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# Using PDCA Cycle to Improve the process of Supplying Cooling Hydrogen for a Combined Cycle Generator at Rabigh Power Plant

Engineer, **Waleed Basheer Alsaadi**
Saudi Electricity Company, Generation Sector, Rabigh Power Plant, Engineering Department, Jeddah, Saudi Arabia
E-mail: waleed.alsaadi@gmail.com

**Prof, Hani Alamri**
Faculty of Economics & Administration, King Abdul-Aziz University, Jeddah, Saudi Arabia
E-mail: halamri@kau.edu.sa

## Abstract

Organizations seek to improve their performance by reducing costs and increasing profits to stay in the market and increase competitiveness. Optimal allocation of available resources helps organizations make optimal decisions in customization, minimizes costs and improves performance.

This project aims to utilized Kaizen continuous improvement method within the power generation industry. Rabigh Power Plant, as many other generation stations, has ongoing effort to improve daily work activities. The project highlights the experience of using continuous improvement methodology to incrementally increase plant performance, achieve economic savings, and maintain the continuity of electricity flow.

The study applied Kaizen methodology to improve the procedure of supplying hydrogen cooling gas to the third combined cycle's (CC3) generator at the fourth stage of Rabigh Power Plant. The study recommends to re-engineering the existing system to utilize stage one's hydrogen generation plant. The finding shows that re-engineering the system will improve the process cycle by around 98% and reduce the number of tasks by 86%.

**Keyword:** Kaizen; PDCA Cycle; Total Quality; Continuous Improvement Process (CIP), Saudi Arabia; Power Plant; Hydrogen Cooling System; Resources Optimal allocation.

**ملخص البحث :**

تسعى المنظمات إلى تحسين أدائها من خلال خفض التكاليف وزيادة الأرباح للبقاء في السوق وزيادة القدرة التنافسية. يساعد التخصيص الأمثل للموارد المتاحة المؤسسات على اتخاذ القرارات المثلى في التخصيص وتقليل التكاليف وتحسين الأداء.

يهدف هذا المشروع إلى استخدام طريقة كايزن للتحسين المستمر في صناعة توليد الطاقة. تبذل محطة رابغ للطاقة ، مثلها مثل العديد من محطات التوليد الأخرى ، جهودًا مستمرة لتحسين أنشطة العمل اليومية. يسلط المشروع الضوء على تجربة استخدام منهجية التحسين المستمر لزيادة أداء المصنع بشكل تدريجي ، وتحقيق وفورات اقتصادية ، والحفاظ على استمرارية تدفق الكهرباء.

طبقت الدراسة منهجية كايزن لتحسين طريقة توريد غاز التبريد الهيدروجين لمولد الدورة المركبة الثالثة ***(CC3)*** في المرحلة الرابعة من محطة رابغ للطاقة. توصي الدراسة بإعادة هندسة النظام الحالي للاستفادة من محطة توليد الهيدروجين في المرحلة الأولى. تظهر النتائج أن إعادة هندسة النظام ستعمل على تحسين دورة العملية بحوالي 98٪ وتقليل عدد المهام بنسبة 86٪.

**الكلمات المفتاحية**: كايزن ؛ دورة ***PDCA*** الجودة الشاملة؛ عملية التحسين المستمر ***(CIP)*** ، المملكة العربية السعودية ؛ محطة توليد الكهرباء؛ نظام تبريد الهيدروجين تخصيص الموارد الأمثل،

# 1. Research Background

There is a growing interest in application of Kaizen continuous improvement method across varies modern industries. Findings of many studies report the successful implementation of this method in different manufacturing sectors over the past decades but is just emerging to appear in power generation business [EPRI, 2009]. Rabigh Power Plant, as many other generation stations, has ongoing effort to improve daily work activities. This project highlights the experience of using continuous improvement methodology to incrementally increase plant performance, achieve economic savings, and maintain the continuity of electricity flow.

Adapting process improvement strategy aim to address waste, inefficiencies, current assets and systems condition, and culture within the existing processes or activities. This strategy sets clear goals, visions, and necessary steps which enable the organization to achieve sustainable growth and sustainable competitive advantage. It requires well understanding of the current process, involving skilled people, choosing right methodology, carefully prioritizing improvement opportunities, setting reasonable and achievable goals, and take necessary actions and tasks to implement the achieves these goals. The most common methodology for continuous improvement initiatives or projects is Kaizen and its PDCA cycle.

Kaizen, continuous improvement, is an approach to make small and ongoing positive changes which can obtain major enhancements. Finding wastes, root causes of mistakes, and correcting them is one of the basic characteristics of Kaizen. Another characteristic is that it seeks to improve systems rather than the human resources. It views occasion and mistake as a chance for improvement. Unlike total quality management, kaizen emphasizes incremental improvements which makes it easier to implement.

Thermal power plant is a power station in which heat energy converts to electrical energy by the mean of steam-driven turbines. Normally, these plants consist of huge equipment, various systems and auxiliary systems, and specific purpose facilities. Running these plants in an efficient and economical way is a challenging goal. Each system, and subsystem, requires different operation process, procedure and manpower. Some process encompasses waste steps and weaknesses which requires special attention to eliminate them or reduce it negative cost impacts. This can be attained by conducting continuous improvement program to discover possible weaknesses and reveal potential improvement opportunities.

A continuous improvement program is any procedure, plan or process within a work area that helps enhance the way things are performed on a regular basis. This could be through minor or major process enhancement.

## 2. Literature review

Seeking quality is a concern for all kinds of companies. It is significant for manufacturing, servicing, and utility providing companies. Understanding the operation processes within a firm, eliminate the wastes, and optimal allocation of assets and resources have been one of the most significant issues in the utility quality literature. Considering electricity generation as mainly an utility provider, the need to deliver customers with reliable and consistent electricity is becoming more challenging.

The word Kaizen is derived from two Japanese words “Kai” which means change and “zen” which means for the better (Palmer, 2001), these two words compound together translate as "good change" or "improvement" , but Kaizen as a methodology has come to mean "continuous improvement". Imai (1986) defines Kaizen as “ongoing improvement involving everyone, including both managers and workers.”

Kaizen is a Japanese philosophy that promotes small improvements made as a result of continuing effort. This small improvement involves the participation of everyone in the organization from the top management until the lower level employees. The long-term improvement is achieved by having the employees working gradually towards higher work standards. Kaizen strategy has been successfully implemented by the Japanese industry after the World War II (Imai, 1986). Kaizen was initiated as a response towards problem faced by the Japanese industry after the World War II such as limited resources and difficulties to obtain raw material. Therefore, the Japanese companies started to look into how to improve their production processes by minimizing waste and optimizing process efficiencies. Initially Kaizen initiatives were led by Toyota Motor Company in their effort to become a global automotive leader which tried to emphasize on incremental changes, low cost solution, employee empowerment and the development of organization that holds continuous improvement with emphasis on process improvement rather than the result (Imai, 1986).

The aims of doing Kaizen is to do improvements in term of costs, quality, flexibility (Bessant et al, 1994) and also productivity (Choi et al, 1997). Through Kaizen, it focuses on three improvement areas which are Muda (waste), Mura (discrepancy) and Muri (strain) (Imai, 1986). The tools that are used to implement Kaizen, also known as Kaizen umbrella, are Total Quality Control (TQC), Total Productive Maintenance (TPM), Quality Improvement, Automation, Zero Defect (ZD), Kanban, Just-in-time (JIT), Quality Control Circle (QCC) and the suggestion system (Imai, 1986). A study by Nordin et al (2010) conducted among Malaysian Automotive Industry companies found that Kaizen was the main leading lean practice in Malaysia. A similar result was also found in a study done on the electrical and electronic industries in Malaysia by Wong et al (2009).

Continuous Improvement or Kaizen is a strategy normally adopted by a company where teams of employees at various levels through cross-functional effort with collective talents within the company work together proactively on improving specific area within the company (Imai, 1986). In implementing Kaizen, companies strongly emphasize the involvement of the plant floor employees with some level of empowerment given to them to identify and solve problems related to the workplace issues. Kaizen, if implemented correctly, can encourage employees to think differently about their work and boost the morale and the sense of responsibilities among the employees regarding their workplace. This is because through the empowerment given by the top management, employees will start to feel that they are also partly involved in the decision-making and improvement process.

To implement Kaizen, companies will adopt the Plan-Do-Check-Action (PDCA) cycle to solve both unit-functional and cross-functional problems in their activities (Imai, 1986). During the planning stage, employees will try to identify areas that need improvement. Once they have identified the problem areas, the next step is to implement the Kaizen. To implement the Kaizen the employees can use various techniques to develop a clearer understanding of the current waste areas such as the Five Whys technique or Value Stream Mapping (VSM) technique.

The PDCA method is known as a procedure of enhancement and controlling in which each member of the improvement team should be familiar with to be effective. It is first introduced by Walter A. Shewhart in the 1930s at Bell Laboratories in USA. Two decades after, W. Edwards Deming applied it in quality improvement studies (that’s why PDCA cycle is also known as Deming Cycle). The PDCA cycle is a total quality management method which may applicable for any type of business including accident and diseases preventive (Andrade, 2003)

PDCA (Plan-Do-Check-Act) is a four-stage method for continually enhancement processes, services or products, and for solving issues. It involves methodically testing probable solutions, evaluating the outcomes, and adapting the ones that have approved to work. The four-stage of PDCA are:

**Plan –** Find the problem, gather related data, and recognize the problem's root cause, develop hypotheses about what the concerns may be, and select which one to test.

**Do –** Develop and execute a solution; test the possible solution and measure the results.

**Check –** Audit and compare the result before and after implementing the potential solution. Make necessary corrections, restudy the result, take measurements and decide whether the hypothesis is supported or not.

**Act –** Report the results, and update others about process modifications. If the solution was successful, adopt it. If not, tackle the next problem and repeat the PDCA cycle again.

## 2.1Problem Statement:

Organizations seek to improve their performance by reducing costs and increasing profits to stay in the market and increase competitiveness. Optimal allocation of available resources helps organizations make optimal decisions in customization, minimizes costs and improves performance.

Rabigh oil-fired power plant (RPP) located on the Red Sea coast, about 150 km north of Jeddah in Saudi Arabia, is currently the first biggest thermal power plant in the world with total generation capacity of 7,160 megawatt. It is owned and operated by Saudi Electricity Company (SEC). RPP has 10 steam generation units, 40 gas turbine units, and three combined cycle units with different capacities and was developed in seven stages. The first stage was constructed and commissioned in the 1980s by Mitsubishi Heavy Industry (MHI). It comprised of four steam units each with 220 MW capacity.

As we have seen above, Rabigh Power Plant (RPP) occupies great importance in the energy sector in the Kingdom of Saudi Arabia. Therefore, finding ways to reduce cost, eliminate waste from process, improve system availability and reliability, increase profits, enhance performance and enrich the work environment is a key factor to its operation business. This can be done by conducting continuous improvement program like Kaizen, or by implementing six sigma or TQM program.

According to my work experience in RPP, there are several opportunities for improvement. Suppling hydrogen gas to stage four combined cycle's generator is up in the list. In my opinion, there are many wastes in the current operation process in dimensions of time, cost and procedures. Improving these dimensions will improve overall system performance and reduce cost in the same time. The huge improvement of system performance, safety, availability and reliability, and cost reduction can be accomplished by the mean of using the hydrogen generation plant of stage one or six.

## 2.2Study Objectives:

The objective of the study is to implement continuous improvement methodology, i.e. kaizen, to reduce wastes in process, minimize cost of operation, improve process safety, and increase availability and reliability. It aims specifically to:

- **Objective 1: Plan:**
  - **Objective 1.1:** Gather a list of possible opportunities to enhance in RPP.

    Due to the nature of RPP; has seven stages, long construction period, different technologies, and diversity system, subsystems and auxiliaries, finding opportunities to enhance will be the first step in our study.

  - **Objective 1.2:** Choose one opportunity to enhance.
- **Objective 2: Do:**
  - **Objective 2.1:** Studying the current situation (measurement and analysis)
  - **Objective 2.2:** Innovating enhancement and implementation plans. (encourage solutions and shoos an idea)
- **Objective 3:** Make Improvement Recommendations

**Check and Act:** phases are excluded from this study, as they can only measure after implementing the recommendation for the Plan and Do phases.

## 2.3 Study Area and Society:

The study will be limited to RPP employees. The study community includes all managers and section heads in RPP, and all employees of stage four in Rabigh Power Plant at the Saudi Electricity Company. The following table shows the population of the study.

| Position | Description | Number | Total |
|---|---|---|---|
| Managers | Power Plant Manager | 1 | 5 |
| | Operation Managers | 2 | |
| | Maintenance Manager | 1 | |
| | Technical Support Manager | 1 | |
| Section Heads | Mechanical Maintenance | 2 | 10 |
| | Instrumentation and Control Maintenance (I&C) | 2 | |
| | Electrical Maintenance | 2 | |
| | Electrical, Instrumentation and control Engineering (EI&C) | 1 | |
| | Mechanical Engineering | 1 | |
| | Quality and Performance | 1 | |
| | Stage IV Operation | 1 | |
| Stage IV Employees | Formans | 20 | 105 |
| | Technicians | 85 | |

**Table 1: Population of the study**

In determining the sample of the study, given that the study is limited to 120 employees of Rabigh Power Plant in Saudi Electricity Company, the researcher will apply the study to all members of the study society. So, the study community will include all managers in RPP and all employees in stage IV.

### 2.4 Primary Data Sources:

Two data sources were used to collect the primary data:

1. PDCA team: through meetings, surveys, investigations, and operational reports which are considered as internal sources too.
2. Questionnaires: used to achieve the objective of identifying improvement opportunity from the point of view of the employees of the Rabigh Power Plant.

## 3. Implementing Continuous Improvement Process

The Continuous Improvement Process (CIP) is an unending effort to enhance products, services, or processes. It's is six steps organized methodology to plan, classify, arrange and implement improvement efforts according the outcomes data and innovations on the PDCA Cycle (Plan, Do, Check, Act). The CIP provides a clear framework and procedure which allows good understanding of the improvement process. The CIP can be aligned with firms' visions and objectives at all time.

The six (6) phases of the Continuous Improvement Process -which will be implemented in this research- are:

**1. Identify Improvement Opportunity:** Select the appropriate process for improvement.
**2. Studying and Analyzing the current situation**: Identify and verify the root cause(s).
**3. Develop an optimal solution:** Plan actions that correct the root cause(s).
**4. Implement the solution:** Confirm the actions taken to achieve the target.
**5. Study the result and adjust:** Ensure the improved level of performance is maintained.
**6. Standardize the solution:** once the solution works, adopt and make it global within the firm

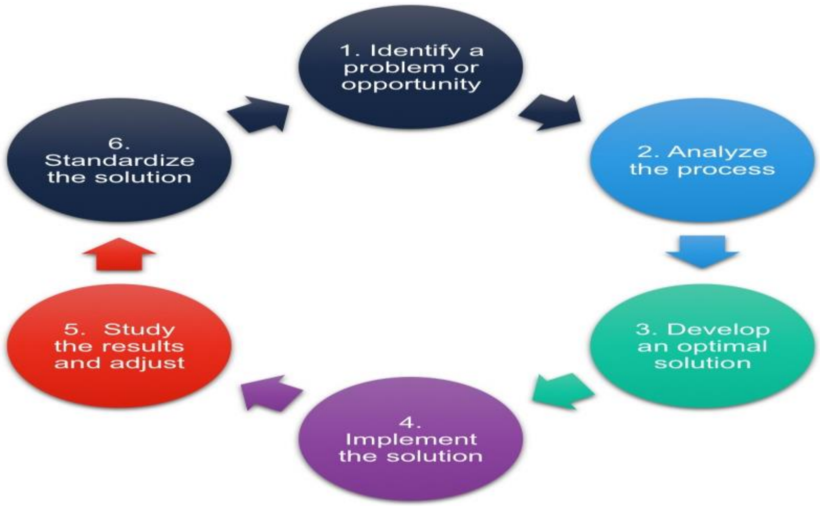


**Figure1: CIP Phases**

## 3.1 Phase 1: Identify Improvement Opportunity

Phase 1's goal is to identify the possible opportunities for improvement. It aims to select the appropriate process for improvement. This can be achieves through a sequence of sub-steps starting by arranging the customers according to their degree of importance, and conducting face to face meeting with them and recording their needs and requirements. Then the CIP team evaluate all customers' needs to select the most important opportunity to improve.
So, phase 1 consists of the following steps:

1. Identify and arrange customers according to importance.
2. Identify the basic requirements of customers.
3. Choose one process for improvement.

By applying the first phase of the methodological improvement process, the result of this phase ended up with improving the combine cycle hydrogen cooling system process.

## 3.2 Phase 2: Studying and Analyzing the current situation

In this phase, the CIP team focuses on the selected problem, describes it, works to collect more data and information about the subject improvement process. It tries to describe the process in details, sets the needed inputs and the desired outputs, determines the main and subsidiary tasks along with responsible people to perform each task. Next, the team must set some criteria and metric measurements for improvement. Then, the team determines the wastes in the process and eliminates them. In some cases where the process is complicated, the team develops a list of root causes for the problem and suggests possible solutions. Finally, the team should set the required change(s) and the desired result.

Practically, phase 2 consists of the following steps:

**3.2.1 Process boundaries:** Identifying the beginning and ending of the process with desired output

**3.2.2 Map Processes: Documenting** the process as it is in reality, characterizing the current state of the process (Actual Process)

**3.2.3 Electing Process Metrics:** Select measure factors of improvement

**3.2.4 Process Metrics Improvements:** Analyze the map to find area(s) of improvement at procedure level

**3.2.5 Identify gaps and explain their causes**

## 3.2.1 Process boundaries:

**The beginning of the process:** start when hydrogen level in the generator becomes low.
**End of process:** end when the hydrogen pressure inside the generator reaches the required level.

## 3.2.2 Map Processes: Documenting the process as it is in reality

Once the CIP team decided which process to enhance, they have to document each step using a flowchart or alike tool. The objective of these tools is to show the process and ongoing details of each task or step visually.

## 3.2.3 Electing Process Metrics: Select measure factors of improvement

Process metrics are measurement factors that are used to evaluate the performance of a specific process within a business unit. They are valuable tool for any company wants to monitor, evaluate and improve their operational performance across the firm.

Metrics allow the company focus on the most vital factors that have a deep impact on its success, growth, and sustainability. Metrics also help the organization to grasp better understanding of the existing status of the process. Moreover, they help firms to make good predications and make good decisions.

In Saudi Electricity Company’s CIP project(s), a different types of process metrics is applied. It includes only five types of metrics:

- **Procedures:** the number of steps and instruction to perform a specific process
- **Time:** The total time to perform a specific process and\or the time required for finishing a certain task.
- **Cost:** same as cost effectiveness
- **Follow-up:** the required effort to monitor and control the process and\or the task(s)
- **Precision:** the required accuracy and safety degree to perform the task(s)

### 3.2.3.1 Questionnaire for selecting process improvement metrics

In order to focus on the required process metric(s) to study and analyze the necessary improvement.

50 questionnaires were distributed. We have got 50 feedback. By calculating the average of importance degree and satisfaction degree, we obtained the following result:

| No. | Improvement Metric | Importance Degree | Satisfaction Degree |
|---|---|---|---|
| | | 0-10 | 0-10 |
| 01 | Procedures | 9.96 | 1.14 |
| 02 | Time | 8.42 | 1.38 |
| 03 | Cost | 9.46 | 4.48 |
| 04 | Follow-up | 9.72 | 2.06 |
| 05 | Precision | 9.00 | 8.22 |

**Table 2: Result of Questionnaire for selecting process improvement metrics**

### 3.2.3.2 Importance- Satisfaction Matrix:

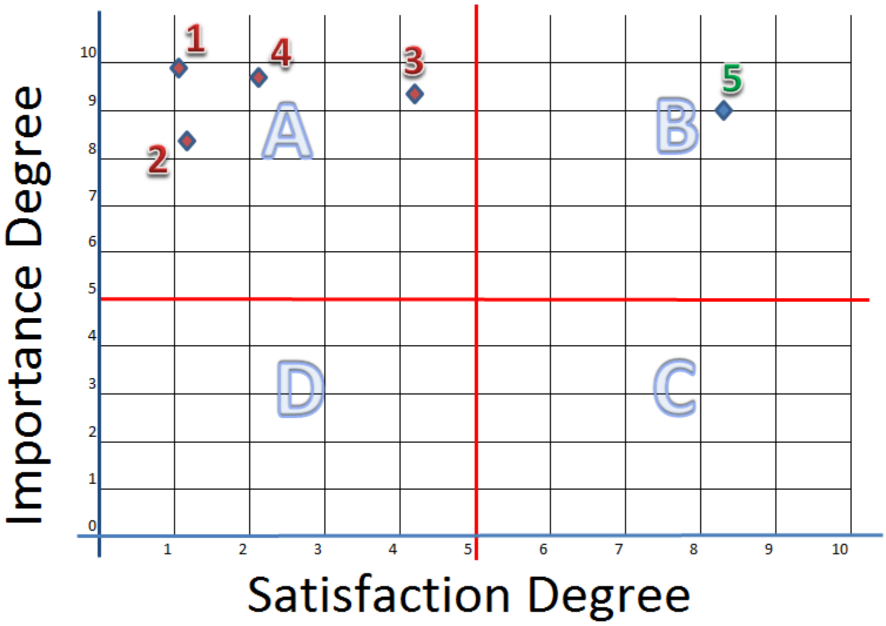


**Figure 2: Importance – Satisfaction Matrix I**

The tool shows that we need to improve the following factors:

1. Procedures
2. Time
3. Cost
4. Follow-up

## 3.2.4 Process Metrics Improvements

Here we focus on how the task is being done or performed by measuring performance based on the four factors: procedures, time, cost and follow-up.

**3.2.4.1 Improvement in procedures only:** Analyze the map to find area(s) of improvement at procedure level

In this step, we identify wastes and inefficiencies within the processes. We try to answer: what is (are) the step(s) that should be eliminated? And where can we make enhancements?

The team analyze the process and determining unnecessary steps (Non-added value steps) in the existing process.

### 3.2.4.1.1 Process Time and Procedure

A meeting held with system operator and operation chief charge to collect the timing data for each task, unfortunately there is no record for such data. However, we try our best to estimate the time required for each task and the final result is listed in the following table:

| Metric | Actual | Desired |
|---|---|---|
| Process Time | 4030 Minutes | 90 Minutes |
| Procedure (No. of steps) | 43 | 7 |

**Table 3: Time and steps metrics (actual vs desired)**

### 3.2.4.1.2 People involved in the process:

The following table shows the frequency - number of repetitions – of people involved in the process before improvement

| No. | Responsible | Frequency |
|---|---|---|
| 1 | Unit Operator | 3 |
| 2 | Local Operator | 12 |
| 3 | Operation Shift Engineer | 6 |
| 4 | Operation Manager | 4 |
| 5 | Cylinders Transfer Team | 4 |
| 6 | TSD Manager | 4 |
| 7 | Material Section Head | 5 |
| 8 | Power Plant Director | 1 |
| 9 | Main Store Supervisor | 1 |
| 10 | Industrial Safety officer | 1 |
| 11 | Supplier | 2 |
| Total | | 43 |

**Table 4: People involved in the existing system process**

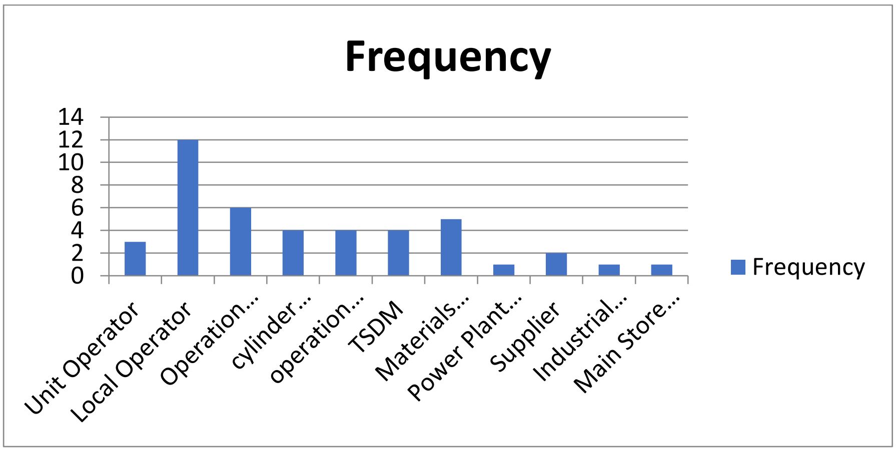


**Figure 3: Histogram for people involved in the process**

## 3.2.5 Identify gaps and explain their causes

In this step, we determine the difference between desired and actual performance, and identify the root cause(s)

### 3.2.5.1 Identify Gaps (in improvement for procedure only, no re-engineering)

Gaps = Actual performance– Desired performance

Process Time Gap = 4030 – 250 = 3780 Minutes
Procedure Gap= 43 -7 = 36 Steps

| Metric | Actual | Desired | Gap |
|---|---|---|---|
| Process Time | 4030 Minutes | 250 Minutes | 3780 Minutes |
| Procedure (No. of steps) | 43 Steps | 7 Steps | 36 Steps |

**Table 5: Gaps in Time and steps metrics for "improvement in procedure only"**

Note: the 250 minutes are the estimated process time for the 7 tasks reported with "NON" waste type in Table 07.

### 3.2.5.2 **Explain root causes:** identify the likely cause of the problem

Referring to the "Cause-and-effect diagram", the causes of the problem may attribute to:

1. Procedure:
   a. Number of people involved in the whole process.
   b. Number of tasks
   c. Time to prepare and putting cylinders in service
   d. Importing cylinders by suppliers
2. Resources:
   a. Old technology and process procedure, dated back to 1980s
   b. Using Cylinders

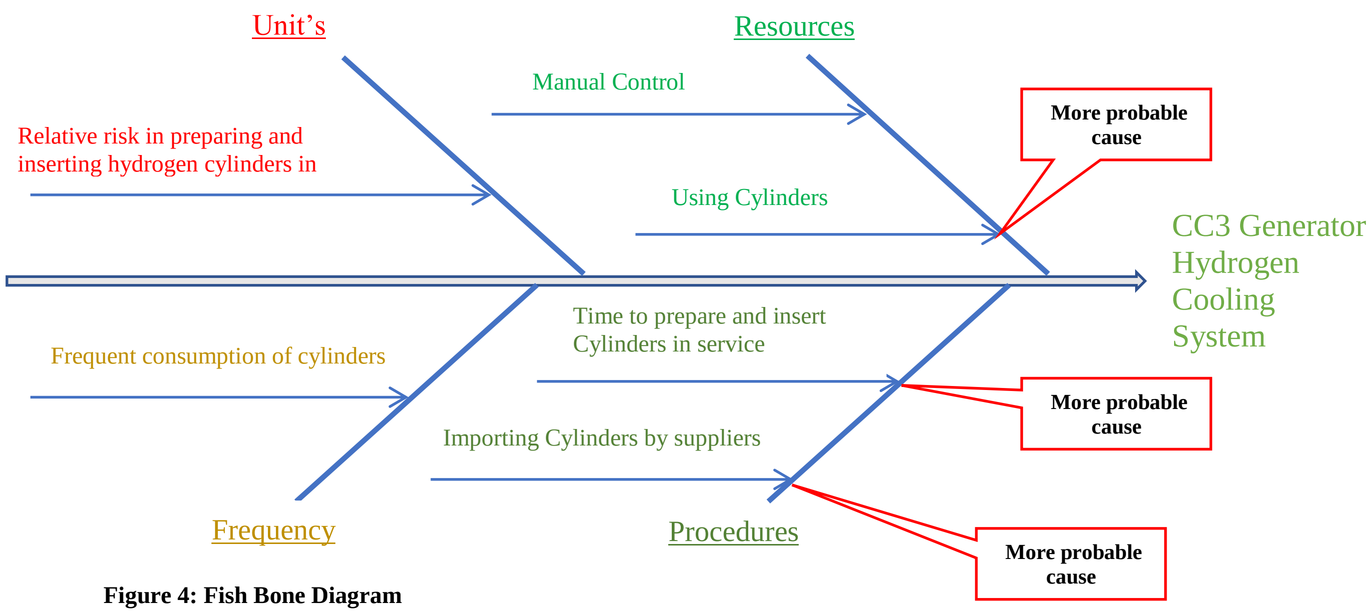


**Figure 4: Fish Bone Diagram**

## 3.3 Phase 3: Develop an optimal solution:

In this phase, we plan and implement actions that correct the root cause(s). Based on the previous phases, we innovate subtle improvements and establish delicate operation plans.
Phase 3 consists of the following steps:

- 3.3.1 Determining goal(s): the extent of desired improvement.
- 3.3.2 Conducting force field analysis
- 3.3.3 Specifying optimal recommendations.
- 3.3.4 Financial Analysis for implementing improvements.

### 3.3.1 Determining goals (the extent of desired improvement)

The idea of improving the current status of the cooling system of the third hybrid unit (hydrogen cooling system) is based on:

1. Abandon the use of hydrogen cylinders:

   After studies, it became clear that most of the system problems are limited to this part. The idea of eliminating this part and feeding the system from a safe and reliable source of hydrogen was introduced.

2. Utilization existing hydrogen generating units - for the first stage or sixth stage - to feed the system with the necessary hydrogen.
3. Keep minimum number of hydrogen cylinders for backup only.

### 3.3.2 Conducting force field analysis:

Force Field Analysis assist team to consider the pressures for and against a decision or a conversion plan.

The following table shows the result of the conducted force field analysis:

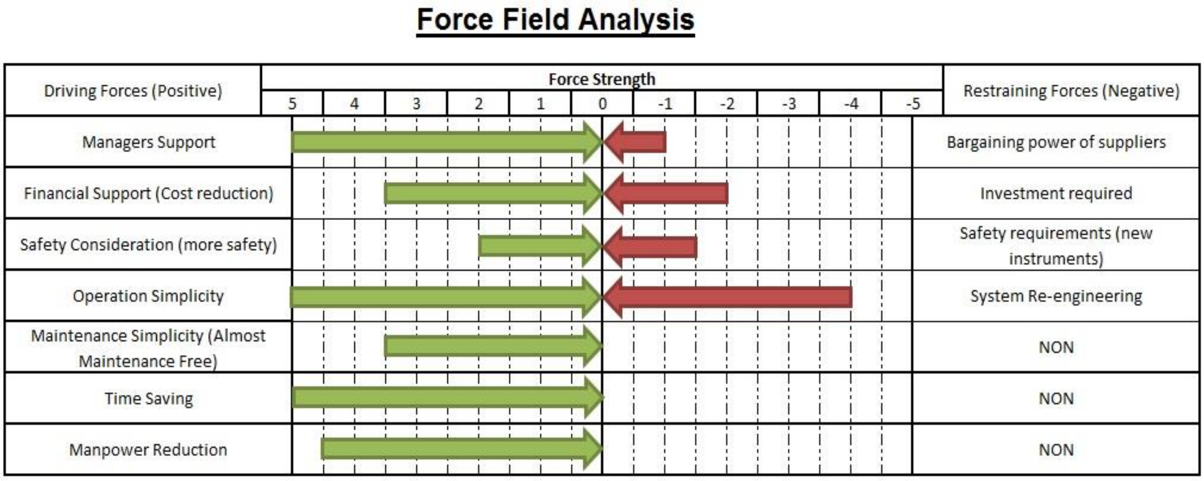


**Figure 5: Force Field Analysis**

### 3.3.2.1 Setting priorities: the dominant forces

1. Driving Forces: (Forces supporting change)
   a. Managers Support
   b. Financial Support (Cost reduction)
2. Restraining Forces: (Forces opposing change)
   a. Investment required
   b. System Re-engineering

### 3.3.3 Specifying optimal recommendations

System need re-engineering to utilizing the use of existing hydrogen plant at stage I.

1. Use hydrogen available from hydrogen generating plant.
2. Make pipeline from hydrogen generating plant to the CC3’s generator.
3. Equipping the new pipeline with digital measuring instruments and fully automated control systems.

### 3.3.3.1 Improvement result:

The process map after re-engineering is as following:

| Task # | Main Task | Subsidiary Tasks | Responsible | Note |
|---|---|---|---|---|
| 01 | Confirming hydrogen pressure inside generator | | | |
| 1.1 | | Confirming hydrogen pressure is at least 30PSI | Unit Operator | |
| 1.2 | | Confirming hydrogen purity is more than 94% | Unit Operator | |
| 02 | Checking hydrogen Plant operation status from local | | | |
| 2.1 | | Checking that instruments are reading properly and there is no gas leakage | Local Operator | This step can be cancelled by the mean of state of art digital gas leakage detectors instruments, but we keep it to complain with safety requirements |
| 03 | Raising hydrogen pressure and improving its purity inside the generator | | | |
| 3.1 | | Local operator report the status of field devices to the unit operator | Local Operator | Complaining with safety only |
| 3.2 | | Unit operator start the process by just one click command | Unit operator | Fully automated: system send open command to the new installed control valve and get feedback signal |
| 4 | Ending process | | | |
| 4.1 | | System stop the process by sending close command to the control valve | Automation System | |
| Total Subsidiary Tasks | | 6 Tasks | | |

**Table 6: process map after re-engineering**

## 3.3.3.2: People involved after improvement

The following table shows the frequency - number of repetitions – of people involved in the process after improvement

| No. | Responsible | Frequency |
|---|---|---|
| 1 | Unit Operator | 3 |
| 2 | Local Operator | 2 |
| 3 | Automation System | 1 |
| Total | | 6 |

**Table 7: People involved in the process after re-engineering**

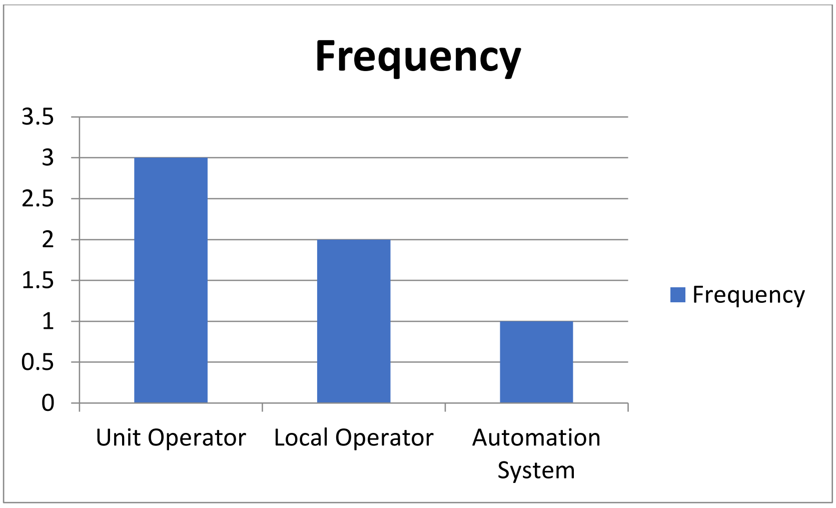


**Figure 6: Histogram of people involved in the process after re-engineering**

## 3.3.3.3 Determining Gaps:

Gaps = Actual – Re-engineering
Process Time Gap = 4030 – 90 = 3940 Minutes
Procedure Gap= 43 -7 = 36 Steps

| Metric | State | Measures | Gaps | Improvement % |
|---|---|---|---|---|
| Procedure (Steps) | Existing State | 43 | NA | |
| | Procedure Improvement (only) | 36 | 7 | 16.28 % |
| | System Re-Engineering | 6 | 37 | 86 % |
| | | | | |
| Time (Minutes) | Existing State | 4030 | NA | |
| | Procedure Improvement (only) | 3780 | 250 | 6.20 % |
| | System Re-Engineering | 90 | 3940 | 97.77 % |

**Table 8: Improvement comparison in process time and procedure**

## 3.3.4 Financial Analysis for implementing improvements.

The distance between stage I hydrogen plant and the CC3 generator at stage IV is about 800 meters.

### 3.3.4.1 Investment needed

The following table shows the investment needed in thousands Saudi Riyals Initial cost of the project is estimated to be SR 930,000 to SR 1,035,000 and is breakdown as follows:

| No. | Description | Amount (Thousands SR) |
|---|---|---|
| 1 | Engineering design and drawing | 60-65 |
| 2 | Automation System Software Editing (Adding one logic sheet and one graphic screen to existing system of CC3) | 80-90 |
| 3 | Pipes and accessories (Materials) | 500-550 |
| 4 | Civil Works | 120-140 |
| 5 | Installation and Testing | 170-190 |
| Total | | 930-1035 |

**Table 9: Estimated Cost of Re-engineering**

### 3.3.4.2 Project recovery period:

H2 Cylinder capacity = 5.49 m3
Cylinder price = 750 SR
Average daily consumption of H2 = 2.5 cylinders (approximately)
Average daily cost = 2.5*750 = 1,875 SR
Average annual cost (based on 300 days) = 1,875 * 300 = 562,500
Cost based on 10 years = 5,625,000
Project recovery period = 1,035,000/5,625,000 = 0.184 * 10 years = 1.84 year (calculated based on the maximum estimation cost of the project)

So, the recovery period is approximately two years.

<u>**Note:**</u> The remaining three steps which are: Implement the solution, study the result and adjust, and Standardize the solution can only be done and measured after implementing the previous three steps. So, they are excluding from our current study and can be planned as future step at Rabigh Power Plant.

# 4. Study Findings

The researcher applies the Continuous Improvement Process (CIP) –or Kaizen- to simplify the process of hydrogen cooling system for CC3 generator at Rabigh Power Plant. The study society consist of 120 employees, all Stage IV staff in addition to higher management crew at RPP. After collecting questioner forms, 23 forms were excluded because they were not valid for the study. These forms constitute 19% of the study total society sample.

The improvement done in two major aspects:

1. Eliminating waste from the existing system procedure
2. Abandon the use of hydrogen gas cylinders, which need re-engineering

# 5. Study Discussion

**Objective 1: Plan:**

- **Objective 1.1:** To gather a list of possible opportunities to enhance in RPP.

  Team's communication with RPP's customers reveals that there are many opportunities for improvement. The team reported the most important fourteen possible improvement project in the study.

- **Objective 1.2:** Choose one opportunity to enhance.

  The team used the voting tool to minimize the list. Using the Voting Tool, processes were reduced to only six opportunities out of fourteen. The voting was done among the project team only. The team avoid asking the customers – RPP staff- to choose among a long list of fourteen project, instead we decided to meet together and reduce the list as minimum as we can.

  The two opportunities which got the highest importance degree and lowest satisfaction degree are:

  1. CC3 Generator Hydrogen cooling system
  2. Ball Cleaning System of Steam Turbines

  Here, another procedure was followed to choose only one out of the two opportunities. According to five criteria (Safety requirements, Accuracy needed, Problems Repeated Amount , Possibility of improvement , and Possibility of Cost Reduction), the questioners result shows that "CC3 Generator Hydrogen cooling system" opportunity is the one that we have to improve.

**Objective 2: Do:**

- **Objective 2.1:** Studying the current situation (measurement and analysis)

  The researcher spends a considerable time in understanding the current situation of the process subject to improve. He used the table to show the process and ongoing details of each task or step.

  The current situation includes:

  - 43 tasks and sub-tasks
  - 11 individuals involved in the process
  - Process time is 4030 minutes

- **Objective 2.2:** Innovating enhancement and implementation plans. (encourage solutions and shoos an idea)

  The researcher made two improvement to the existing system

  **First:** Improvement in procedure only:

  The researcher identified wastes and inefficiencies within the existing processes. By analyzing the situation, he observes the following:

  - 36 tasks considered as “wastes” with 3780 minutes processing time
  - 5 tasks can be completely canceled
  - The desired number of tasks are 7 tasks with approximately 250 minutes processing time.
  - All the 36 tasks cannot be eliminated from the existing system by only improving the procedure.
  - As a result, this improvement is considered as invaluable and we need to find another solution, which is re-engineering of the existing system.

  **Second:** Re-engineering of the existing system:

  To find a valuable and practical solution, the researcher introduced Phase 3 – in chapter four- which is “Develop an optimal solution”. The optimal solution found to be using the existing hydrogen generation plant – an asset of stage I at RPP- . The idea is based on the following main points:

  I. Eliminating the use of hydrogen cylinders and find alternative safe and reliable hydrogen source.

  II. Utilization existing hydrogen generating units - for the first stage or sixth stage - to feed the system with the necessary hydrogen.

III. Keep minimum number of hydrogen cylinders for backup only.

By implementing this solution, we observe the following points:

- Number of total tasks becomes 6 only (86 % improvement compared to existing system)
- Processing time becomes 90 minutes only (97.77 % improvement compared to existing system)
- Number of individuals involved in the process becomes two only in addition to the automation system. (72.73% improvement compared to existing system)
- Project recovery period is approximately two years.

The following figures and tables summarize the results

| | Improvement % | |
|---|---|---|
| | Process Time | No. of Tasks |
| Procedures only | 6.20% | 16.28% |
| re-engineering | 97.77% | 86.00% |

**Table 10: Result of improvements (Procedure only vs. re-engineering)**

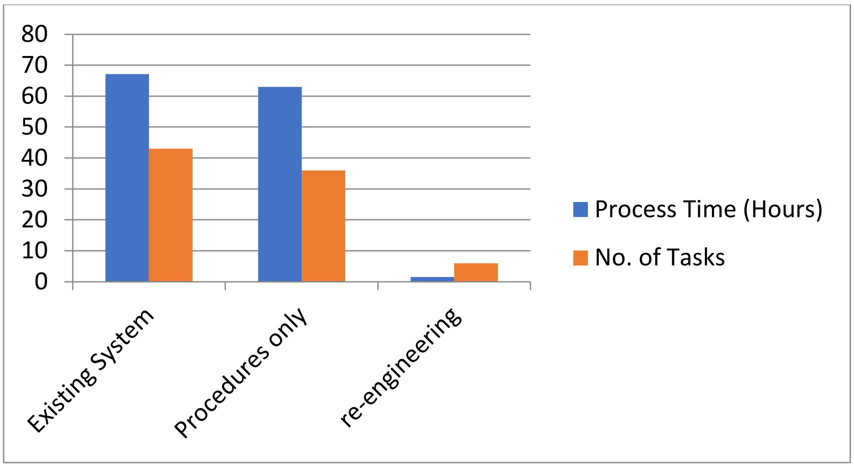


**Figure 7: Histogram Comparison of Existing System vs. Improvements**

## 6. Conclusion

'Kaizen' means continuous improvement. It is a methodology that supports continuous, incremental process changes. It can make improvement by eliminating "waste". Kaizen team can help to improve efficiency, satisfaction, production, costs, procedure and other hard measures in any process. By bringing kaizen into RPP workplace, it is no more surprising how big an effect minor changes can make, and how the philosophy of continuous improvement can bloom.

Kaizen philosophies can be adjusted from their well-established origins in the manufacturing segment and utilized in electrical power plants. Kaizen can increase the reliability of power plants at lower operation cost. Continuous improvement should be a strategic component of long-term asset and staff development. [EPRI, 2009].

The purpose of the research was to implement continuous improvement methodology to solve the problem of supplying hydrogen gas- as a cooling media – to the CC3's generator.

It was concluded that the existing system has many wastes; many peoples involve in the process, many tasks with long periods of waiting, repeated tasks, over processing, motions, and above all inefficient mechanism using hydrogen cylinders. The new idea "using the existing hydrogen generation plant" becomes a giant leap in abandon the using of cylinders, making the process of supplying hydrogen more safely and reliable. Re-engineering the system reduces time and procedures, it makes financial saving, eliminates complexity from system. Moreover, the new idea becomes more acceptable, comfortable and pleasing to all parties in RPP; the management, operation, and maintenance staffs.

# References

Andrade FF. O método de melhorias PDCA. [thesis]. [São Paulo]. Escola Politécnica da Universidade de São Paulo, 2003. [cited 2012 Feb. 14] Available from: http://www.teses.usp.br/teses/disponiveis/3/3146/tde-04092003-150859/

Bessant, J., Caffyn, S., & Gilbert, J. (1994). Mobilizing continuous improvement for strategic advantage. EUROMA, 1, 175-180.

Choi, T.Y., Rungtusanatham, M. and Kim, J.S. (1997). ‘Continuous improvement on the shop floor: lessons from small to midsize firms’, Business Horizons, Vol.40, No.6, pp.45-50.

Imai M (1986), Kaizen: The Key to Japan‟s Competitive Success, McGraw Hill, New York, USA.

Nordin, N., Md. Deros, B., & Abdul Wahab, D. (2010). A Survey on lean manufacturing implementation in Malaysia Automotive Industry. International Journal of Innovation, Management and Technology, 1(4), 374-380.

Palmer V S (2001), “Inventory Management Kaizen”, Proceedings of 2nd International Workshop on Engineering Management for Applied Technology, pp. 55-56, Austin, USA.

Wong, Y.C., Wong, K.Y., & Ali, A. (2009). A study on lean manufacturing implementation in the Malaysia Electrical and Electronic industry. European Journal of Scientific Research, 38, 521 – 535

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# LIST OF FIGURES



# LIST OF TABLES