector, the electric motors are a major energy-consuming appliance. Malaysia should consider resetting the minimum energy efficiency standards for electric motors in the future to reduce electricity consumption. The initial step towards implementing energy efficiency standards is the creation of a procedure for testing and rating equipment. An energy test procedure is the technical foundation for all energy efficiency standards, energy labels and other related programs. The adoption of an international test procedure will secure a place for Malaysian products in the international marketplace through their accreditation. This will avoid time delays associated with developing a new test procedure. Also, since there is a trend towards international agreement among the test procedures for appliances and electric motors, this paper can be considered as a supporting argument for this purpose (Mahlia and Yanti, 2009). Based on my opinion, engineers should design or purchase electric motors which have been tested with IEC 60034 standards as it will be tested for energy efficiency standards and energy labels. By doing this, consumers would be able to ensure that the motors are certified for energy efficiency standard instead of retrofit motors in the market.

Saidur et al.,(2009) have determined that utility bills and electrical energy bills can be saved if high efficiency motors, Variable Speed Drives and capacitor banks are used for industrial motors. The return of investment (ROI) using energy-efficiency strategies for larger motors for VSD is reasonable (e.g. within 1–3 years). It was also found that more energy can be saved at levels of higher speed reduction (i.e. speed reduction above 40%). The required kVAr and cost of kVAr to improve the power factor that can reduce resistance (I2R) losses and this is estimated in their paper. It is clear that this study empirically examined the saving technique for industrial motors in Malaysia. This methodology would be very useful to be implemented in industries because most of the industries are using motors for their machineries.

Variable Speed Drives are highly reliable and cost-effective in terms of controlling the speed of electrical motors. Efficiency of electrical motor applications can be improved and saves a high amount of electrical energy by installing VSDs. Not only they less maintenance required but VSDs provide the most energy efficient capacity control, able to reduce mechanical and thermal stresses on belts and motors, and have the lowest starting current of any starter type. Thus, the motor is protected while keeping the process running, reduce pump failure caused by pump cavitations, and reduce maintenance on valves and piping. One of the excellent opportunities to reduce energy consumption is by applying VSDs to the Heating, Ventilation & Air-Conditioning (HVAC) systems. VSDs are an option to match the required loads thus savings energy and improve the economical features of motors (Saidur et al., 2011).

### 7.3 Compressed air energy

Since energy audit method is a convincing tool to help gather necessary data for estimating the energy usage of compressed-air, necessary measures can be implemented to avoid energy wastages. Based on a study conducted, it has been determined that only around 10–20% of total energy input is profited for useful work in compressed-air system. High energy losses take place in the form of air purging to eliminate heat and also through compressed air leakages. Hence, these are the proable areas where energy savings opportunity can be applied for extensive amount of energy recovery in compressed-air system (Saidur et al., 2009).

Based on my opinion, energy audit should be done regularly to identify the areas that consume high energy in compressed-air system. By doing this, we could investigate what causes the energy consumption to be high and find a solution how to solve the problem by using the available computer tools for the compressed-air system.

### 7.4 Current and Voltage

Honrubia-Escribano et al. (2012) discusses and evaluates the electrical behavior of widely-used industry equipments under voltage dips, including characteristics such as magnitude, duration and point of the voltage wave initiation of voltage dip. Working temperature and the presence of scatter bands is studied as well. Adjustable speed drives play an important role in controlling rotating machines. The experiments performed over the industrial computer generate a voltage tolerance curve with a rectangular shape. Another conclusion deduced from computer tests is focused on a current surge at the end of the voltage dip found when the voltage signal is restored to its nominal value. This high current surge may trip the internal protection of the computer and causes the device to switch off automatically. This paper thus gives a detailed and updated assessment of the electrical behavior of common industry equipment facing voltage dips. It is clear that this study empirically examined the effects on voltage dips and the electrical behavior of common industry equipment. By studying this, we would be able to understand the effects when the voltage is not stable. This study is also important when we going to perform any voltage balancing for industrial machines.

### 7.5 Air Conditioning

Mahlia et al. (2000) proves that that the energy efficiency standard for room air conditioners offers multiple benefits to society, utility, and to the environment. On the other hand, it also reduces energy consumption, reducing maximum demand, $CO_2$ and other emissions. The calculation result is the minimum amount that can be saved due to implementation of the minimum energy efficiency standard for room air conditioners. The survey was conducted in 1998. In my opinion, it is true that during the year of 1998, there were very few energy efficiency air-conditioners in Malaysia. But as technology emerges, there is a wide range of energy efficiency air-conditioners in Malaysia. But in order to replace it the office or other area, there are few challenges need to be faced in implementing them. Top management has to agree for the replacement. Replacement of energy efficiency air-conditioners should show significant return of investment (ROI) which would be accepted by the management. Thus, by reducing emission of $CO_2$, it also contributes to reduction of power consumption in the industry.

Ahmed et al.,(2005) have reviewed the methodology to reduce the energy consumption of a central air conditioning system that serves for various rooms with different thermal insulation conditions. Moreover, the cooling requirements are not the same as that for an air conditioner dedicated to a single room. The proposed control mechanism is by correcting the thermostat settings located in the AHU room with the data obtained by a set of sensors for temperature and humidity from the each rooms served. In the proposed scheme, the upper boundary of the comfort zone i.e. 25°C and 70% is used as the target for the temperature and relative humidity in each of the rooms served by a central AC unit. It is clear that this study empirically examined the technique of energy savings for central air-conditioning system. The same methodology could be implemented in industries which uses central air-conditioning system regardless of the brand. Prior into implementing these methods, each of the production room specifications are needed to fine-tune the AHU system to ensure that the room served does not disrupted with the air quality. A study need to be conducted because different production rooms would have different requirements.

### 7.6 Energy Saving Strategy

Abdelaziz et al. (2010) have reviewed various energy savings strategies such as energy savings by management, technologies and policies. The strategy could not be implemented by an individual but participations of company's top management are needed in planning various energy management projects on consecutive period. Usage of high efficient electric motors, reducing boiler flue gas temperature and usage of VSD motors to match the existing machine requirement have been found to be cost-effective and energy conservative to reduce energy consumption of major energy using equipment in the industrial facilities are the methods that have been discussed. These strategies are found to be economical in most cases. $CO_2$ can be reduced by implementing this strategies and reduce energy usage as well. It is clear that this study empirically examined the methodology to implement energy savings strategies in industrial sector. Energy saving is also a synergies cooperation and coalition of three concept which contributes important success factor such as developing an efficient manner of energy usage with minimal energy chain loss anticipation, removal of the non performance energy equipment and business sustainability.

## 8. Methodology

### 8.1 Energy audit

Electrical energy audit is an inspection, verification, conducting survey and analyzes the usage of the energy for industrial equipment and machines in an industry. It is also a decision-making process for further actions that need to be taken by management for energy savings implementation strategy. Energy usage needs to be identified so that waste can be discovered and understanding the operation process to suit the specific requirement of the industry.

The methodology of the energy audit is by using Six Sigma strategy tools. Six sigma qualities are referred to the virtual elimination of defects from every process, product and transaction in the company. However, the real impact of Six Sigma is that it is a business management process and not just a quality metric. Fig. 1 below shows how the six sigma works.

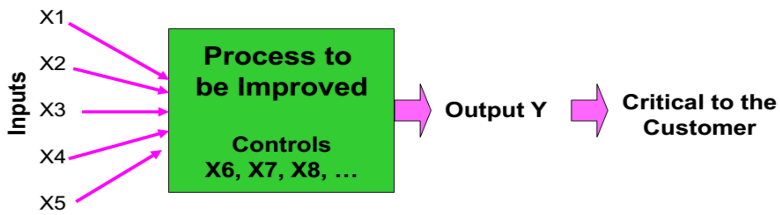



Fig. 1: How six sigma works

Six sigma works from right to left from the figure shown above. Information on what is critical to the customer (CTQ) needs to be examined and we will also need to define the process output(s) that are closely related to the CTQ. Process controls and inputs that effects the output the most needs to be determined with new modes of operation in the X's to dramatically improve Y and satisfies the customer. Finally, the solution would be optimal arrangement and control of the X's and Y would be inspected and the inappropriate ones are eliminated or abandoned. Six sigma also requires no capital investment. The tool that will be used to analyze data would be Minitab.

### 8.2 DMAIC Flowdown

CTQ (Critical to Quality) is a key measureable characteristic whose performance standards must be met in order to satisfy customer. Project Y's is where the process output that directly relates to the CTQ and the specifications for these outputs are determined as "defects". Candidate X's are the process inputs, controls, and factors that potentially give impact on the Project Y. "Vital Few" X's are those X's that can be used to achieve Six Sigma performance. Fig .2 shows the DAMIC Flow down chart.

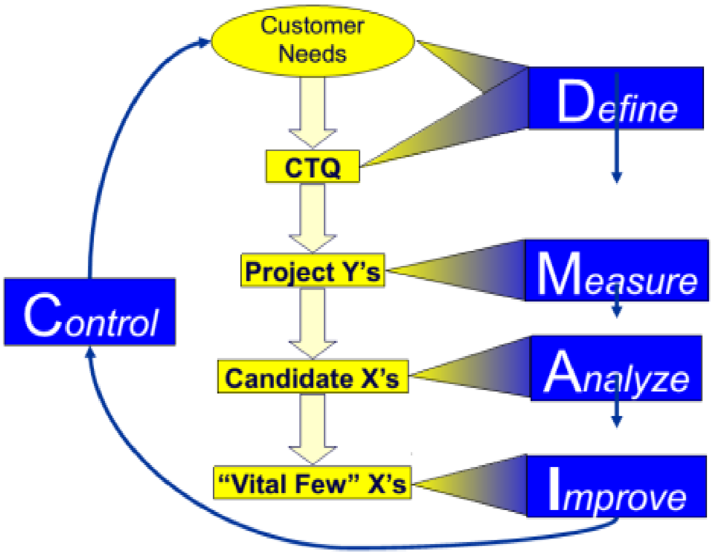



Fig. 2: DAMIC Flow down Chart

'Define' is the first step where the problem should be described that needs to be worked on for its value to the business. 'Measure' is where the defects, baseline information are gathered about the product/process and improvement goals will be establish and defined. 'Analyze' is to determine which process inputs influence the key process output(s) the most. 'Improve' is to identify ways to improve performance that will help to achieve the project goals. 'Control' stage is where the solutions are implemented and it establishes ongoing mechanisms to "lock in" the improvements and to share them elsewhere.

### 8.3 Data collection method

Figure. 3 shows the data collection plan for this whole project. Electricity is the variable that is going to be measured and input (X) will be identified. The type of data will be continuous because 'time of day' is used. Measurement tool that will be used is Yokogawa Power Analyzer (Model: CW 240) and monthly electricity billing. The measurement resolution would be kilowatt hour (kwh) and kilowatt (kw). The sampling frequency will be done monthly to ensure the sustainability of the solution implemented. Primary data will be collected directly from the power analyzer and monthly TNB electrical bill.

| Data Collection Plan | | | | | | | |
|---|---|---|---|---|---|---|---|
| WHAT to Measure | | | HOW to Measure | | | | WHO is Measuring |
| Measure Operational Definition | Type of Measure Output (Y) or Input (X) or Process (X) Stratification (X) | Type of Data Continuous or Discrete | Measurement Tool | Measurement Resolution | Sampling Scheme Systematic/Random/Stratified Random | Sampling Frequency | Who is collecting the data? |
| Electricity | Input (X) | Continuous | Billing/ power analyzer | kWh/kW | Systematic | Monthly | Pratheep |

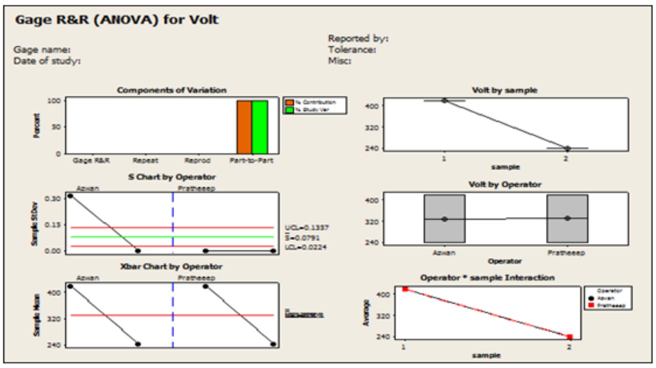
Fig. 3: Data Collection Plan

## 8.4 Data Screening

A minimum of 10 samples will be taken by 2 engineers for the two same processes. Measurements will be repeated 3 times for each process. Data will be analyzed using ANOVA method which is preferred for Six Sigma. Focus on the '%Contribution' whereby if the contribution is less than 10%, the data is acceptable. The data will be acceptable when '%Study Var' is lesser than 30%.

## 8.5 Findings

The reliable test conducted showed that the data is reliable. The tool used was Yokogawa Power Analyzer (Model: CW 240). The data was analyzed using ANOVA method and the results are shown in Fig. 4 as below.




| Source | VarComp | %Contribution (of VarComp) |
|---|---|---|
| Total Gage R&R | 0.0 | 0.00 |
| Repeatability | 0.0 | 0.00 |
| Reproducibility | 0.0 | 0.00 |
| Operator | 0.0 | 0.00 |
| Part-To-Part | 16191.0 | 100.00 |
| Total Variation | 16191.0 | 100.00 |

| Source | StdDev (SD) | Study Var (6 * SD) | %Study Var (%SV) |
|---|---|---|---|
| Total Gage R&R | 0.158 | 0.949 | 0.12 |
| Repeatability | 0.158 | 0.949 | 0.12 |
| Reproducibility | 0.000 | 0.000 | 0.00 |
| Operator | 0.000 | 0.000 | 0.00 |
| Part-To-Part | 127.244 | 763.463 | 100.00 |
| Total Variation | 127.244 | 763.464 | 100.00 |

Number of Distinct Categories = 1134

Fig. 4: Measurement System Analyses

Based on the results above, the %Contribution is 0.00% and %Study Var is 0.12%. The data proves that the measurement device is relevant because the acceptable range for %Contribution is <10% and %Study Var is <30%.

With both tests, the underlying hypothesis is that the data is a random sequence. When any p-value is smaller than 0.05, we reject this theory (hypothesis) of randomness. Fig. 5 below shows the run chart of maximum demand from 2011 to 2012 (After outlier is removed). Result shows that the P-value for clustering is lesser than 0.05 which means the power usage is not evenly distributed.

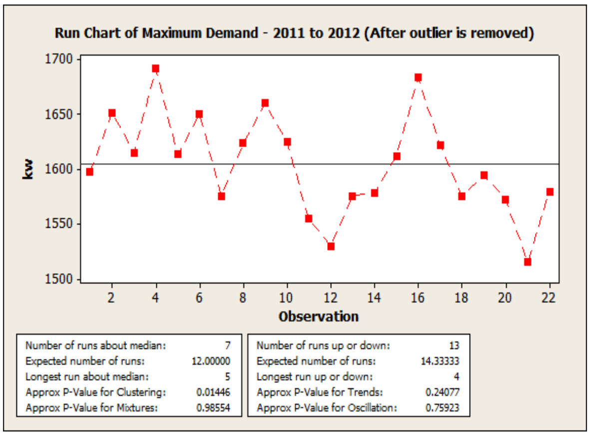



Fig. 5: Run chart of Maximum Demand

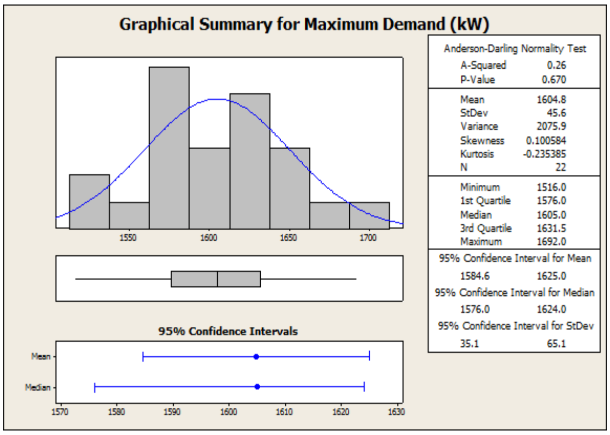
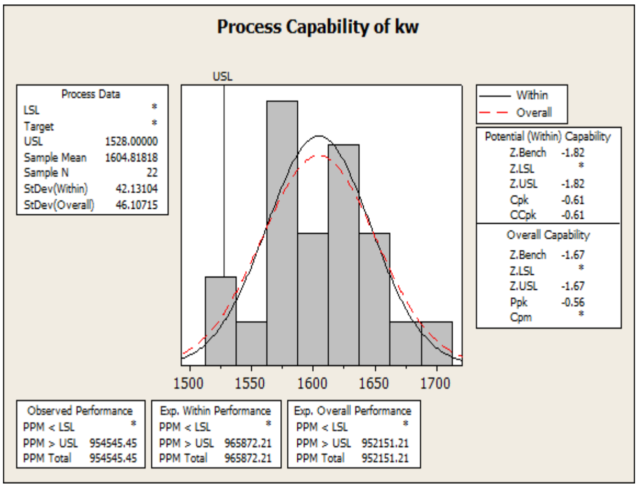



Fig. 6: Graphical Summary for Maximum Demand (kW)

Fig. 6 above shows the graphical summary for maximum demand (kW) from 2011 to 2012. From the summary above, we can conclude that the power variation is between 1516 kw to 1692 kw and the median power is 1605 kw. The data is normally distributed by referring to the p-value which is more than 0.05.

Fig. 7 shows the process capability of Maximum Demand (kW). The Z-Score is the primary measure of process capability. It is directly related to defect level whereby the higher Z-scores represents that process produces fewer defects. Loosely speaking the Z-score represents the distance your process mean falls from the spec limits (expressed as the number of standard deviations from the spec limits). It will be used for continuous data, based on assumption that the process data are normally distributed. It also shows that the process is not capable by referring to Overall Cpk which is -0.61 and Sigma Level is -1.82.



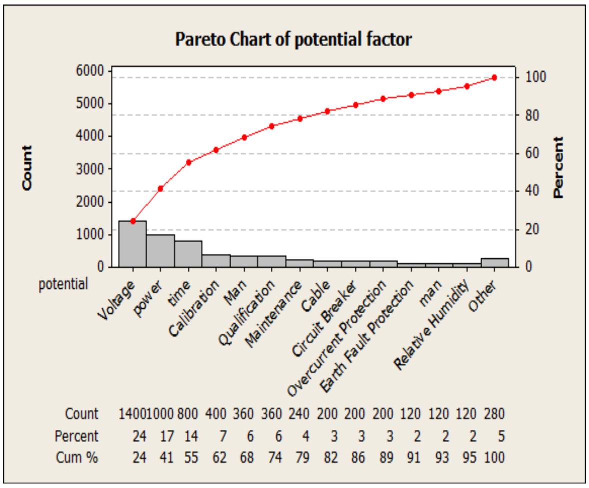




Fig. 7: Process capability of Maximum Demand

Fig. 8: Pareto Chart of potential factor

Based on the Pareto Chart from Fig. 8 above, there are 8 critical factors which are voltage, power, time, calibration, man, qualification, maintenance and cable. Fig. 9 below shows the Pareto Chart of process step from Potential Failure Mode and Effects Analysis (PFMEA).

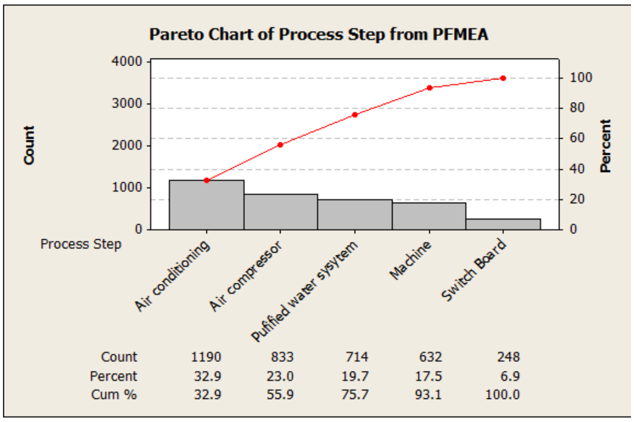



Fig. 9: Pareto Chart of Process Step from PFMEA

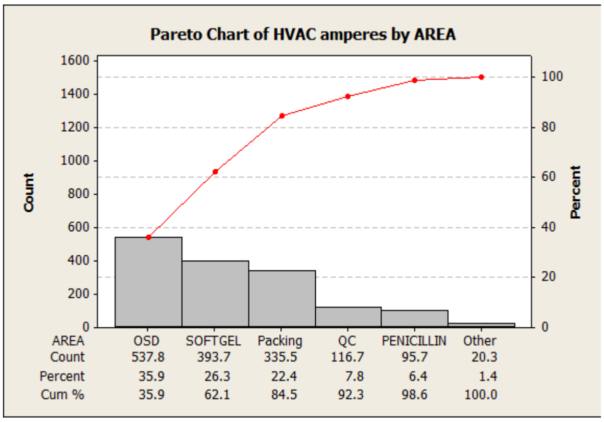



Fig. 10: Pareto Chart of HVAC amperes by department

We can determine that air conditioning contributes the highest possibility from the chart above. Therefore, we could narrow down our analysis to air conditioning in UPHA Pharmaceutical MFG (M) Sdn Bhd.

Fig. 10 shows the Pareto Chart of Heating, Ventilation & Air Conditioning (HVAC) amperes by department. From the data collected, Oral Solid Dosage (OSD) department contributes the highest power consumption which is 537.8 amps which is equivalent to 20% of the total energy usage in UPHA Pharmaceutical MFG (M) Sdn Bhd.

## 9. Recommendations

From the analysis above, voltage contributes the highest potential factor for this problem. Therefore, the proposed solution would be reducing the voltage at main transformer. The average outgoing voltage from main transformer currently is 421V. Power consumption can be reduced by tapping down the transformer to 415V. According to Ohm's law, total power will be reduced when voltage is reduced. The current (amps) is unable to adjust because it is depending to the load at machine, equipments and so on. The second recommendation is to increase the chiller 'chilled water temperature' by 0.5°C for OSD Department. By doing this, the total load for chiller will be reduced at energy savings will be realized.

## 10. Conclusion

Six Sigma strategy tools have been used to conduct this study and performing energy audit inspection, survey and analysis of energy flows. Data collection plan was organized to identify what, how and who to measure for the whole project. Data screening was done and results proved that the measuring device Yokogawa Power Analyzer (Model: CW 240) is reliable based on the results from ANOVA analysis. The analysis shows that voltage contributes the highest potential factor for the energy bill to be high and OSD Department consumes the highest electrical usage in UPHA Pharmaceutical MFG (M) Sdn Bhd. Hence, to overcome this problem, two proposed solutions have been recommended which are tapping down the outgoing voltage at main transformer to 415V and increase the chiller 'chilled water temperature' by 0.5°C.

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