Applying TRIZ to Solve Electricity Maximum Demand Problem

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ABSTRACT. This paper aims to provide a systematic approach by applying TRIZ to reduce the maximum demand of the targeted plant, and nonetheless, it does not demote the working quality and environment. TRIZ tools such as engineering system defining, function analysis, cause and effect chain analysis, and engineering contradiction are applied according to achieve a suitable solution to alleviate the problem. From the finding shows that the root cause of high maximum demand (MD) in the plant is due to the company does not has a proper standard on energy savings, using large demand machinery and old aged appliance which are unable to control. The root cause and contradiction are resolved by applying TRIZ tools. Hence, it can be concluded that TRIZ is an innovative and systematic tool in problem-solving.

KEYWORDS: Demand-side Management, Industrial, Maximum Demand, TRIZ.

1 INTRODUCTION

As the population of the world continues to increase, the demand for energy consumption in the industrial sector rises over the decades. The demand for energy usage originates from large machinery, HVAC (heating, ventilation, air-conditioning) for machinery cooling, lighting and miscellaneous appliances variant according to different industry. The rise of demand for electricity and tariff rating forced the industry customer to seek solutions for their expensive electricity bill by installing alternative energy sources or limiting their energy usage (Pacheco, 2012). Thus, energy savings and energy efficiency have become a trend in the industry. Apart from able to reduce the operating cost and electricity billing, using electricity efficiently will also contribute to saving the environment.

Generally, electric utility companies are often using multilayer or multi-tiered pricing when calculating the electrical bills for their respective customers. The attributes of this pricing tactics can be the difference between each utility companies (Mortaji, 2014). In this case, the prices rates of electrical energy are usually the highest when there is a maximum demand which is also known as the peak period from 8 am to 10 pm. The highest demand value recorded at a 30-minutes interval in the month will be recorded by the utility company and charged at a much higher rating known as maximum demand (MD) (Boreikoz *et al.,* 2017). Hence, the industry consumer eager to reduce the MD charge to reduce their electricity bill.

Engineers are always expected to come out with solutions to improve or resolve the facing situations regardless of any engineering fields. Several engineering tools have been announced to help the engineers to have a more systematic approach as they are dealing with their problem in order to achieve an effective and innovative solution. TRIZ (Theory of Inventive Problem Solving) has proven its value in both research and industrial field with highly positive feedbacks (Gaikwad *et al.,* 2016).

1.1 Problem Statement

Maximum demand has been problem arousing the industry customer as well as the utility supplier. The utility supplier must set a high rate for the high peak demand during the peak period to compensate on the energy storage amount. MD will be the culprit of expensive electricity bill if it was not considered. In addition, by not wasting energy and use it efficiently also helps the environment. The conventional method to tackle the MD problem is by performing demand-side management or installing external energy sources such as renewable energy or Gen-set. Either method will require high capital cost to the company or may not be suitable to deploy at the company's plant site.

1.2 Research Objectives

1. To find ways of reducing the MD using TRIZ.
2. To reduce the electricity bill for the targeted company.

2 LITERATURE REVIEW

2.1 TRIZ Flow Process

The TRIZ process flow for solving a problem is detailed in Figure 2.1.

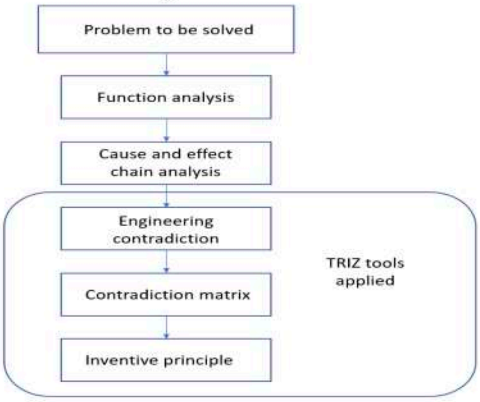

Figure 2.1- TRIZ problem-solving map

The initial phase is to identify the problem to be solved then come out with the cause and effect chain analysis to make sure all related factors of the problem are considered with the aid of function analysis. After completing the preparation, TRIZ tools such as engineering contradiction, contradiction matrix and specific inventive principle can then be applied accordingly (Albers *et al.*, 2014).

TRIZ research claimed that different industries are all solving similar problems. With enough and appropriate framework done, it allows bridging the gap systematically between different sectors. In other words, the expert in a field able to refer to the work done by other experts in another field that have solved similar problems. TRIZ is rather important due to these problems may not appear to be same at first sight.

2.1.1 Function Analysis

Function analysis is the study carried out on two or more components in terms of their interactions between one another (Gaikwad *et al.*, 2016). These interactions were given a functions term. The actions among two components are known as functions. It can be further categorised into useful and harmful functions. Useful functions comprise of normal, insufficient or excessive. The normal useful function does not harm the object, whereas insufficient and excessive useful functions may create undesired effect on the object.

Figure 2.2 shows the function analysis done for the targeted plant. The excessive waste of energy may turn into heat which causes the air compressor and other cooling units to work excessively to bring down the temperature. There is no insufficient function detected in the following diagram. However, there are relationships such as the user has been using the machines excessively which leads to high amount of heat generated. Heat is harmful in the system due to its an unwanted product in the manufacturing process and may cause machines to break down.

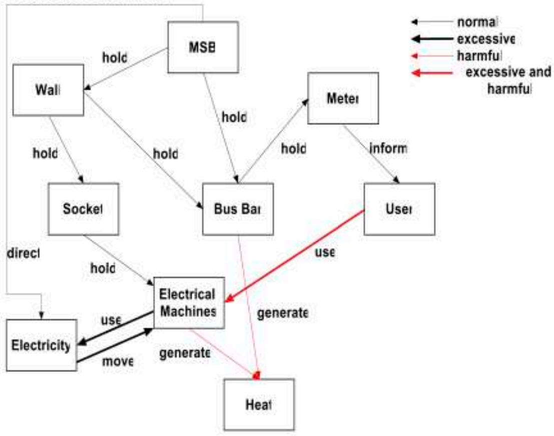

Figure 2.2-Function analysis for the problem

2.1.2 Cause and Effect Chain (CECA)

CECA holds a vital role in TRIZ as well as other problem-solving tools to generate solutions or concepts. By doing CECA correctly, the root cause of the problem can be obtained, most probably solutions can be then generated. Thus, it is worth paying attention in CECA to reduce the chances of implementing the ineffective solution which waste time, money and efforts. The process of generating CECA is identical to "5 Whys". The user will need to prompt the causes of the original problem. Brainstorm from high level to low level by continuously asking "Why?".

The following step is to review on all these root causes to be either discarded, plausible or considered as the potential root cause to the original problem. Every potential root cause must consider on the revised problem. In majority of the cases, solving these root cause will not be straight forward and requires resolving a contradiction.

From the CECA shown in Figure 2.3, it is able to deduce that the possible root cause of MD occurring in the plant is due to two major reason, unable to perform control algorithm due to aged machineries and eager of high quality product which leads to using large energy demand appliances.

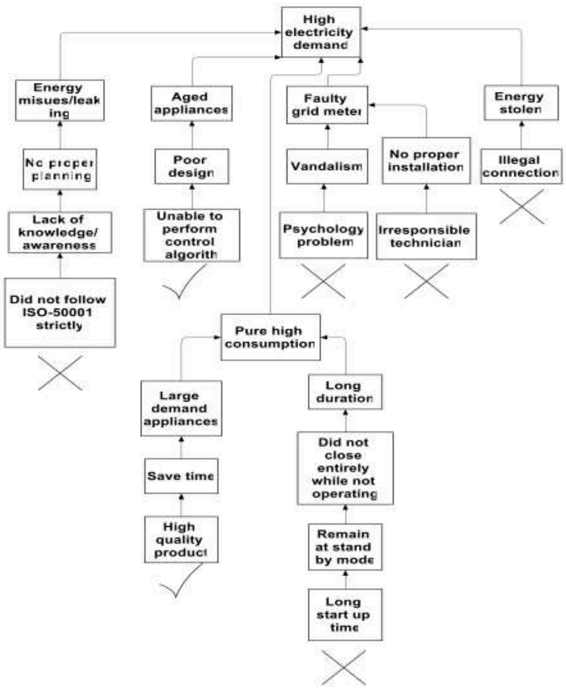

Figure 2.3- Cause and effect chain analysis

2.2 Demand-side management (DSM) and Intelligent load management

People implement DSM system and intelligent load management system differently for different reasons. Some for electrical maximum demand reduction to encounter the Time of Use (TOU) rate charges for the monthly electricity bill, protecting heavy electrical machine or equipment and some for solving power quality problems or electrical disturbances by removing some loads from the power system instantly encounter generation deficiency condition. The common disturbances that can lead to this condition are faults, loss of generation, system islanding, switching errors and lightning strike (TNB, 2018). However, DSM system, smart load control system and intelligent load management serve the approximately same purpose which is to evaluate and implements energy reducing strategies that involved peak load shifting or (TOU) load shifting, load starting, shedding of non-critical loads in order to reduce the electrical energy charges as much as possible.

DSM which is also known as the load management system mentioned earlier can maintain the power system's operational quality with produces a more economical and reliable operating system (Eom *et al.*, 2016). DSM access the efficiency and determine where and when should the energy reduction strategies apply to, for instance shifting load from peak period to the off-peak and near-peak period operation or turning on and off the non-essential power lines and machine by not affecting the industry operation. DSM can be designed in such a way that shedding the non-critical loads during the maximum electrical demand charges happen to reduce the operating cost.

Intelligent load management is a method that provides control strategies to prevent the unpleasant situation like under-voltage, under-frequency, poor power quality situation that is able to cause electrical disturbances for instance tripping problem to the power system for example, starting up of a large machine that causes an instantaneous voltage sag may cause sensitive equipment to misoperate and lead to disturbances happen in the electrical network (Boreiko *et al.*, 2017). Besides, intelligent load management can be configured to control the running efficiency and starting up of machines that lead to a reduction of electrical demand for each facility.

3 ENGINEERING CONTRADICTION (EC)

Referring to Figure 2.1, EC is the part to develop the contradiction statement to the problem's situation and apply TRIZ tool which is the Altshuller's contradiction matrix to solve the problem. The Altshuller's matrix contains the 39 engineering parameters and leads the engineer to solve problem by applying the specific solution among the 40 inventive principles. EC denotes that in an Engineering System if an improvement (improving parameter) in one parameter results in degradation (worsening parameter) of another parameter. As TRIZ idea is to solve these is to solve the contradiction. EC can be formed by referring to the CECA that has done previously. Figure 3.1 shows an example of how to make use of Altshuller's contradiction matrix.

Contradiction Matrix		Worsening Parameter			
		14. Strength	15. Duration of action of moving object	16. Duration of action of stationary object	17. Temperature
Improving Parameter	17. Temperature	10, 30, 22, 40	19, 13, 39	19, 18, 36, 40	+
	18. Illumination intensity	35, 19	2, 19, 6		32, 35, 19
	19.Use of energy by moving object	5, 19, 9, 35	28, 35, 6, 18	-	19, 24, 3 ,14

Figure 3.1-Altshuller's contradiction matrix

3.1.1 Engineering contradiction 1

If industrial electrical appliances are able to perform control algorithm over the usage, **then** energy-wasting will be reduced, **but** the user will need to fork out large capital cost.

Table 1 shows the inventive principles recommendation for EC. It shows that the suitable inventive principles are #10 Preliminary action and #26 Copying.

Table 1-Inventive principles for EC 1

Altshuller's contradiction matrix	Inventive principles	Suitable inventive principle
Improving parameter: Energy wastage is reduced (#21 Power) Worsening parameter: Fork out large capital cost (#32 Ease of operation)	#26 Copying #33 Discarding and recovering #10 Preliminary action	#10 Preliminary action #26 Copying

The proposed solution for EC 1 is to perform DSM. After having some conversation with the targeted plant manufacturer and site visiting, the plant has already had their SCADA and EMS ready. However, significant loads are aged and unable to perform control technique. Thus, by applying TRIZ inventive principle #10 Preliminary action, the user may list down all their loads and classify them into shiftable load and non-shiftable load (Olawuyi *et al.*, 2018). In order to see the effect brought by the algorithm, the shiftable load must be replenished to be able to control and communicate with the SCADA. The major capital cost will be able to reduce as non-shiftable load occupied the major load amount. Set the priority value for all shiftable load.

To further improve and ensuring MD able to be mitigated completely, an off-grid supply source is recommended. A conventional method such as solar power requires a high capital cost. By applying TRIZ inventive principle #26 Copying, the solution is by getting cheaper sources, the varieties are battery storage or diesel Gen-Set (Masri and Halim, 2014), and some in-house load-shedding and load scheduling.

3.1.2 Engineering contradiction 2

If industrial electrical appliances have high power consumption, **then** the user able to have a high-quality product, **but** the electricity demand will be high.

Table 2-Inventive principles for EC 2

Altshuller's contradiction matrix	Inventive principles	Suitable inventive principle
Improving parameter: Have high-quality product (#39 Productivity) Worsening parameter: Energy demand is high (#21 Power)	#35 Parameter Changes #20 Continuity of useful action #10 Preliminary action	#35 Parameter Changes #20 Continuity of useful action

This section is the continuation of section 3.1.1. A control algorithm is derived suing the TRIZ inventive tool, #35 Parameter Changes and #20 Continuity of useful action. The idea of the control algorithm to be carried is presented in the flow chart, Figure 3.2. Apart from that, adding in controllable loads which are loads that can be tuned down without interrupting the major operation the plant will further enhance the algorithm. The more shiftable and controllable loads, the obvious the result in energy savings and better efficiency.

According inventive principle # 35 Parameter changes, the user code will change the priority level of the appliances according to time. This is due to in order to maintain the operation, majority of the loads are not shiftable or controllable. However, the loads maybe controllable under certain conditions. For example, the air-conditioner are the main priority in the plant to prevent over heating in the line, when maintenance or turn-over, the priority level can be tuned down to lower the burden of the battery/Gen-set.

While for inventive principle #20 Continuity of useful action, the algorithm will make sure to obey the priority level of each equipment set by the user to ensure no interruption on the major process when the usage hits the capped MD level. While the usage is lower than the MD, the extra power can be used to store into the battery to prepare for the upcoming MD. As for Gen-set, it can be settled outside the algorithm by sending the signal out to indicate low fuel level.

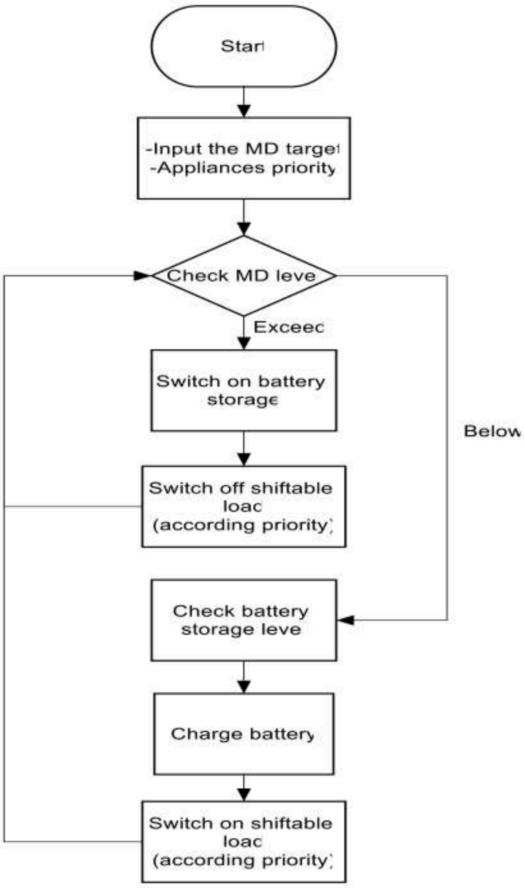

Figure 3.2-Process flow of the control algorithm

4 CONCLUSION

TRIZ is a process, philosophy and consist of a series of tools specifically on the concept of resolving contradictions problem faced in our daily lives. Engineering contradictions are the crux of many issues where compromise is needed to balance among a worsening and improving parameter. This may be acceptable in certain cases; however, as the technology advances and knowledge are being pushed to the edge, equipment will deteriorate further. In other words, to be the tip of the cream among all potential competitors, innovative solutions which do not limit to compromise on any parameters is needed. MD problem has been arousing the targeted company's plant for several years. The problem has even worsened as the energy demand increases over the period and tariff increases. The conventional method to solve MD problem is not favored by the company as it is time-consuming and requires high capital cost. Thus, this has created a contradiction situation and TRIZ able to perform. In this paper, TRIZ performs the study on the inter-relationship on each function and deduced the targeted root cause that is causing the MD to occur. Then, based on the CECA and function analysis, it can come out with the corresponding EC and make use of the 40 inventive principles and 39 parameters. In this paper, it provides a tailor-suit solution for the specific company by applying TRIZ.

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