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Simulation of The Steam Power Plants Operation and Maintenance to Reduce the Cost of the Power Generation

Muqdad Hammad Khaleel

YÜKSEK LİSANS TEZİ

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İmza 

Muqdad Hammad Khaleel

Tarih: 08.08.2016

ÖZET

YÜKSEK LİSANS TEZİ

Buhar Santrallerinin Elektrik Üretim Maliyetini Azaltmak için İşletme ve Bakım Simülasyonu

Muqdad Hammad Khaleel

Selçuk Üniversitesi Fen Bilimleri Enstitüsü
Elektrik-Elektronik Anabilim Dalı

Danışman: Yrd.Doç.Dr. Nurettin ÇETİNKAYA

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Jüri
Yrd.Doç.Dr. Nurettin ÇETİNKAYA
Yrd.Doç.Dr. Bayram AKDEMİR
Yrd.Doç.Dr. Mümtaz MUTLUER

Elektrik buhar santralleri elektrik enerjisi üretimi alanında rekabet içerisinde konumunu güçlendirmeye çalışmaktadır. Bu konumu güçlendirme harcamalarını minimize etmek için sürekli bazda modern ve günümüzde kullanılan stratejilerin uyarlanmasını ve santrallerdeki işletmesel sistemlerin performansının iyileştirilmesini gerektirir. Bu mevcut stratejiler içerisinde en önemlisi santrallerdeki bakım ve işletme yönetimine odaklanmaktır.

Elektrik buhar santralleri dünyada enerji şebekelerinin omurgası olarak kabul edilir. Bu santrallerin yönetiminde birçok farklı işletme politikası kullanılabilir. Burada buhar enerji santralleri arasında bakım ve İşletme açısından birleştirilmiş sistem hatta performans ve sonuçları karşılaştırma için birleştirilmiş sistem bulma zorluğu vardır. Santralin kendisi veya doğru şekilde seçilmiş benzer santrallere ait performansları belirleyerek karşılaştırma yöntemi ile santrallerin incelenmesi; bize bakım yönetim yöntemlerini iyileştirme, santraldeki işletmesel sistemlerin verimliliğini artırma ve ekipmanların ömrünü uzatma; böylelikle santralin üretkenliğini yüksek verimlilikle devam ettirme imkanı sağlar. Bakım ve işletme yönetiminin iyileştirilmesi ve enerji santrallerinde karşılaştırma uygulamalarının uyarlaması; benzer santrallerde en iyi uygulamaları bulmak ve performansı artırmak için kullanılmalıdır. Bu tezde elektrik buhar santralleri için bakım işletme yönetimi yapabiler bir model önerilmiştir. 2009-2013 yılları asasındaki döneme ait Baiji elektrik buhar santralinin verileri kullanılmıştır. Elektrik buhar santrallerinde verimin arttırılması ve maliyetin azaltılması için kullanılan başarılı uygulamalar, bu çalışmada önerilen bakım-işletme yönetimine adapte edilmiştir.

Anahtar Kelimeler: CBM, CM, CMMS, DMAIC, PdM, PM, RCM, SixSigma.

ABSTRACT

MS THESIS

Simulation of the Steam Power Plants Operation and Maintenance to Reduce the Cost of the Power Generation

Muqdad Hammad Khaleel

THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCE OF SELÇUK UNIVERSITY
THE DEGREE OF MASTER OF SCIENCE OF PHILOSOPHY
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Jury
Asst.Prof.Dr. Nurettin ÇETİNKAYA
Asst.Prof.Dr. Bayram AKDEMİR
Asst.Prof.Dr. Mümtaz MUTLUER

Abstract

Electric steam power stations are working to strengthen its position in the competition within the field of production of electric energy. Strengthen this position requires the adoption of modern and sophisticated strategies on a continuous basis to minimize expenses and improve the performance of operational systems at the stations. The most important of these strategies is in place to focus on the management of maintenance and operations at the stations.
Steam power plants are considered the backbone of the electrical grids in the world.

These stations, there are many designs, and principles of work, and the fuel is user to run. Even similar stations in these things differ in the policy pursued in the management. Therein lies the difficulty of finding a unified system for maintenance and administration or even compared to the performance and results between the steam power stations. Studying of the station by the Benchmark through determine the keys of performance in the station itself or with the similar stations selected in accuracy. Allow us to develop methods of maintenance management and improve the efficiency of operational systems at the station and extend the life of equipments, thus continuing the productivity of the station in high reliability. To promote the maintenance management and to increase the reliability of power stations adoption of application of the Benchmark to find the best practices in the station or similar stations and use them to improve performance. We will focus in this thesis to create a model for the management of maintenance in the steam power stations (Baiji steam power station of a case study) by comparing the practices at the station (interior benchmark) and find her results, and adoption of the data provided from 2009 to 2013. The work on the development of the administration's policies in the station during maintenance operations increased the efficiency rate in the operation and maintenance.

The benchmarks have been adopted as a basis in the maintenance management and find successful practices of the station gave a comprehensive and accurate vision to increase efficiency and minimize expenses.

Keywords: CBM, CM, CMMS, DMAIC, PdM, PM, RCM, SixSigma.

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Last but not least, to all my brothers and their families and to my friends who gave me moral support through telephone, e-mail and (SMS), God bless you all.

DEDICATION

I would like to dedicate this work to my parents; my late father, and my dear mother.

Muqdad Hammad Khaleel
KONYA-2016

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LIST OF SYMBOLS

AF	Availability factor
CBM	Condition based maintenance
CM	Condition monitoring
CMMS	Computerized maintenance management systems
CTQ	Critical to quality
DCS	Distributed control system
DMAIC	Define, measure, analyses, improve control
DMADV	Define, Measure, Analyze, Design, and Verify
DMM	Dynamic Maintenance Management
DPMO	Defects per million opportunities
EAM	Enterprise asset management
FMEA	Failure mode and effect analysis
FMECA	Failure mode, effect and criticality analysis
FR	Failure rate
JIT	Just in time
KPI	Key performance indicators
MTBF	Mean time between failures
O&M	Operation and maintenance
PDCA	Plan-Do-Check-Act
PdM	Predictive maintenance
PM	Preventive maintenance
RCFA	Root cause failure analysis
RCM	Reliability centered maintenance
SIPOC	Supplier-Inputs-Outputs-Customer
TPM	Total productive maintenance
WIP	Work in progress

1. INTRODUCTION

In this simple presented of this research are trying to pass quickly on the subject and interest from research and clarification of industrial competitiveness and developments in this field.

1.1. Background

In recent year's maintenance operations in industrial facilities was taken a great importance. Attention to development maintenance operations came for several reasons the most important maintaining the continuity of equipments work for as long as possible and increase the profits as well as minimize the required expenses for maintenance. A maintenance management operation became one of things that industrial facilities do not differ on it, but monitors have special development budget because of their direct link to increase commercial profit and they relate to a period of discontinuity and continuity of work by increasing the reliability and efficiency (Waeyenbergh ve Pintelon, 2002). The development ideal maintenance program in works achieve to good continuity of work and this is reflected in the high rate of production and enhance the facility position in the commercial market competition (Crespo Márquez ve ark., 2014). Get rid of the causes of the various outages one of the most important pillars of success in enterprises, in addition to the ability to output the required quantities on the limit time with less costs. The adoption of industrial installations strategies own management of maintenance and personnel training and warehouse administration, helps continuity (Cigolini ve ark., 2009). For ongoing work to update the systems and methods of work in the facilities, became necessary to work to archive all data related to operation and maintenance.

And the development of the information gathering models and the use of modern methods and programs for analysis to avoid faults and increase profits (Swanson, 2001). The use of predictive maintenance (PdM) requires collected the information of equipment's thoroughly and review previous data for maintenance. To locate deviations and their causes and find appropriate to treatment for each case. As an example of the quality of information (temperatures recorded during the work period, the vibrations occurring on different parts, lubrication times and the quality of materials) the original values for manufacturers, the lower and upper operating boundaries (Berry, 2015).

The studies that are made on the maintenance operations including Benchmark, is applied in the subsequent maintenance operations to get rid of forced shutdowns and

preventive maintenance and unscheduled maintenance. And thus control of the maintenance operations and reduce costs (Prajapati ve ark., 2012).

Many studies have shown that half of industrial facilities management system does not apply effective maintenance programs. This led to the failed in facilities to achieve profits or access to the required levels of performance efficiency and thus not achieve the set aims. The development of a comprehensive maintenance program for industrial plants it requires the allocation of part of the financial investments to work to create the necessary tools, and the use of experts in the field staff urged to adhere to practice the system and make them aware of its importance (Sharma ve ark., 2012).

2. KAYNAK ARAŞTIRMASI

The last years of the past century have seen a lot of books, studies and research and scientific journals that dealt subject of maintenance in various industrial facilities. As a result, it included studies of the maintenance process minute detail preparation through the development of plans before, during and after maintenance operations.

The true concept of the benchmark process is determining the highest standards of technical and administrative operations in industrial installations.

Finding excellence in maintenance and production factors and study the reasons that led to the success of the work on the sustainability of excellence and the possibility of improvements in the processes or take advantage of them in the another operations. Many companies relied on the application of the benchmark and prepare the appropriate strategy depending on the quality of practices and the nature of the entity's business and the proposal on the process for benchmark models (Bhutta ve Huq, 1999).

Study Type Condition Based Maintenance (CBM) and the associated operations and equipment and the nature of the information collection; work on the use of modern screening devices. Study the proposals submitted by the companies and the adoption of IEEE Std. 1451, IEEE Std. 1232, and ISO 13373-1 and evaluate the life span of the equipment and access to the result of that technical progress should be invested to increase equipment life and improve the condition. Is split (BCM) to the following categories: measurement devices and sensor protection devices and alarm test method and to make sure, mistakes and expectations, and group decision-making. IEEE Std. 1451 to develop the sensor module and used in ISO 13373-1, and the development of diagnostic devices using the ISO 13373-1 and IEEE 1232 (Bengtsson, 2004).

Life depends entirely on energy to cover the daily activities of life in the factories, homes and other, and when planning for the operation and management of these systems is measured the reliability. Despite high interest in controlling the process of interruption of electrical power sources and to develop measures to reduce them, but it is repeated in a permanent (sometimes an unplanned). The using of mathematical methods is to determine the quantity and quality and develop appropriate policies to work on risk assessment in the case of a power outage. As a result of natural disasters that occurs in the United States and damages them.

And guide researchers towards the future study of these cases and to discuss other areas (Castillo, 2014).

Collect detailed information on power stations Preventive maintenance in the steam stations and other stations, and how to take advantage of the information in the operation and control of the planning. By studying the data is recognized as the condition of the equipment and the life span for it. The development of a strong and a flexible management system is to take maximum advantage of information to the development of the station. Develop a plan for proactive maintenance to identify deteriorating equipment and determine the quality of the required work scheduled, based on the examination information and the date of the start equipment in the work. Take advantage of the information management in the steam stations operating in Japan to manage steam stations in data and develop a proactive maintenance model (Kanda ve ark., 2000).

Cases of repeated failures as a result of vibrations are occurring in the rotating parts of the turbine and the instability of operational situations. Lead to a lack of stability of the station practically work. Those rely on staff with experience in operating and maintenance operations and follow the strategy of maintaining the design values for the operation of the equipment limiting the failures cases. Work on the adoption of the reliability of operating in steam power stations with the turbine 500 Megawatt. Through the study of data collected for five consecutive years and track failures and causes, and determine the cost of maintenance and the required time. All these measures are by following the method of failure mode and effects analysis (FMEA) for the classification of the factors of old failures and improve the reliability of the system through the development of its functionality tree in the station. Follow the necessary measures to improve the reliability by following the maintenance plan, routine surveillance of equipment and training and development the skills of human resources and manpower in the use of modern equipment and programs (De Souza, 2012).

The works total productive maintenance (TPM) in the power stations to reduce the time of power outages and thus reduce the losses and waste. These studies were done and work to increase the availability and Overall Equipment effectiveness (OEE). Working to a make is the most of the power plants to benefit by applying the methodology (TPM). Analysis the different aspects of the (TPM) applied in the steam power stations. Discuss the necessary gadgets to implement the (TPM) and the challenges we face in the practical aspects of this method. The method (TPM) work is done on the training of operators to determine the possibility of mistakes and learn some simple processors and is regarded as a member of the maintenance team. Because many

of the facilities are not considered operators a part of the maintenance process (Sharma ve ark., 2012).

Work on the preparation of a unified maintenance program for electric station includes various types of maintenance (corrective and pre-emptive and scheduled and emergency) or the total productivity maintenance (TPM). So as it needs the application of these types of maintenance to balance adequate investments for the purpose of training and providing the required materials. Therefore through this study explain the relationship between of these maintenance policies and their impact on performance achieves higher performance and gain the ability to effectively address the errors rate. Through the results obtained shows a strong and effective bonding between the different types of maintenance and that it has been implemented in these stations (Swanson, 2001).

3. ADMINISTRATIVE MAINTENANCE METHODOLOGY

In this section, we describe the context in research and development to give an overview of research related research topics can be found as well as the reader, aims to analyze existing theory.

Research is to obtain reliable results, theory and empiric results and whenever necessary to build one.

Maintenance activities are carried out on the assets of any assets in order to continue to perform the desired functions. And maintenance management, coordination and control, planning, appropriate monitoring devices, applications and production facilities and operations in accordance with maintenance activities (Kahn, 2006). Scheduled maintenance improvement and maintenance activities to ensure that they are analyzed using the right combination of maintenance strategies. Over the past twenty years, maintenance has changed than perhaps any other special management. The changing number and should be kept anywhere in the world of physical assets (facilities, equipment, and buildings), due to a variety of tremendous growth, and these designs and more complex a new maintenance techniques and organization and maintenance responsibilities views changing. Maintenance is responding to changing expectations. This safety and the environment, the growing link between maintenance and product quality information, the increasing pressure to achieve high availability of plant and equipment failure cost control measures to contain the rapidly growing information and effects.

In this regard, corporate staff departments, as well as a large number of workers leaving the maintenance activities of large financial resources showed the importance of each. And a thermal system will then circle the care of a variety of factors, thermal stations, thermal plant fuel and technological complexity of nature, air and depends on very much. Growing employee thermal energy interests and base load at thermal power stations and develop the optimal approach to care and maintain the high availability and reliability in the face of reality and resources; it continues to be a problem for maintenance teams to meet to ensure the sustainability of the process plant and increasing expectations.

Road maintenance has been offered by different authors in different views. In this research, signal analysis and decision-making processes used in the design of the maintenance procedures using the maintenance management method. Road maintenance

refers to the way in which maintenance tasks and planning decisions. Applicable four basic care strategies are (Kahn, 2006):

Failure or breakdown maintenance

- Corrective action (unscheduled)
- Preventive maintenance described in (based on time)
- Predictive maintenance based on the condition of the equipment (based on the condition) Maintenance requirement (the main reason for the result)
- Proactive focus on alleviating

The organization also has a different approach for maintenance projects.

Project work is an important part of the maintenance strategy.

Corrective strategies minimum investment, high operating costs and provides a minimum of equipment availability. Generally, predictive and proactive strategies that require major investment, low operating costs and resulting in higher equipment availability. The best strategy forestry equipment and economic analysis and on the basis of risk assessment is to use a different strategy for each piece of equipment. Figure 1 shows this best practice care 10% correction strategy blends the best practice model of care maintenance strategies shown, called the optimal mix, and 30% to 50% and 10% predictive preventive and proactive. The current practice with corrective maintenance is over 40%, but there is much room for improvement (Kahn, 2006).

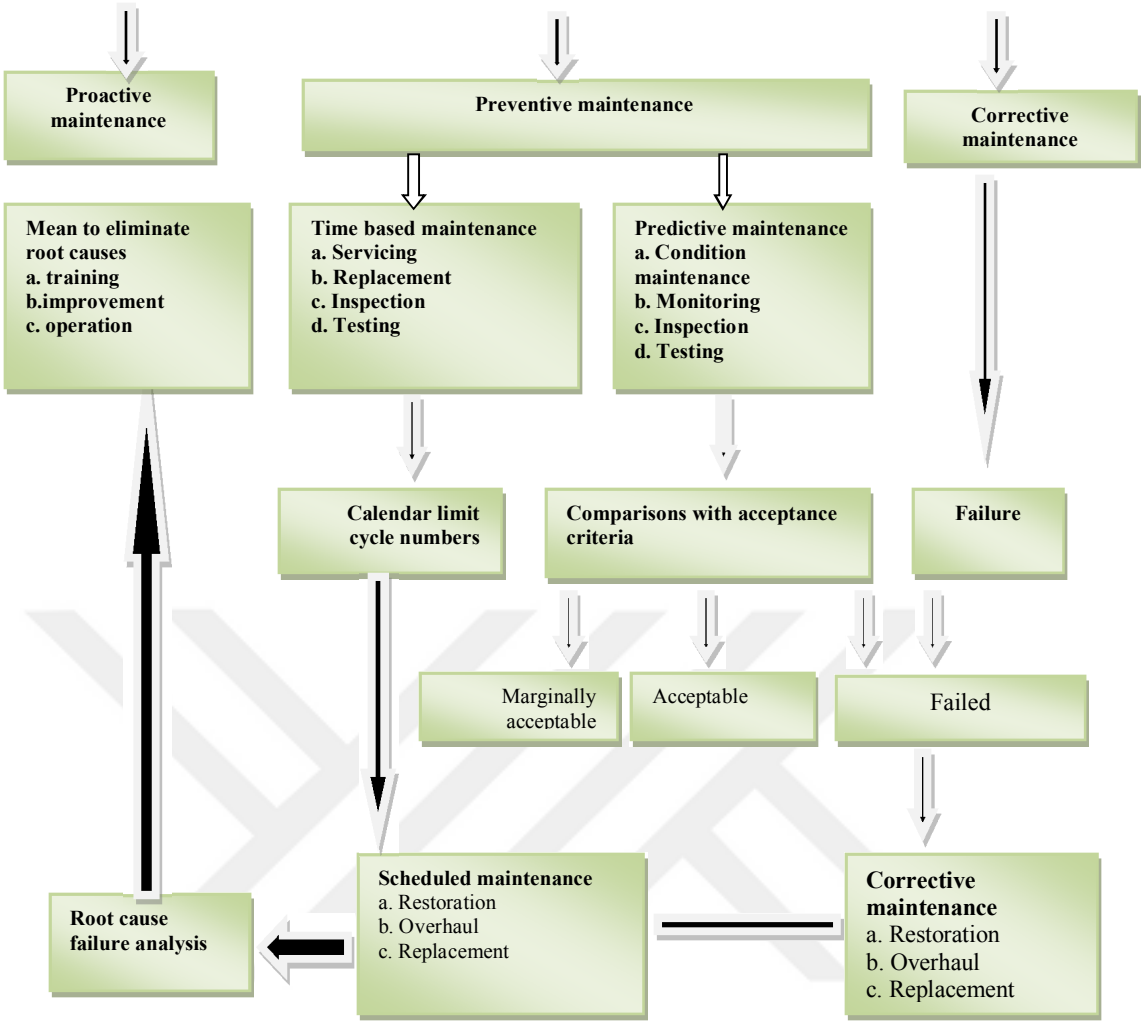

Figure 3.1 The best practice maintenance model

3.1. Corrective maintenance, Deterioration or Interruptions Maintenance (Unscheduled)

Corrective maintenance approach was undertaken so that in the case of failure or having been an obvious error. Standard conditions, such as (Bengtsson, 2004) identify corrective maintenance:

"Failure to recognize and carry out the required maintenance function after government intended to put a judgment."

Maintenance is performed on machines fail is defined as any event this method. This method is the first impression that the most cost-effective labor and related costs are minimal because it looks like.

But on closer inspection machines fail and large expenditures for the allocation of urgently needed labor, parts and repair / manufacturing process can install depending on the speed of change and shows that lost revenue due to lack of production.

Obviously, this method unpredictable has the best maintenance and associated high costs.

In addition, this may constitute a risk to personnel and facilities unexpected failure.

Unexpected maintenance and unscheduled equipment downtime main negative reaction. When a piece of equipment and spare parts delivery and order parts are not available failures, delays ensue. If there is an urgent need for these items, you must pay a premium for express delivery. Now produced by equipment failure or stored and the function of the back is tougher and you need to take expensive measures. Similar or duplicate equipment or technology to meet the needs of rapid prototyping in temporary, but can be a great cost. To prevent or control any of them (or lower) procedure because it did not take failure occurs Also, there is no ability to influence. This is only applied to one type of maintenance and ineffective labor and materials are all used. References are to work the collapse of whatever are most urgent issues.

In the case of failure often occurs at the same time, an attempt to bring all the errors under control maintenance order is a necessary type of application. "Stability" maintenance work will be transferred to the next most urgent cases and thus, cannot be expected to use them for spare parts because of high levels should be kept constant emergency reforms and then used (but not necessarily fit). This leads to high costs and is not an effective way to run a bookstore.

Corrective Maintenance Fault recognition after it was aimed to cause the desired function can be carried out and the equipment is state care. Corrective maintenance may be immediate or postponed (Márquez, 2007).

• Instant care. After detecting the error in order to avoid unacceptable consequences carried out without delay care.

• Deferred Maintenance.

It does not take place immediately after detecting a fault corrective maintenance, but delayed, and some rules were based care.

3.2. Preventive Maintenance

(Bengtsson, 2004) have been described as preventive maintenance type:
"Element according to specific criteria designed to reduce the possibility of failure or performance degradation care or at predetermined intervals."

It is a program of preventive maintenance programs collapse progress. Preventive maintenance (PM) in order to prevent failures and errors that the timetable for planned maintenance procedures. PM equipment before it actually occurs primary goal is to prevent failures. It was originally designed to protect and improve equipment reliability by replacing worn components before failure.

Activities so that PM controls and partial or complete equipment repairs at regular intervals, oil changes, lubrication and be counted.

They know that instead of repairing worn parts before they cause system failure or addition, workers can record equipment deterioration.

Recent technological advances have provided the means for more accurate and effective equipment maintenance and diagnostic scanning.

An ideal program for the PM is to keep all equipment failure before they occur. There are several misconceptions about PM such a misunderstanding PM is unnecessarily expensive.

This logic would even say absolutely normally cost more to stop scheduled maintenance would cost to run the necessary reforms equipment regularly. This may be true for some of the components, but long-term benefits and cost savings associated with a need to compare but PM only. Without PM, for example, it would be a waste of time production costs resulting from the collapse of scheduled equipment. Also, the PM system services will provide savings as a result of increasing the effective life. Preventive maintenance list (smart) includes the maintenance and condition.

3.2.1. Time-based maintenance

This is a regular maintenance interval made in a calendar and a certain number of operating cycles, or can be made after a certain number of working hours. These stamps are founded on the basis of the recommendation of the manufacturer and the operating facilities and industrial experience. Population protective equipment to be addressed in the initial operational phase of care established by the accumulation of experience and is refined.

Overall, the population coverage equipment and associated maintenance tasks and the to the performances at the beginning of a systematic evaluation of the relevant factors as set the frequency (Dhillon, 2002):

The importance of the general plant equipments are failure function.

- Office equipment cycles.

- Duplication equipment.
- The effectiveness of maintenance activities to prevent failure.
- Failure to estimate the effectiveness of maintenance activities.

Tracking shows that a large number of maintenance tasks, knowledge are high and reliability centered maintenance processes that lead to equipment failure.

Advantages PM

- Cost-effective in many capital-intensive operations.
- Allow flexibility to set periodic maintenance.
- To increase component life.
- Energy-saving.
- Low equipment or process failure.
- Low replacement cost.
- To improve the Spare parts inventory management.
- Low system crashes.
- To increase the reliability of the system.

Disadvantages:

- Probability of catastrophic failure is still high.
- Heavy industry.
- Maintenance includes unnecessary performance.
- Plug-in accidental damage likely to make unnecessary care.

Long-term effects and cost comparisons usually prefer PM only maintenance procedures on the implementation of the system have failed.

PM the following two conditions (Manzini ve ark., 2009) with a logical choice:

- The component failure rate has increased. In other words, increases with the passage of time on the wear part implies error rate. It does not make sense exponential distribution (which includes the constant failure rate) is supposed to be PM component.
- The total cost of the PM work will be less than the total cost of the corrective actions

(Note: The total cost of corrective actions, including single and / or needs, etc. downtime costs, loss of production costs and its safety is a critical component failure cases, intangible costs, such as loss of reputation concrete-ins).

The following methods (Chalifoux ve Baird, 1999) it is recommended to determine first periodical:

- Experience failure prediction. Some equipment failure, date and provides an intuitive feel for when to expect personal experience equipment failure.

In such cases, it is related downtime. As a control group, so at least three monitoring visits are not to be expected per failures before PM. That's enough technicians on a piece of equipment to become familiar with three visiting "look" will. In most cases, it will wear out with age it is prudent to shorten the viewing time approached.

- The distribution of the statistics. During use statistics to determine the basis for selection of the patrol, distribution and failure probability must be known. can provide information about the probability distribution equipment exceeds some life (Niebel, 1994).

Lack of in the informations, or "conservative approach". The most common practice in the industry due to lack of information and poor monitoring techniques to track every two weeks or monthly equipment. This often leads to excessive control. In such cases, the monitoring equipment without affecting adversely the efficiency of this time may be significantly increased.

3.2.2. Equipments conditions based in maintenance

According to (Bengtsson, 2004) defined as:

"Condition based maintenance carried out following a forecast derived from the analysis and evaluation of significant parameters of the degradation of the item."

Predictive Maintenance (PdM) program to regularly monitor the measurement time measurement devices and measurement equipment businesses go beyond the boundaries of the goal, corrective action. Required equipment repair and preventive maintenance work requires less than an hour of a number of parts. However, new tools to collect and analyze data and predict repair traceability of measurement cycles, requires training and programs.

As with any new technology, it is important proper implementation and training. This particular has become increasingly sophisticated and technology-oriented technology is a real need in the PdM. Most industry experts agree (as well as most respected equipment manufacturers) to be applied properly, the player training and equipment monitoring and repair serious commitment to use at home if you have to buy the equipment.

Such a commitment is not a site with an outside vendor other methods of execution, which contracted for these services and make a good search for a preferred

option for the program and equipment and experience would rely on(Sullivan ve ark., 2004).

Condition-based maintenance (CBM) objective is to improve reliability and availability by identifying maintenance needs according to operating conditions of the equipment. "Forecasting Techniques" use

Techniques to monitor the situation and notes the time and probably used to highlight further in order to determine and failed to develop a proactive manner, the plant's ability to plan and move.

PdM / CBM device monitoring and maintenance operations directives clause can be analyzed to determine the requirements indicator, we assume that cost. In terms of low cost allows the most effective maintenance program and at the right time the correct maintenance work determination (Dhillon, 2002).

Close to predict the failure of this equipment, as well as integration with the status of all available data in order to avoid expensive maintenance (CBM) is performed on the basis of continuing.

Diagnostic capability to determine the operating conditions of this process as measured by the monitoring system depend to a large extent is not appropriate.

This maintenance program is, so viewing the work in process equipment necessary to continue to allow malfunctions.

The main objective of the program optimum maintenance strategy that includes predictive maintenance is the basic terms (Dhillon, 2002):

- Improve the availability of
- A reduced forced outages
- Improved reliability
- Develop life equipment
- Reduce the repeated re-building wear
- Reduce the possibility of disassembly and re-assembly problems
- They can identify problems when they occur
- Remember maintenance costs
- Decrease maintenance costs
- Decrease hours
- Decrease parts inventory requirements

Condition Based maintenance, shows a series of tasks performed by detecting immature equipment failure, and to determine the necessary maintenance procedures, necessary equipment to fail after the release of the nascent state assets that can run its status back.

Continuous monitoring is installed using case-based monitoring tools or activities at specific time intervals to monitor permanent (e.g. on-line diagnostic digital devices or systems, used clothing bearing turbine generator control orientation) can be created, diagnosis, or Orientation functional status of equipment.

The results of these activities and supporting existing equipment control and predict the future functional skills and to determine the nature of the work program required maintenance (Dhillon, 2002).

It should be used as part of a comprehensive program for various techniques and extra care.

Overall plant equipment, vibration since calculation for the majority mechanical systems or machines is a prerequisite that is the most important element of the maintenance program.

However, it will not provide all the information necessary for a successful maintenance program is a prerequisite vibration.

This technique is limited mechanical condition, other critical parameters needed to maintain a secure and efficient mechanism is limited to track.

Therefore, a comprehensive maintenance program on the basis of other cases should include monitoring and diagnostic techniques (Dhillon, 2002).

These techniques are:

- The vibration control.
- The Acoustic analysis.
- The technique for operated and analysis of motors.
- Thermographs
- The friction.
- Process parameter control.
- Visual inspections.
- Other non-destructive examination techniques.

Additional benefits and (PdM) some disadvantages:

Advantages:

- Increase operational component life / availability.

- Shortage of equipment or process an unexpected break.
- Reduction in the cost of parts and labor.
- Increase the quality of products.
- Increase workers and environmental safety.
- Improve the morale of the workers.
- Increase energy saving.
- Improving efficiency and equipment reliability.
- Direct concentrate on the trouble.

Disadvantages:

- Additional costs for screening and diagnostic equipment.
- Additional costs to train workers.
- Potential savings are not easily seen by the administration.

If the PdM maintenance better than PM maintenance, why we continue to use the PM maintenance?

Answer of this question is:

Determining the nature of the operation is the most effective method.

To ensure the highest reliability in the works of the actual maintenance work must be a combination of PM and PdM. Each degree of application depends on the type of equipment so when working with the machine. Pumps, fans, gearboxes, gears and other rotating machinery, machinery and methods suitable for hydraulic oils and lubricants PdM control large stocks. Facilitate and critical timing with assets tend to require changes to sensitive changes, which requests tend to alleviate precise adjustments, or have a lot of time must be reset came and links, Their activities are in PM.

To select the appropriate method or intelligent strategy includes the following decision-making process(Peters, 2006):

- If you develop equipment for many of the problems (defects) to consider.
- Sufficient predictive tool for the detection of various maintenance problems often encountered if the use of extrapolation. Need or may be a combination of several PdM method.
- PdM it is not enough tools available to use open high PM. Forced out that defects are not covered by the modes enough that preventive maintenance inspection tasks.

- If after inspection techniques, we decided together, to determine the frequency to be applied for particle control tasks. Some monitoring equipment will be satisfactory only using PdM, and other equipment that require PM. As a result is, some of the ways to provide coverage necessary to provide a combination of reliable performance.

It does not detect defects would be wise to apply various methods for providing the equipment.

3.3. Proactive Maintenance type (The root problem)

This proactive approach is equipment and procedures to assess the predictive first response. Corrective overwhelming majority, Preventive maintenance work created and modified controls and internal business as a result of predictive procedures. The aims of this method are to perform constant current equipment characteristics, production capacity, and maintain continuous improvement.

Still fragile maintain a proactive system, but repair and maintenance and a well thought out plan and is likely to be available if applied well.

Proactive Systems also as he did not get far behind, to protect less likely to need radical reform.

Characterized by proactive maintenance of the following positions(Chalifoux ve Baird, 1999):

- In an attempt to ensure that past mistakes will not be repeated in the future design is the design, construction, architects, engineers and designers to maintain a feedback loop maintenance technicians.
- Shows in terms of life cycle maintenance and support functions. These perspectives often appear often to cut maintenance activities to save money in the short term cost more money in the long run.
- To provide the right mix of established and continuously improve and re-evaluate the implementation of maintenance operations.

Uses the following basic techniques of proactive maintenance to extend the life equipment (Chalifoux ve Baird, 1999):

- Proper installation and re-tender.
- Partial failure analysis.
- The root causes failure analysis.
- Reliability Engineering.
- Testimony / verification based.

- The discovery of the deterioration.
- Controller redundancy.

3.4. The maintenance of projects

The aim of the project is work plant and equipment to make it a better, in regular maintenance targeting keeping the function of equipment to keep the current state. Maintenance equipment function maintains and improvement the equipment in the project is the important goals. To increase the reliability, planners need to think about projects at the institutional level. These projects are to upgrade the old systems in plant by development and place a new systems and equipment. As well as enterprise-level projects, also the amount of plant-level plant project work. It agreed to perform at a superior level of project equipment or helps to restore the necessary equipment can be ordered in any transaction. Continuous plants need in assessing the plant project ideas to make it more reliable (Higgins ve ark., 2002).

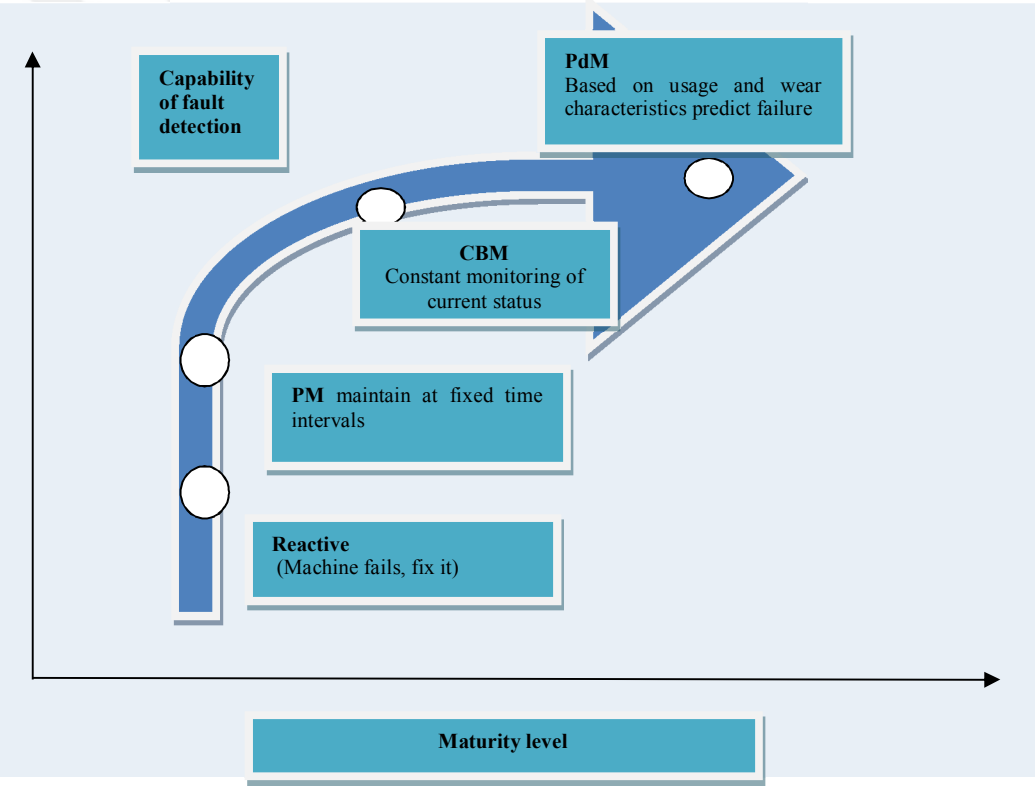

Figure 3.2 The representation of the four maintenance types in terms of maturity level and capability of fault detection. Based on (KANGE ve LUNDELL).

4. CLARIFY THE METHODS OF ADMINISTRATION

The management techniques will used in this thesis:

- six-sigma,
- lean maintenance,
- Reliability centered maintenance (RCM).

And have been writing a number of books and do a lot of research and articles in order to explain and determine the types of maintenance and management of the maintenance and promotion of methods used in industrial facilities. Competitive marketing methods usually make their way to confusion and a comparison and choose the right way is essential.

4.1. Six-Sigma Method

With reference to (Kahn, 2006) the primary objective of the methodology Six Sigma is the enforcement of a strategy based on the measurement which concentrate on improving the process and reducing contrast improve by applying Six Sigma projects. The process of Six-Sigma (DMAIC), (Define, Measure, Analyze, Improve and Control) is a system optimization of existing operations that fall under the specifications and are researching for gradual improvement.

There are two major types in a six sigma taken from Deming (Plan-Do-Check-Act) cycle, (Kahn, 2006):

- DMAIC is applied in a present process and improves it;
- DMADV is applied to differentiate modern jobs or plan designs.

To utilize a six sigma there are five phases must be applied, shown in Fig. 4.1

- Define: Identify the top level and operational objectives of the current project.
- Measure: To collect data related to measuring key aspects of the current process.
- Analysis: the collected data to confirm the relationships between reason and result.

How to determine the relationship, and try to make sure that all the factors are revised?

- Improve: Applying the techniques like as a design experiments based on the data analysis to optimize the procedures.
- Control: They provide a way to correct deviations from the target before defects appeared.

Process is to create a transition to a production process capability, and put control mechanisms and develop a system for continuous monitoring.

The following sections can be applied at each step of the process Description Six Sigma steps (Kahn, 2006).

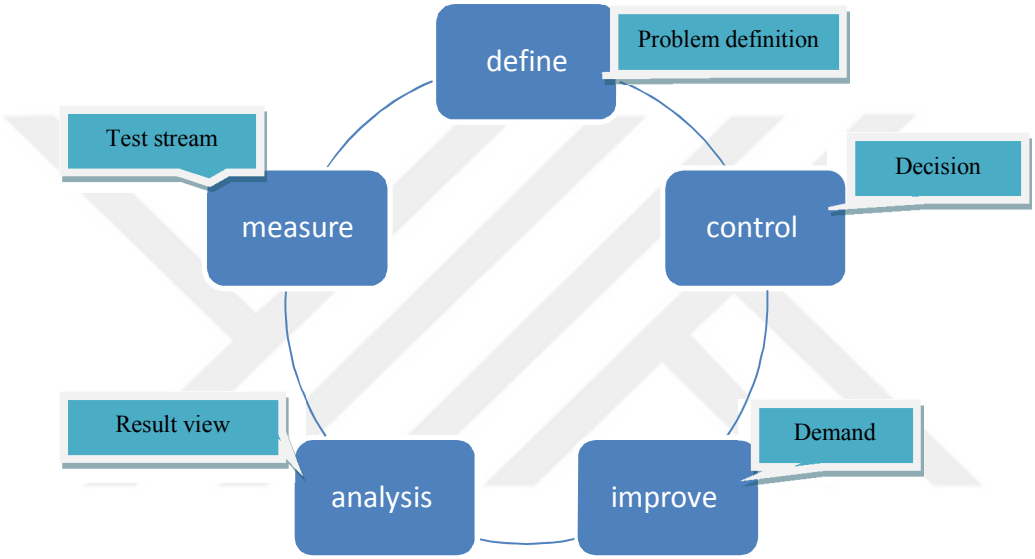

Figure 4.1 Basic DMAIC phases

4.1.1. Define:

This step is aim to determine the definition of main pain in the organization. And they may include:

- The high outage ratio
- Down the necessary equipment
- Frequent defects
- The ongoing work of the staff for extra hours
- The need of spare parts
- Unnecessary works

To move to define the design process and it is important to define the basic issues to decision.

It is applicable tools include: the quality requirements, diagrams, road maps, input and output sources.

4.1.2. Measure

This step is aim to a measure of collect information and data about the current status. Identification is of information sources and information gathering methods. This includes the dating through deposition and bases of existing procedures and equipment. DMIAC are available to measure the following steps:

- Data gathering methods
- Analysis measurement method
- Control schedules
- Operation schedule

4.1.3. Analyze

The purpose of this step is to determine the reason of troubles. The information gathered in the Measure step is analyzed in extensively, source and impact relationships are searched, and defeat reasons and results are estimated. Applications utilized to analysis the information are:

- Reason and result charts
- Pareto chart
- Faults tree analysis
- Expertise and experience

4.1.4. Improve

Through this step, make appropriate proposals to resolve the problems and devise a strategy to develop them for approval by officials and funding. In any case, solutions must be suitable in terms of appropriate cost (keeping in mind the resources and adjusted a time to finish the work). Applications utilized to analysis the information are:

- Benchmark
- Decision-making chain
- Brainstorm

4.1.5. Control

The goal from this step being implemented to ensure that maintenance projects to develop an active surveillance, the expected earnings will be found, and continue ongoing work for lasting development

Applications utilized to analysis the information are:

- Confirm directions and differences
- Supervision the key performance indicator (KPI)

- The implantation of the continued improvement program. Need to control parameters using a continuously operating Measure step graphical monitoring fees and criteria used in graphics.

4.2. Lean Maintenance

The searchers defined the Lean maintenance as " proactive process utilize planned and add up maintenance actions when total productive maintenance (TPM) practices applied maintenance policies advanced meanwhile the application of Reliability Centered Maintenance (RCM) logical thinking and expert by authorized (self-directed) work groups utilizing the 5S procedures, Kaizen periodically improvement cases, maintenance teams - complete maintenance by the tied by utilize of their requests system and their computerized management maintenance systems (CMMS). And lean maintenance depending on its classification to (operation, maintenance, and repair), the depot supplied the spare parts in the limit time, analysis of the root causes of the failure (RCFA) by maintenance engineers to support and increase the reliability, Partial failure analysis, analysis the maintenance processes activity, Measuring trends in the case of immediate maintenance" (Peters, 2006).

From the above define; the Lean maintenance type depends on the factors below:

- Proactive maintenance
- Autonomous maintenance
- Scheduled maintenance
- Productive capacity maintenance
- Delegating maintenance teams
- Computerized management maintenance systems
- Five (S) procedure translated from Japanese (sort, straighten, scrub, standardize, and sustain).
- Kaizen cycle
- Maintenance staff is an experienced and highly skilled
- Effective requests management
- Flexible storage system (to supply the spare part in necessary time)
- Maintenance Engineering teams to measure the reliability

Lean key principles:

- Decreasing the waste
- Maintain the continuity of resources

- Increase customers' confidence
- Enterprise development value
- Professional management
- Granting moral reward outstanding employees
- Optimal use of the equipment
- Measuring systems (lean execution)
- Easy and rapid communication within enterprises
- Raising the scientific level of the workers and to support development courses

Tools:

- 5 (s) steps

- Sort (Elimination of additional operations)
- Straighten
- Scrub
- Standardize (Previous steps)
- sustained (Expansion of operations)

- Painful Wastes

- Raising production before ordering.
- Loss of time due to the wait
- Extra steps to move products
- Not to use appropriate and modern equipment
- The accumulation of material in the stores
- Wasting time due to find schemes and maintenance tools and spare parts
- Manufacturing errors (infamous piece)

- Unified workflow (times of work, action range)

Lean maintenance is essentially accuracy and decreased necessity for maintenance problem-solving and rehabilitation (Kanda ve ark., 2000). Lean maintenance is working on survey the causes that lead to the suspension of equipment and not just the normal maintenance. Maintenance teams can start Lean Maintenance through automation, electrics, hydraulics and intelligent control systems from the actual reasons of failures, and Interruptions resulting from aging illustrated above. Electrical circuit failure, hydraulic valves failure and other failures not just the symptoms, there is the underlying cause of unscheduled equipment shutdown.

From this we will get the:

- Higher earnings ratio
- Uptime approaching 100%
- Low cost of maintenance significantly
- Reduced reliance on external support

High Readiness, income, Profitability, we can take from Lean maintenance applied (Kanda ve ark., 2000) .

4.3. Reliability Centered Maintenance (RCM)

Reliability centered maintenance (RCM) presence of any company is a process that determines what should be done to ensure that we continue to work as required in the situation of the current activities (Moubray, 1997).

There is much difference and branches of the old RCM practiced now, its purpose to overcome the mistakes and overcome them by facilitating the failure modes and effects analysis (FMEA) and find solutions that fit to work. RCM method treats with several major problems not treats with by another maintenance types. These facilities admit that all the equipments for plant safety procedures or have not had same prominence. It admits that the multi-use equipment design during operation is exposed to factors of collapse more than the rest of the other equipment (Moubray, 1997). For put integrated maintenance plan for any station or a manufacturing facility should know that these facilities do not have open budget for equipment and staff, and must be define the priorities to be carried out and to ensure that our facilities operate optimally. More concise image and clarify, RCM is a way through which you can manage equipment of industrial plants and resources that we get in order to reach a high degree of reliability at the lowest possible cost. RCM depends largely on predictive maintenance; add to that we must leave the maintenance of equipment that does not directly affect the reliability of the facilities left to a reactive maintenance practice. RCM approach to sustained high performance echo maintenance program allows all maintenance work to be dominated by the following estimation methodology crashes to take advantage of the current approach (Moubray, 1997).

- 50% to 60% PdM.
- 20% to 30% PM.
- 30% to 10% RM.

For this reason, the application of RCM methodology and the use of modern scientific methods for predictive maintenance and utilization, A reflection of the benefits and abuses of RCM on predictive maintenance programs. One such benefit is RCM permit the industrial facilities continuing work to increase the reliability and the lowest possible costs (Sullivan ve ark., 2004).

The main factors of RCM procedures containing:

- Preparation of studies and statistics about the system used, materials and investments in order to take optimal decisions which is in the interest of beneficiaries.
- Give clear and precise picture of the performance criteria for the beneficiaries in terms of production capacity and the speed of work and the quality of the product.
- As appropriate that the RCM operations determine the desire of the beneficiaries and their needs in terms of Business risks, and the safety of workers, and potential impacts on the environment, and how to control the rate of production, control equipment, and other similar actions.
- Identify the challenges faced by the system and that leads it to failure and discovers the types of faults and the result from these faults.
- Follow failure modes and effects analysis FMEA way to find the reasons that lead to the occurrence of faults.
- Setting process for the management of the reasons for the failure of the plan through the study results available techniques.

Methodological steps to manage failure:

- Determine the cause of failure
- Re-design of the system and organization in a new path
- Modulation the style work management
- Predictive and Preventive maintenance

The RCM methodology as it has advantages also has disadvantages

Advantage:

- It can be considered one of the most active methods in maintenance
- Reduce maintenance costs by avoiding non-required maintenance
- Reduce maintenance ratio times
- Decreases the proportion of unexpected stops in equipments
- Directing the maintenance activities on key equipment and influential

- High reliability at work
- Work on the root cause analysis of problems

Disadvantages:

- Require to run a high cost for the preparation of the studies, the staff, and necessary devices
-

RCM is working to raise the efficiency of maintenance operations that take place on a regular basis and the result is reflected on all the events within the system. Designing an active maintenance agenda through the RCM and to improve maintenance operations and we can of advanced preparation of equipment when they are in the process of maintenance, and prepare the necessary studies and timings (Moubray, 1997).

5. BENCHMARK

5.1. Benchmark Definition:

There are lots of definitions of the benchmark, all of these definitions revolve around the study of cases, and the formation of a common database, And through them to find the best ways to improve the work of the stations and companies (Figure 5.1).

In a more simple, benchmark is benefit from the experiences and past mistakes in order to improve, or the sense clearer and more detailed benchmark mean continuous and systematic work to find ways and applications that reach the work of industrial facilities to the ideal stage (Spendolini, 1992). The benchmark can be described as identify, understand and develop the work, production and maintenance of equipment, customer services to improve the working methods of industrial facilities in accordance with specific methodology (Harrington ve Harrington, 1996).

Benefits that we get from the benchmark:

- The continuous development of work and regulation
- Take advantage of the successful people in the industrial fields
- Find the level of performance of the institution
- Management the speed and momentum of work
- Identifying violations occurring in the system, and evaluate the results of performance
- Raise customer confidence
- Improvement on the commercialization level

Benchmark provides us with the following indices:

- Full knowledge to work policy and system. To make sure that the health of the work we are doing compared to the results (the speed of decision-making, efficient maintenance, staff experience).
- Study areas of active modification. And is a comparison of the industrial facilities to identify good performance.

Benchmark is the benefiting policy from the experiences of other facilities, and tries to apply the most successful ones on our facilities, and to avoid mistakes occurring.

It includes continuous work and precise, to measurement and comparison and analysis of the policy work in various industrial facilities in order to find ways for our arrival to the exemplary work.

The benchmark should not be just a theoretical study, But it must be applied and draw conclusions from them. The benchmark is not just tables and figures are made to

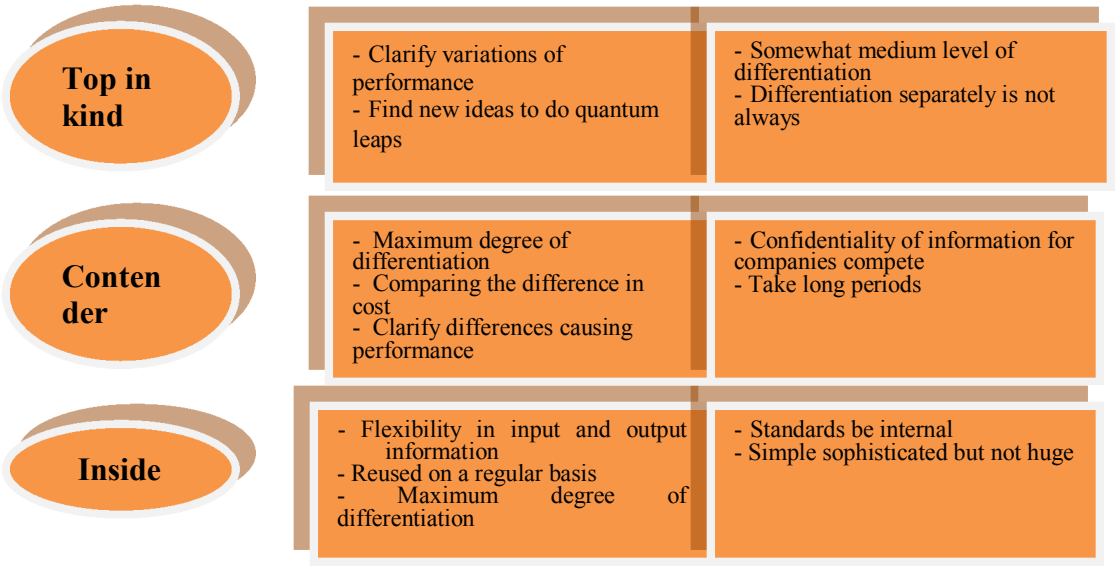

Figure 5.1 Tactics to benchmark (Kahn, 2006)

Measure the success of the facility; the benchmark must work continuously to detect errors and irregularities in the system. The benchmark is to set goals and meet the challenges and obstacles, and to help find solutions and conditions to reach the goals perfectly. In order to understand the benchmark well and describe what they are, it is important to understand the mechanism of action and the benchmark methodology (Watson, 2008).

Table 5.1 Illustrates contained and is not contained in benchmark

Benchmarking contain:	**Benchmarking not contain:**
detection procedure	Not prepare a rigid process
refinement approach	Cannot address all the problems
New Source Specific mutations	Backing ongoing during work
Extensive knowledge of the quality of work	Fashion administration, (a gadget of the work)
Scientific analysis of the action steps	On a personal basis, (Mental speculation) or judgment
Learning from past experiences	A tool to measure performance
Generate constructive and unconventional ideas	just a process of comparing quantities
Learning through practical experience	Do not stop on the opponent analysis

5.1.1. Benchmark types

We can divide benchmark into various types when doing benchmark for the industrial facility (Wireman, 2004):

- Interior
- optimum pursuit
- Competitively , analogous business

Interior:

Various businesses in the departments of industrial facilities and within its borders it is called interior benchmark. This method is characterized by easy access to the required

data and information, allowing us to easily make comparisons in order to clarity of vision at the facility and concerted efforts (the desire of the administration to the success of the work, Staff cooperation to the similarity of vision, Ease of movement, and past experience resulting from working for the same facility).

These factors help us to do the comparison hold quickly and easily. But from the other hand, one of the defects of an interior comparison cannot lead to the desired improvement. With this, we get small additional improvements by irreplaceable interior benchmark application because it provides a percentage of the revenue with the rest of the application with other improvements. To get good results from the application of Interior comparison will encourage facilities to apply exterior benchmark (Wireman, 2005).

Competitively, analogous business:

This type of benchmark depends on other industrial facilities (competition) with similar products. In other projects opponents used this benchmark type. The openness of companies helps to share information with others to facilitate this type of benchmark, but there are companies that do not allow the knowledge of industrial secrets. But the concentrate is on the administrative organization of the work of benchmark with other facilities competition. Most often is the study of the numerical criterion instead of a specific process improvement in this type of benchmark. We will find more incremental improvements to competitor's facilities that have similar programs in competitively benchmark. As a result the rate of improvement will be Not quickly somewhat.

Optimum pursuit:

The Optimum pursuit aimed to seek at finding the main way to make the optimal benchmark process. Dealing with this method, a comprehensive study of the various industrial sectors, geographical variation, and to develop strategies operandi and find opportunities to improve performance. The facility studies operations conducted by other industrial facilities, and took them superior experiences and apply them to their systems will lead to a high jump in the entity's business systems compared with opponents companies (Higgins ve ark., 2002). The adoption is of these practices whenever they are early, the greater the profits of the facility and increased its deployment opportunities in markets. Success in determining the best applied is the most important factors to success, and this preference comes from (Higgins ve ark., 2002):

- The highest efficiency at work

- Higher profit ratio
- The proportion of the provision of services to users
- Reducing the proportion of the cost

Must have information when searching for the best practice we will find many successful practices of companies. There is no integrated facility because all the installations have the force points and defect points. So, things that requires improvement by the benchmark in facilities that differ due to differing of policy and the nature of the facility. Therefore, to ensure the comparison process and get the best results, the facility should be gathers all the information about the nature of work and the preparation of a comprehensive Methodology study. After the application of different types of benchmark on facility systems, Study results and the percentage of improvement each way will we set the most appropriate method to continued focus on this method and ensure continuous improvement. The determination of the appropriate method for benchmark will help us to achieve a high percentage of profits. The most significant thing that you add us to identify the best method possible to achieve huge cognitive mutation that leads to increased competitiveness shares of facility (Wireman, 2005).

5.2. Procedures of Benchmark

In general there are four steps from which to coating the optimization processes (management and performance) this steps is a Plan-Do-Check-Act (PDCA) or it is known Deming Cycle (Watson, 2008). We can through Figure 5.2 see PDCA methodology by benchmark operations.

In order to avoid the large expansion in benchmark operations, and for a great focus on maintenance management in steam power plants. We will discuss the PDCA steps that we follow to make benchmark.

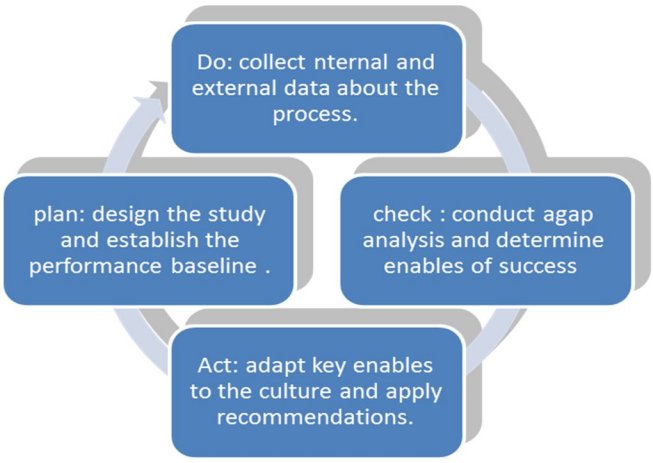

Figure 5.2 Procedures of deming cycle

According to (Richard ve ark., 2000): In order to search the comparison between the two applications similar in terms of excellence and style, we have seven ways to the benchmark procedures. The combination of interior benchmark process (in our facility) and external benchmark to similar facility has credible and reliability, this will give us the desired results according to standards set for benchmark. The main purpose of a comparison is to find the best application can take advantage of it in further improving the regulatory framework, and not only to calculate the production difference between the two facilities.

1. Determination the topic: selecting main factors of maintenance performance signals in order to benchmark required.
2. Project search: determine the facility and the methods of information gathering.
3. Information gathering: go to the facility and meeting with employees.
4. Information study: Study and analyze the information to assess the performance variables during the given period.
5. Discuss results: Find the results and put it in statistical formulas for ease of comparison.
6. Adjust enforcement: set final reports for the effective practices in order to train workers in the maintenance and application it.
7. The performance improving: Start working on the plan to improve the performance of the facility.

The 1st.stage: Determine the benchmark practice and the development of plans

The main stage is to begin the procedures of benchmark. So we must accurately identify the elements of performance to get the best benchmark. The determination of the

elements of performance helps us to know the loopholes in the current system, and to know the distance to reach the goal, and give us an references of the stages of a work in progress to treat the loopholes.

The main performance factors in maintenance could be classified as follows:

- basic data
  - The facility and employees data
  - The cost of employee's development
  - Technical data for the facility
  - Daily operational data for sections
- Performance administration maintenance
  - Requests administration
  - Breakdown administration
  - Stockpiling administration
- The procedures of maintenance
  - Actual maintenance works
  - Support activities for maintenance
- accident information
  - Directly accidents at work
  - Accidents on the long-term

The 2nd.stage: finding the partners, gathering the information, and set the solutions

In order to choose the right contender for benchmark a facility should follow the following steps:

- Initiate to adopt preliminary targets
- Develop the necessary standards for the work of the Joint benchmarking with the competitor
- Identify good practices at our facility, and best practices in the facility contender.
- In order to determine the possible competitors in the benchmark process are placed parallel study

This is the stage on a high level of magnitude, which is determined the higher grade between competitors by collecting the required information and data. Things that are being studied at this stage, to determine the quantity and quality of data, the departments covered by the study, trends of projects.

Confidence and arrangement make the process of information gathering easy. For sober and highly credible database configuration make forms an easy dictation and comprehensive.

There are many sources for the preparation of the database at the moment.

Including what can be reached through the Internet or through scientific journals and specialist books.

By going to the facilities and make is a questionnaire or by the direct interview with the specialists.

If we collect new data through surveys and developed research work at our facility, we must have this information be classified according to the type of confidentiality, and decide on the share information with competitors when doing the benchmark (Bhutta ve Huq, 1999). When working on a benchmark study, the Task Force of benchmark to gather information in various ways. The team following several methods to collect the data and find out times of use, as it must explain the positive and negative characteristics of each method as shown in Table (5.2) and Table (5.3).

Table 5.2 Information gathering form (1)

Method	Checklist information	The Questionnaires	Collected by communication
Illustrate	Study and analysis available information of maintenance	Information that has been shared with competitors, which include the problems and solutions, modern methods for maintenance and other	The forms that have been adopted to obtain the required information.
Application time	Relying on the previous information for the preparation of the new work plan	When there are multiple sources for data collection	When there is not enough time to collect the data from the expected sources
features	The sources give us a huge amount of data.	Ease of data collection and increase it with the passage of time and the possibility of analyzing through use of special maintenance programs	The largest number of participants, not knowing the identity helps to give opinions more clearly
abuses	Data classification and determine their significance requires a long time.	Cooperation is a small, random answer because of the different culture of the participants	The employment of persons competent to collect data and to deal with subscribers

Table 5.3 Information gathering form (2)

Method	Checklist information	The Questionnaires	Collected by communication
Illustrate	Direct congress with competitors and examine the stomach issues between the parties.	Preparation of study sessions among the members of the benchmark groups of the Competitors.	Visit headquarters and departments of the competition company's in order to see the business and how to manage.
Application time	When it comes to study each step separately and make sure and store information electronically.	Differing views or the presence of more than one source of information.	When follow-up the workflow must take into account social factors.
features	Giving confidence to others and accept different opinions and	High flexibility to share information and easily conduct mutual meetings	The ability to conduct of business in the system control

	encourage them to express their views we will get excellent data.	between the two teams to study the good procedures by specific dates.	(verification, measurement).
abuses	Wasting time and not respond well when you talk about important details.	Management of major things, at least minimally workflow requirements.	Preparation and planning properly.

There are a lot of methods for information gathering. In addition, the benchmark work team is responsible for determining the methods used to gather information, taking into account the coverage of all steps of research, as well as other important operations, like the quality of the information collected, the investment required, the time required to gather information, the proportion of evolution. The questionnaires are previous information, and on-site examinations, more than the methods used in the conduct of research studies to benchmark. Some of methods illustrated in Fig (5.3) (Castillo, 2014).

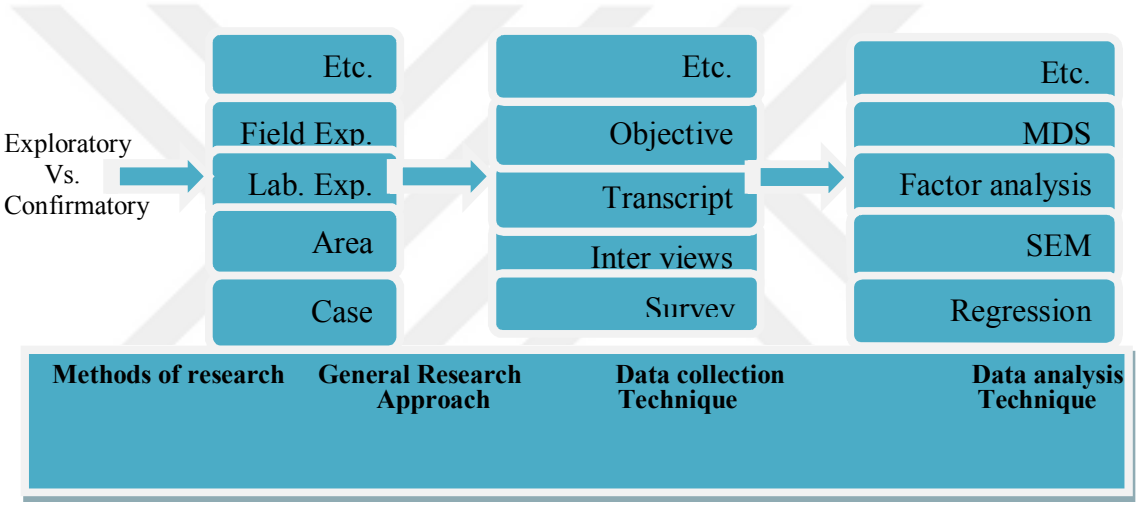

Fig 5.3 Methods of research methodologies

The 3rd.stage: benchmark procedures and analytical performance

We can complete this stage through:

- Setting the general formulas for data
- Data comparison for each practice with the corresponding practices in the company's competition
- Studying the collected data that and analyze it
- classification all the information

Upon completion of the data gathering and classification, we begin the next phase of information dissection.

Data is analyzed through the following processes:

- Ensure the validity of data
- Classified information

- Determine deviations and errors during data collection
- Get rid of random data (it is not work-related)
- Deduced the results

Order to optimize and easier the use of information when you need it, It is developed and classified according to sections and equipment known at the facility to use in planning for maintenance work. Discern information from the progress of the new performance compared to past performance. To make is the information more accessible and helpful, setting in the form of illustrative curves. The diagnosis and documentation of errors and delays in the work and distractions help us to rectify the mistakes in the early, And save a lot of time and money.

The 4th.Stage: Start by applying the results of studies on the ground to confirm performance

Work start: Experiences learned from competitors, and the results of the studies analyzed, and recommendations made for the development of the entity's business, and action procedures. After the completion of the development his information of management maintenance, and find the advantages and disadvantages in the maintenance practices followed in industrial facility. It is compared with the advanced global facilities. For their flaws are exceeded, the benefit from is the expertise of the major facilities in the method of processing. At this stage, after the completion of the necessary preparations are determined the type of benchmark to develop facility. These phases contain the providing of records and tips, and preparing simple brochures to explain the business plan for employees. The preparation of the final statement: the main objective of the process of benchmark.

- This statement contains: the results and analysis for the information gathered enhanced graphics. The benchmark trends in the processes (positive or negative) and the related recommendations.
- Post the results with the maintenance team and administration departments
- The demand from the benchmark team to present the benchmark results at the staff in the facility in order to encourage them to increase adherence to plans by watching the actual results.

Determine the processes that have been developed: This phase describes the success rate of the facility in the implementation of its plans.

5.3. Rendering Pattern of Maintenance and the Factors of Rendering Applied in Benchmark

In order to benchmark the performance of industrial installations internally or externally (with similar facilities) have been the work of benchmark standards. These standards contain the technical specifications of the production units, the production of each unit individually rate, stopping rate. Applied are the mathematical equations to conduct accounts their own performance factors. These standards give us extra space to use the mathematical equations in order to apply on the information available to calculate the performance factors of the steam power stations. In order to insert the data and analysis is used MATLAB program. To development the standards we will work to setting the using terminology as existing annexes (Appendix 1) in the information gathering.

We will examine a range of performance factors:

5.3.1. The level of production

A lot of studies that done on maintenance in the production of electricity stations found, the measurement of the rate of production level is snapped all the factors that go into maintenance work (spare parts, wages of technicians, maintenance and inspection equipments).

All the maintenance expenses are divided on the unit production rate (MW).

$$\boldsymbol{AEMC} = \frac{\sum_{\mathbf{N=1}}^{\mathbf{n}}(\mathbf{TPMC-TPCC-TTSC-TCCR})}{\mathbf{number\ of\ years}} \quad (1)$$

Where

AEMC = average equipment maintenance cost

TPMC = total plant maintenance cost for every year

TPCC = total pollution control cost for every year

TTSC = total technical support cost for every year

TCCR = total cost for catastrophe and rehabilitation for every year

N = Number of years

The rate of productivity maintenance can be found through: the rate cost of equipment maintenance divided by the cost of the equipment at the inauguration.

$$\boldsymbol{x} = \frac{\mathbf{AEMC}}{\mathbf{Installed\ Capaciy}} \quad (2)$$

5.3.2. The reliability in the thermal power plants

Steam power station cannot continue to operate on an ongoing basis, so as to occurrence of interruptions due to faults or to make periodic maintenance. The sudden

stops, and is not included in the maintenance plan that are causing the biggest losses. The reliability major factors in steam power stations are:

- Sudden stops or force outage rate (FOR)
- equal force outage ratio (EFOR)
- equal force outage rate demand (EFORd)

The most important factor in the operation of steam power station is reliability. Previous factors help us when it's needed to account in totality of the reliability:

$$FOR = \frac{\text{FOH}}{(\text{FOH}+\text{SH})} \times 100\% \quad (3)$$

FOH = Force outage hours

SH = Service hour

For calculating the value of (E FOR) we add a moderate influence on the value of the (FOR):

$$FOR = \frac{(\text{FOH}+\text{EFDH})}{(\text{FOH}+\text{SH}+\text{EFDH})} \times 100\% \quad (4)$$

EFDH = Equivalent forced de-rating hours

The average equal force outage ratio (AEFOR) is found in:

$$AEFOR = \frac{\sum_{N=1}^{n} \text{EFOR}\times\text{SH}}{\sum_{N=1}^{n} \text{SH}} \quad (5)$$

The factor of division the electricity produce rate in the steam power station during a given time on a production time is called available factor (AF). We can calculate (AF) in some partial cases in power station through this formula:

$$AF = \frac{\text{AH}}{\text{PH}} \times 100\% \quad (6)$$

AH = Total labor hours per unit or (availability of hour)

PH = the actual total labor hours per unit (periods of hour)

In addition to these mathematical equations there are further indications and mathematical equations to assess the maintenance work in the steam power stations see appendix (2).

5.4. Advantages and Defects in a Benchmark Applying

We can defined as benchmark the desire of the administration to change the way the department of Labor in industrial facility to more effective ways benefit from foreign experiences in other facilities (Watson, 2008). By observing the performance and recording of violations occurring in the system,

Will consist of our motivation is to correct the course of ongoing operations and to avoid violations in the system. We can see the advantage of benchmark through these limited practices:

- The desire to keep pace with progress in the competition facilities
- Finding violations occurring in the system and work to get rid of them
- mutual work with the rest of the facilities increases the chances of developing in our facility

It must be handled professionally with the benchmark process, the benchmark also contributes to the development of the thermal power station dramatically, and it is possible that affect the station's position if it is not dealt with in a decent. According to (Wireman, 2005), several cases of incorrect use of the comparative work:

- The belief that the benchmark is only a measure of the performance target, and work on the use of benchmark information to reach the targets only away from the rest of the fundamental objectives of the station, like as: a concentrate on reducing the financial disbursements in the maintenance work will adversely affect the rest of the targets that were set. You get the station on the many benefits when there is a joint collaboration with the competition company's and the high application of practices required to benchmark the performance standard. The evolution of the work concepts at the power station does not contribute to profits only, but shows the future visions of the performance level at the station. The fact that some industrial facilities to work on one side of the benchmark and leave work on other aspects will lead to disastrous changes for the facility, for example, focus on the administrative things in isolation from the technical things will lead to the collapse of the infrastructure of the facility.
- The application of the benchmark process before the completion of the necessary preparations for the success of the process (the collection of information for the completion of benchmark, the deployment of comparative culture, etc.). So the station must appoint a person based estimate is based on a combination of guesswork and Account. In order to get a full vision of the possibilities of the station and trends of progress of work, it must be information gathering and analysis process. Applied a benchmark before the completion of preparations will bring us back to the first point of action is an incorrect for benchmark.

And lead to an unbalanced work and failure of the benchmark in the practices of power station. The visit of the competition stations and sees the good benchmark practices; it should be accompanied by a full conception of the practices and study the possibility of its implementation in our station. The assured result for this work is a failure and abolition of the benchmark with the bear the losses incurred in the project.

- Mimicry: one of the incorrect processes in the action applied the successful practice of the benchmark process in a competition stations on our station without taking into account the differences located (administrative, technical, financial). So the defects will be great if this practice was implemented strictly. Differences include, different ways of working administration, quality technicians who are doing maintenance, the trade policy of the station, the strengths and weaknesses points.

Illicit benchmark, the station provider of concealing information from other stations or give them incomplete or incorrect information during direct meetings or through communications. This work leads to a lack of trust between the stations and the failure of the benchmark operations. And adversely affect the evolution of the performance level in stations. The gather information on competitors illegally, by using a questionnaire or by using the circuitous routes affects the future and credibility of benchmark operations.

6. BENCHMARK USING IN MAINTENANCE OF STEAM POWER STATIONS

6.1 Studying Case

In this chapter, we will choose the Baiji thermal power station in Iraq to apply the benchmark practices for measuring the performance of maintenance through five years.

6.1.1. Baiji power station

Baiji thermal power plant are owned and operated by the Iraqi Ministry of electricity (MOE).

NO. Of units = 6 units

The design capacity of unit = 220 MWH

The design capacity of station = 1320 MWH

The manufactured state = Italy

The company that erected station = GIE (Italy)

Boilers = Franco Tosi company (Italy)

Turbines and Generators = Ansaldo company (Italy)

Electric equipments = Magrini Galileo (Italy)

Control systems = Siemens company (Germany)

Station set up time = 1980-1983

Location = Salahuddin province/ Baiji city

The fuel types used = natural gas / heavy fuel oil / crude oil / diesel oil

Unit's connection with general grid date:

Unit one = September 1983

Unit two = December 1983

Unit three = March 1984

Unit four = March 1984

Unit five = August 1984

Unit six = November 1984

Fig 6.1 Baiji steam power station photo from the Degle river side

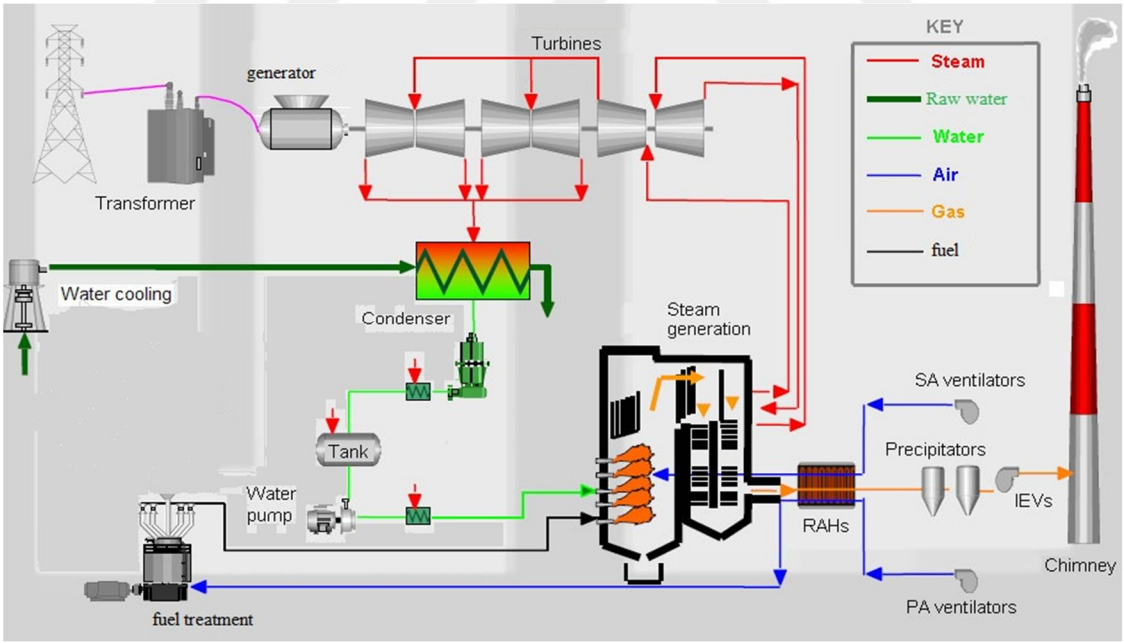

Figure 6.2 The general shape of Baiji steam power station

6.2. The Methods Are Used Through the Maintenance Department at Baiji Thermal Power Station

To develop the plan of work completely during the maintenance period, we must use several methods to manage maintenance; this is because relying on one method only

does not cover all maintenance programs. The choice of method of maintenance should not be random, but it is being studied enough and chooses the appropriate method of application, and there is no objection to the work of a combination of maintenance techniques to reach the best results (Using the six sigma methods and the lean method). In many of the maintenance work, are applied six Sigma stages and are then applied lean to finish the work in the best performance. As well as, the use of two methods are to complement each other, in the stages of overlapping at maintenance work.

In Baiji thermal power station applied to different types of maintenance management or the merger between them according as work requirements (Theodore, 2006).

6.2.1. Six-sigma method

We are in Baiji steam power station use a combination of methods (Lean Six Sigma) in order to confirm the work of plan for the specific departments through continued data collection and analysis.

This data will allow us to know the nature of work between departments and between staff themselves, as well as identification the special job for each department. These practices illustrate the best tactics to get the job done as soon as the best way. In steam power stations there are a lot of defects that can be solved when implementing Six Sigma (Theodore, 2006). For example of this repeated failures cases (emergency stopping, low water quality, high vibrations in turbine, High expenses in maintenance and decrease in the production, Non-compliance with the time limit for the completion of maintenance, A low professional competence for the teams of maintenance and operation). The Six Sigma process working to decreasing the purchase of spare parts through the decreasing the proportion of faults occurring by following a number of methods including

- Pareto chart,
- Failure analysis tree

This working is to determine the causes of failure and moving to treat it.

6.2.2. The lean method

In most cases, the stations do not abide by the application of lean in a complete shape. But is to resort to a quick implementation of measures, such as 5S or (waste) in order is to avoid imbalance in a certain stage in the process and within the plans. And to keep is the continuity of the work at the stations. But this does not mean leaving work in the lean method or it is not an effective method. The lean method selects the obstacles in correct maintenance that able to handling them (Muir, 2005).

The missing time due to: suspense for spare parts needed, and suspense for work orders, the end of the safety works in the maintenance site, the use of staff incompetent, lack of means of communication and transport it is one of the main reasons for waste in thermal power stations. we can take advantage of the lean method to determine the ways of work time loss allocated for maintenance , for example (time required for the arrival of the maintenance teams to the site, lack of necessary tools for the job or the lack of some maintenance materials). As well as the lean method used to reduce the expenditure on labor. Lean methodology aimed at getting rid of waste in the time wasted on maintenance without tangible output, and manpower surplus. Thus it will be spending cuts within this practice to reduce costs by a large margin. There are another use of lean method, is the site maintenance (work) management. 5 S is applied to all aspects associated with the maintenance process, such as maintenance workshops, warehouses, and various maintenance teams. So as to provide good conditions for workers at the station (Muir, 2005).

6.2.3. The reliability centered maintenance method (RCM)

RCM method is aims to follow a regular methodical procedure to provide sufficient time to make maintenance decisions, to resolve the multiple defects in the thermal power stations maintenance and distribution of expenditures and investments allocated for maintenance work. In another meaning, all the faults that occur in the equipment has not be in a same time or in same way, so it must not be treatment methods or evaluation process same. So here we are focusing on the causes and stages of faults. Through the passage of these mistakes in the series of work of RCM which are based in turn on the division of each error into four stages of decisions to get to properly decision through systematic and methodical work. When we have enough time to stopped in order to perform maintenance of the steam power station you can take advantage of RCM significantly. RCM is working to assess the basic necessities for a maintenance operation in the steam power station through studying of the FMEA and updating maintenance procedures used at the station. And work on connecting with the each maintenance operations with themselves. RCM is also working on the use of the:

- root cause analysis method,
- tree of fault analysis,
- and FMEA

To study and discover the causes of faults thereby reducing the proportion of forced shutdowns. Determine and resolve the problems of forced shutdowns will significantly minimize the losses resulting from these shutdowns (Theodore, 2006).

In general, if applied RCM properly in the power stations programs we will achieve many gains, for example, raising the efficiency of the equipment, the low cost of maintenance and operation, minimizing impacts on the ambience and raise the safety of staff. The comprehensiveness of the work in the RCM not only leads to increased reliability maintenance but it offers the potential for further modernization on the maintenance management (Moubray, 1997).

6.3. The Information Gathering

We will discuss in this part the methods used to gather information to carry out the benchmark. I would love to acknowledge the information that will be studied and analyzed for this benchmark returns for the period from 2009 to 2013.

As some of the maintenance data lost due to circumstances experienced Baiji steam power station in 2014, in a bid to compensate for the lost data will be assuming some values without affecting the credibility of the accounts. The information gathering methods will be through (Muir, 2005).

- Direct interviews with (1) the engineers and technicians working in maintenance programs. (2) Administrators and stores staff working in the maintenance programs.
- Questionnaires
- The old maintenance data

Stations that you archive data on a daily basis has made up a vast database, this is done by applying Dynamic Maintenance Management (DMM) method. The enormous amount of information in the station database and classified it to specialties and sections, facilitate the work of researchers who wish to study the part of search. One of the tasks of gathering information is to know the performance scale or key performance indicator (KPI) by collecting information to inform about the quantity and quality in the steam power stations. The use of modern scientific methods in gathering information helps to minimize random information as well as help to gather information accurately, for this the benchmark team must to attention to every piece of information exists and verified. By using flexible methodology to gather information and the scientific and fast deal with developments in a during the maintenance period it will contributes to the progress of the work.

The good knowledge of tools and understand how management to gather information

It helps to prepare preliminary reports for maintenance, which contributes to providing a clear view of the course of the maintenance process. In order to confirm the accuracy of the information, we will design a prototype using MATLAB software to incorporate data and taking them out in the form of graphs, and use it to make some graphs. Preparation of anniversary reports and shares them with the rest of the stations.

MATLAB program can also analyze images of equipment and finding the rate of deterioration in the mechanical and electrical parts, the detailed information for the station will help us identify the similar stations when there is a desire to hold external benchmark. The maximum use of the information collected give us the knowledge of the equipment state and thus the case of the station in general view. It is known that steam power stations differ from each other, as well as the method of data collection vary depending on the vision of team work (Waeyenbergh ve Pintelon, 2002).

The unification process of gathering information in the scope of maintenance works, contributes to the success of the benchmark process and benefit from the experiences of other stations. We will clarify some of the information models that must be collected on the maintenance team to conduct the benchmark, As in Appendix [2]. The use of modern software in the process of gathering information and documentation it, and work to develop them on an ongoing basis within the working team information administration. One of the most duties of gathering information team, make sure of the accuracy of the information and placed in the ranking database is easily accessible (Cigolini ve ark., 2009).

6.4. Analysis of Cost

Considered as the availability and reliability is one of the important success factors in steam power stations.

Keeping the station in a high level from the (availability and reliability) and the low level of expenses in the operation and maintenance works is contributes to the continuation of the life of this station. Most of the expenses in the steam power stations spent on maintenance works and staff salaries, add to it the cost of fuel used in the operation and its additives, and the cost of water treatment. Comprehensive maintenance work that requires the changing of the main parts in the station or Action needed expansions. For this require large expenditures (De Souza, 2012).

We will examine the maintenance expenses that consume dramatically investments provided to the power station. In order to calculate the total expense for the maintenance in the site accurately, it will neglect some of expenses such as safety expenses (pollution of the environment, the safety of staff) and technical consultancy expenses.

We can see in the table 6.1 some maintenance expenses and in the table 6.2 good performance practices.

Table 6.1 Maintenance expenses at benchmark power station (all expenses x 1000 ID)

The expenses type	Period				
	2009	2010	2011	2012	2013
Maintenance types expenses	268,000	220,000	242,000	391,000	547,000
Pollution removed expenses	7,000	1,000	3,000	7,000	15,000
Technical consultancy expenses	51,000	27,000	35,000	60,000	80,000
Catastrophes and repairs expenses	-	-	-	-	-
Equipment maintenance expenses	208,000	170,000	167,000	269,000	401,000

Table 6.2 Maintenance expenses for the good performing at power station (all expenses x 1000 ID)

The expenses type	Period				
	2009	2010	2011	2012	2013
Station maintenance expenses	146,000	146,000	149,000	166,500	399,000
Pollution removed expenses	-	-	-	-	-
Technical consultancy expenses	-	-	-	-	-
Catastrophes and repairs expenses	-	-	-	-	-
Equipment maintenance expenses	146,000	146,000	149,000	166,500	399,000

By studying the data in Table 6.1 and Table 6.2 we can see the maintenance expenses systems in the Baiji power station.

With taking into consideration the relatively ancient age of a station and lack of modernization of operational systems.

The results of the benchmark appear acceptable maintenance expenses to some extent. However, we must put the necessary action and procedures in order to larger reduce expenditure and raise the performance of the equipment. The rise efficiency is not always commensurate with the decline in expenses, because there are many elements that affect them one way or another.

For example: the operational life of the station, the financial conditions that occur on the station, nature of the area that a station built on it.

6.5. Level of the Productivity

We will neglect the additional expenditure values (Pollution removed expenses, Technical consultancy expenses, Catastrophes and repairs expenses) in the table 6.1 and

in table 6.2 to find the average synoptic expenditure of maintenance in the prescribed period for benchmark (5 years).

We will use the equation (1) to find the average yearly expenditure for the maintenance of equipments.

We will take the total maintenance expenses (material, technicians, spare parts etc.) in order to find the level of productivity in station systems maintenance. We will use the equation (2) by dividing the maintenance expense on the productivity of the electricity coming out of the station in (MW) like what exists in the table 6.3.

Table 6.3 level of productivity results

Description	Benchmarked power station	Best performer
Forced outage rate, FOR (%)	2.59	0.67
Equivalent forced outage rate, EFOR (%)	3.46	0.67
Average equivalent forced outage rate, AEFOR (%)	3.2	0.8
Availability factor, AF (%)	89.5	90.5

It is the result of interior benchmark in the Baiji steam power station well, and the level of productivity where conservative to some extent given the operational life.

6.6. The Reliability in Power Station

Key elements by which we can determine the reliability in the steam power stations are:

- forced outage rate (FOR)
- equivalent forced outage rate (EFOR)
- availability factor (AF)

We will use equations (3, 4, 5, 6) in the fourth unit to find a benchmark in power station through finding the elements (FOR), (EFOR), (AEFOR) for the specified time period (5 years). We can see the results in the table 6.4.

Table 6.4 Information of outage

	Benchmark of power station	Good performer
Maintenance productivity level	1,4	1,6

Through the table 6.4 we can see that the benchmark results acceptable to some extent with this, the forced outages require more work and studies to reach a ratio of less than the interruptions to the good performance.

We must not also forget the availability factor (AF), which is taken into account during the development of the general plan for station maintenance, which represents the yearly performance of the station. The availability factor of Baiji station 91, 58%.

6.7. The Operations Analysis in the Maintenance Management

The team of information gathering and archived within the used software they must distinguish between the each type's different maintenance (preventive, predictive, corrective, emergency or reactive).

It turned out from the overlap data there are not enough to distinguish between types. May be the reason due to the use of a blend of types of maintenance and overlap with some in the same location. The benchmark method is mainly working on predictive maintenance and the data collection and archiving process as a basic requirement for maintenance as shown in Table 6.5. Figure 6.2 illustrated the proportion of the maintenance types that have been studied during the benchmark period (5 years). Table 6.7 gives us further clarification about the percentage ratios of maintenance type's expenses in the power station.

Table 6.5 Maintenance types used by the benchmarked power plant

The proportion for each type of application maintenance (Appearance ratio in %)	**Period**				
	2009	**2010**	**2011**	**2012**	**2013**
The emergency maintenance type	13	15	15	16	20
The preventive maintenance type	33	31	31	32	30
The predictive maintenance type	40	40	40	40	40
The scheduled corrective maintenance type	14	14	14	12	10

Tale 6.6 The types of maintenance applied in the power station

the applied maintenance types	the good performance	The benchmark of power station
The emergency (EM)	14	13
The preventive (PM)	13	26
The predictive (PdM)	71	41
The scheduled corrective	2	20

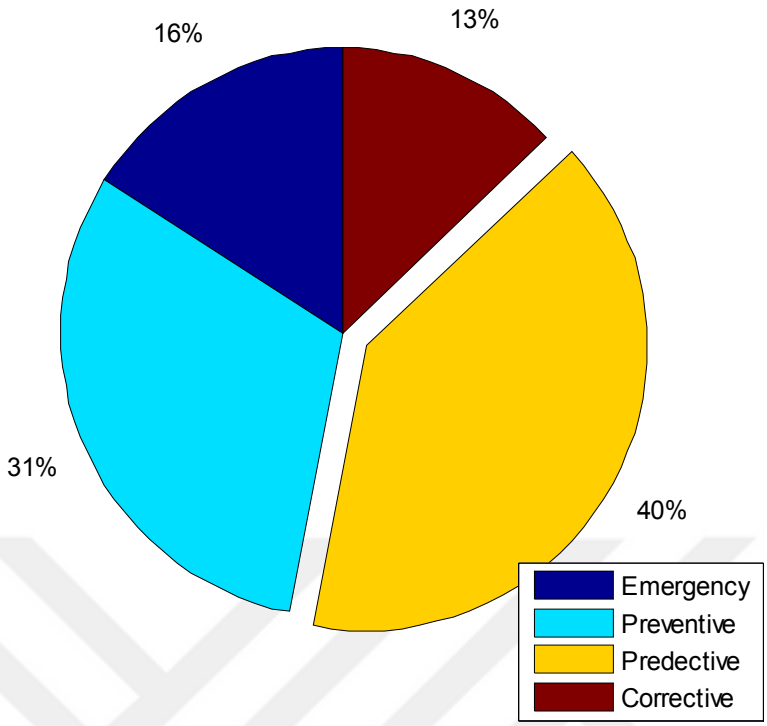

Figure 6.3 The benchmark period results for the maintenance types applied

In the Baiji steam power station and through the findings of the study period, the PdM maintenance and PM maintenance taking the largest share of the maintenance plan. The useing of RCM maintenance methodology is for blending between the working procedures in PM and PdM maintenance for the maintenance period in the station. As noted earlier, the benchmark policy in order to reach the best results in the power station using the blend between the maintenance practices. The increased concentrate on predictive maintenance and scheduled maintenance prolongs the life of the equipment and systems and thus increases the life of the power station. Also it reduces expenditures required in the case of the emergency maintenance.

The height of preventive maintenance ratio for more than 25% in benchmark at the work of station is the proportion is non-good.

In order to reduce the high proportion of these it should work planning department in the power station on the necessary policies for a tendency toward corrective maintenance mode without affecting the plant efficiency. One of these policies that raise the work of corrective maintenance, work to increase the fault detected and analysis of operational readings to know the decadence of the station equipments.

Table 6.7 Maintenance expenses as percentages ratio of each type in the station

The maintenance types in power station	Maintenance expenses as percentages ratio of each type in the station (1000000x ID)
The emergency (EM)	30,176
The preventive (PM)	61,776
The predictive (PdM)	99,272
The scheduled corrective	48,286

The Predictive maintenance is the favorite type in the power stations, because it has the required reliability while providing the flexibility to make adjustments to the plans and high cruise during a work and reducing maintenance time and increase the operating time.

We can increase the profits of the station and reduce maintenance expense through dependence on corrective and scheduled maintenance and reduce the ratio of urgent maintenance and preventive maintenance.

As well as the use of modern technology in the evaluation of the work of the equipment and monitored during operation or after the completion of maintenance work to ensure the reliability maintenance (thermal screening devices electrical and mechanical parts, balancing mechanical parts, safety measures at the site).

In Figure 6.4 we can see the apportionment of maintenance expenses in the power plant during benchmark application.

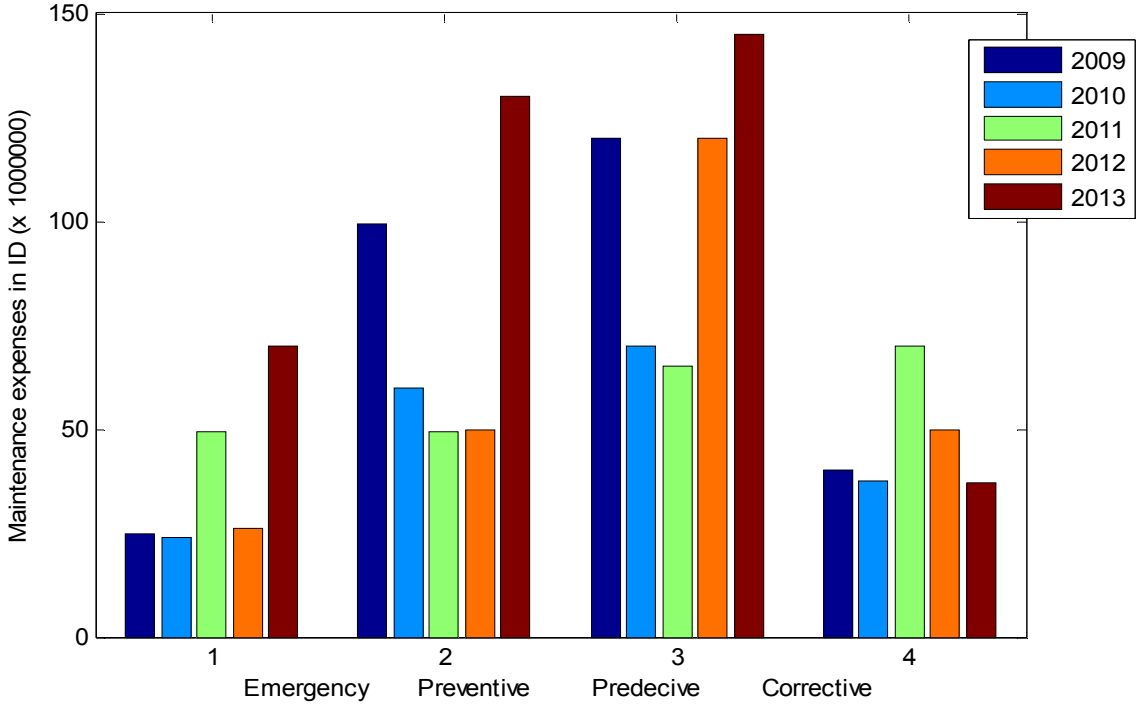

Figure 6.4 The apportionment of maintenance expenses in the power station during Benchmark application period

Predictive maintenance PdM gives high flexibility for the possibility of doing tests on the equipments during work and diagnoses weaknesses. This method requires in specially require the use of some techniques and test equipment for the surveillance equipment for the station systems during work and provide operational data for each device. And allowing the opportunity to address the imbalance in the site without the need to transfer the equipments to maintenance workshops and thus minimize expenses. Besides, the personnel expenses of the monitoring devices are less than the wages of technicians for the rest of the maintenance types in workshops. It is known that the use of modern technologies have high expenses, but the discovery of the deterioration of equipment and treatment early reduces expenses. Modern technologies allow us to know the defect inside the equipments without the need to disjoin them and time consuming or stop the station from work. For example, thermal imaging allows us to walls of the boiler detects the initial cracks, and knowledge of high current in one of the phases in the generator or motors. All maintenance expenses such as staff salaries, expenses of the maintenance requirements, and losses during the period of suspension must fall within the comparison between the types of accounts maintenance.

6.8. The Management of Power Failure or (Outage)

To enhance the competitive position the station in the energy production one of the important thing.

Steam power station depends on a number of main factors, such as the ideal use of resources, ideal planning and management for maintenance practices and rapid dealing with outages at the station.

Power failure or (outage) in the power station means:

The time required to re-connect the units of station with the national grid after its shutdowns. Rising efficiency in the execution of the station when for outage occurred.

It is one of the important factors in increasing the reliability of the station in the center rival and improves the production system in the grid. The time of outage must be added to the time needed by the units to re-connect to the national grid, for this should take into account the time of outage within the plans for the re-operation of the unit. The care is of reducing outage time and work to reconnect the unit to the grid.

It increases the efficiency and competitiveness of the station and reduces the losses from an outage.

So must prepare an effective action plan and the training of staff to ensure the working speed and safety of staff and equipment. The outage plans it must that includes

the maximum benefit from the time of outage, through the effective application of pre-drawn plans and in shortest time. The study and analysis of the causes of outage events through the available database gives us a clear vision for the development of appropriate action plan. The study of outage cases during the benchmark in Baiji Steam power station provides good value for the performance in the station. We can through Figure 6.5 and 6.6 to see the difference between the benchmark and equivalent forced outage rate (EFOR) at the station. Through studying the data we see an increase rate of interruptions for various reasons and thus increase the proportion of the (EFOR). On the other hand it shows us the figure 6.7 and 6.8, the reflection on the subject at forced outage rate (FOR). The planning for the outage in the steam power stations must begin before a sufficient period of their occurrence.

To prepare case study well and prepare action procedures and information required and determine the expenditures and the other logistics matters (spare parts, staff training, and schemes).

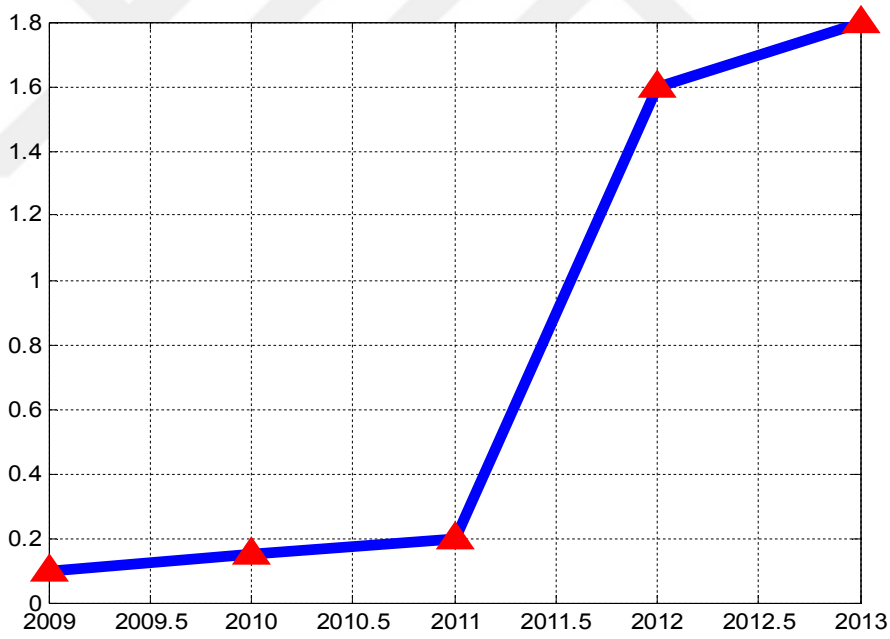

Figure 6.5 best performances in EFOR comparison

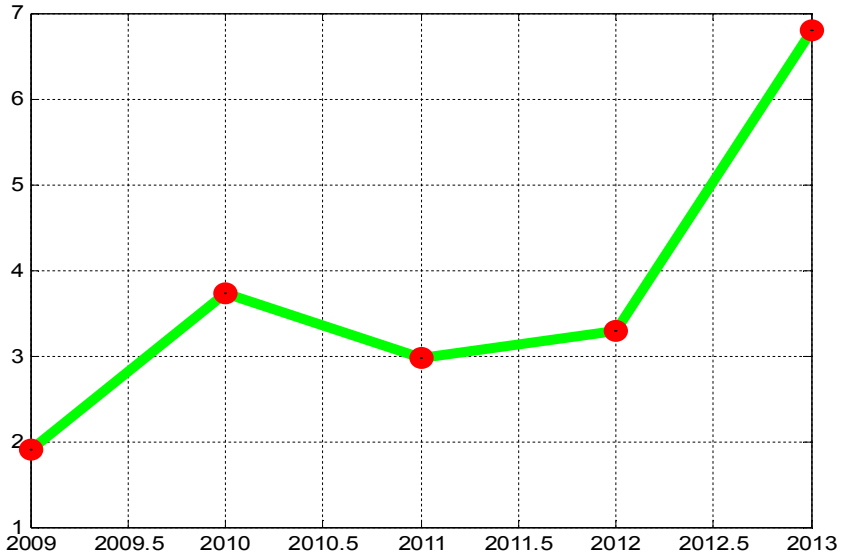

Figure 6.6 Commissioning considerations in EFOR comparison for the station

Each station its own plan to make the most of the outage period this plans includes all practices to be implemented during the period of outage and in detail. The preparing plans for outages presented to the chain of managers within the structure of the station for approval or amendment it.

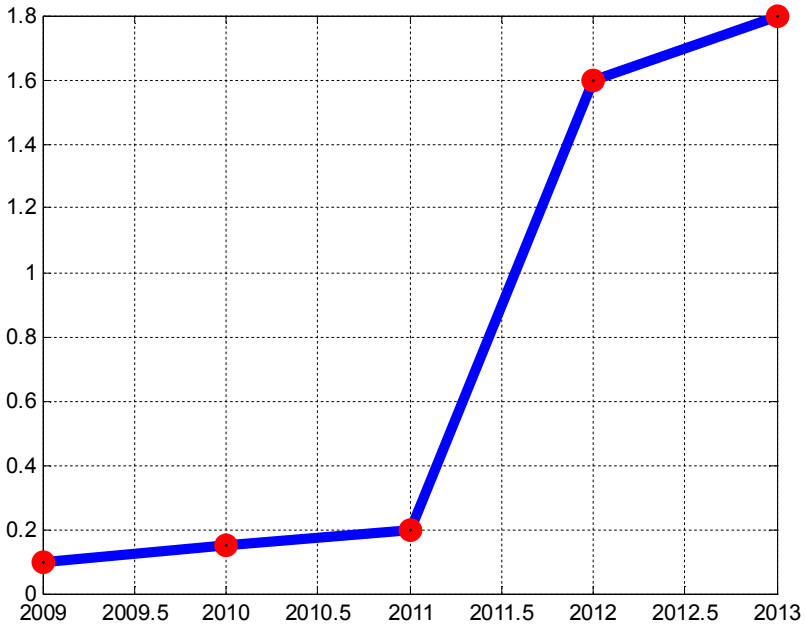

Figure 6.7 best performances in FOR comparison

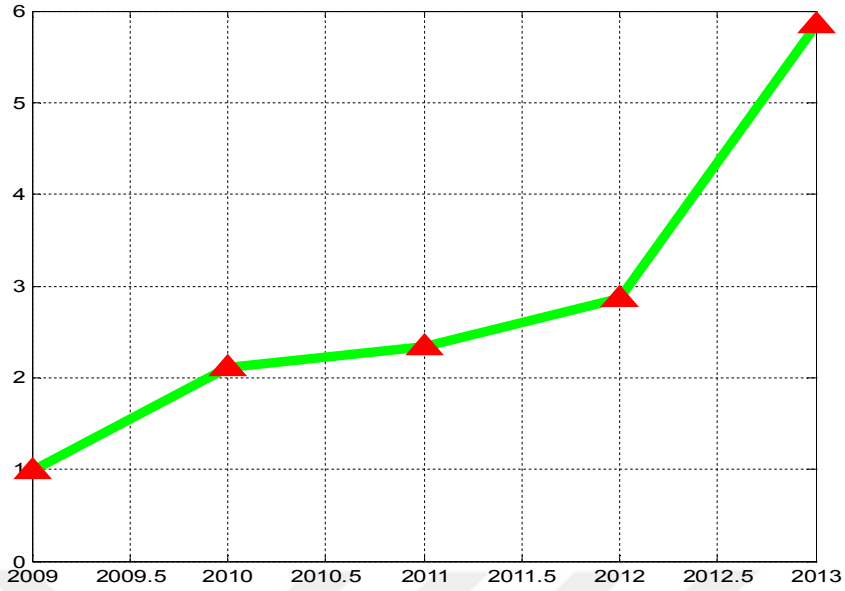

Figure 6.8 Commissioning consideration in FOR comparison for the station

These plans also include the tables of amounts and timing of works flows and distractions and expected challenges. Head of Planning department in the station is concerned for the preparation and submission of outages plans. And use the data received from all departments (electric Dep., mechanical Dep., control Dep., fuel treatment Dep., etc). The plan includes the main aims of the power station at the level of each section for a long period of time in the future to reduce outages.

The core matters that are highlighted in the period of outage:

- Methodology for continuous improvement in management
- Advanced programs for maintenance and testing
- Constant encouragement to employees at the station and urged them to do more
- Industrial safety and raise the level of culture among workers
- Staff training on modern methods for maintenance
- Measure the impact of outage on various fields

6.9. Administrative Structure of the Station

In figure 6.8 illustrating the administrative structural of departments that related to maintenance in the Baiji steam power station. Here we will study the administrative things for maintenance because of its significant impact on the course of actions before, during and after the maintenance. The exact approach of the administration in organizing the maintenance actions contribute significantly to provide stability and continuity for the maintenance processes in the station thus reducing mistakes and raise

the proportion of profits and increase the reliability of the station. As well as to ensure the achievement of the goals set by the maintenance officials and clarify the maintenance type that has been selected. And confirm the rules of maintenance management inside the station. This is the general operations in maintenance management in which common all industrial installations also there are some differences, which tracking the feature of facility and the method of officials thinking in which. The good administrative structure of the station provide a lot of a flexibility in dealing with different cases in maintenance and the granting of powers to the technicians in the maintenance site to make some decisions without reference to officials. This reinforces the confidence to work and increases the reliability of maintenance. The management structure in Baiji steam power station consists of an interconnected series of officials and this allows them to easily communicate and the effectively. Through dividing the staffs into specialized groups and these groups are receiving orders from officials and also give them the notes without delay. The supervision ratio in the station (1) official to (5) from the subordinates, and this percentage is considered very well. The easy organizational structure and smooth in the work of the industrial facilities and one of the most important steps the application of Lean. In addition, the work on continuous improvement within Maintenance departments and control the deviations on maintenance practices during the outage and accept change at the level of workers and officials to adhere to the setting plans. The accumulated experience Working on increased confidence in dealing with work contexts and assume technical and administrative responsibility as well as working to speed up the work and Clerks distractions during workflow. The officials in the station working on the development of the spirit of solidarity and cooperation among the members of the station and the planting of sacrifice and devotion and respect, these human values is working to increase production and continuous improvement in the performance of work and the desire to find the ideal solutions to problems.

There are some strategies procedures must be followed by the stations that wish success:

- put the future vision for the station and setting goals
- Select a task for each team carefully in order to avoid confusion and neglect
- Reduction of administrative routine and increase technical surveillance
- Rely on modern technology to reduce staff numbers

- Providing enough space for flexibility in the labor system
- Develop alternative plan to change the workflow pattern at the station when one of practices is failed.

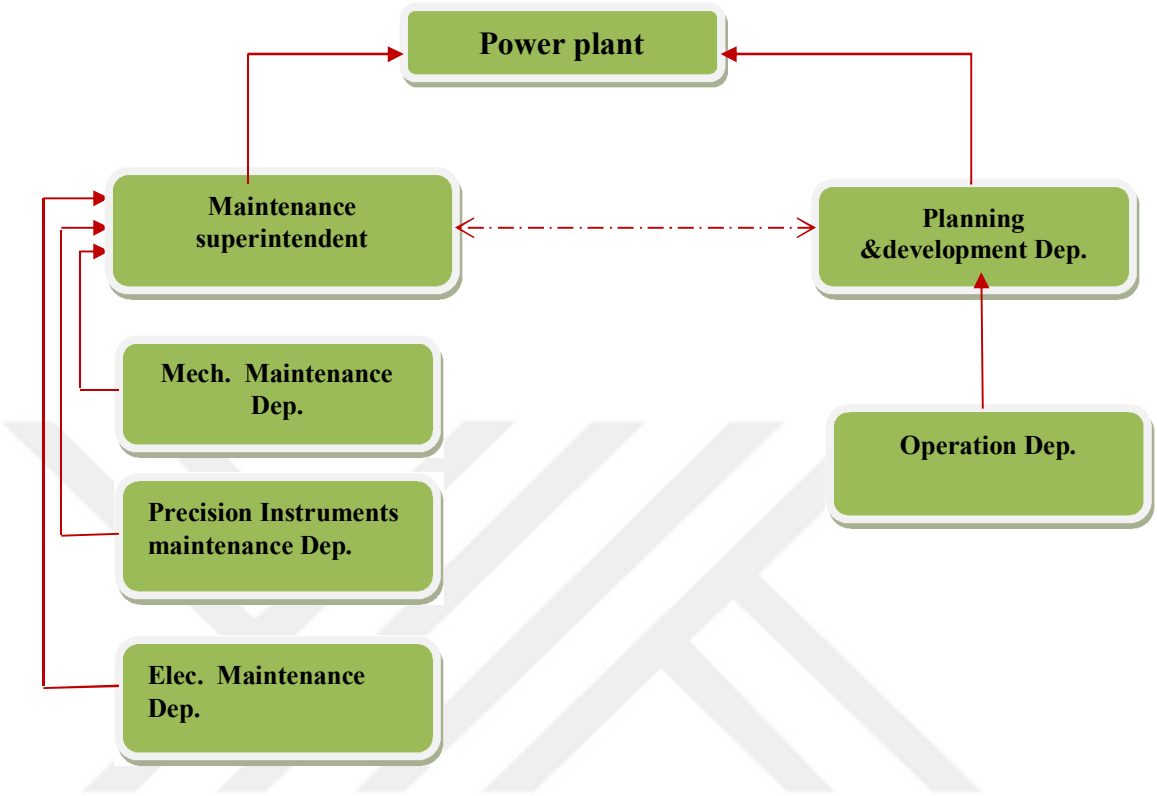

Figure 6.9 Administrative structure of Baiji power station

6.10. Manpower Administration

Various maintenance operations based on:

- The time required for the completion of maintenance
- The skill of the technical team who does maintenance
- The quality of maintenance that are made.

The maintenance operations required a high level of skill from people for the planning and execution correct and gain the time for the trade goals. Skilled technicians work to create the maintenance requirements and arrangement it, such as the necessary tools for maintenance, spare parts that will be used, the special schemes for all equipments. As well as to determine the proportion of maintenance that will be performed and analyzed information that taken from screening devices for each equipment and record all the actions that have been working during maintenance (This information is recorded can refer to it when you need it or share it with friendly companies for the development of skills).

In Baiji steam power station at the time of the benchmark, the number of employees who work in maintenance and permanently,

- Electric maintenance department 35 person , (Engineer + Technical)
- Mechanic maintenance department 60 person (engineer + Technical) including turbine section, boiler section, and pumps section , cooling fan section
- Precision instrument section (30) person (Engineer + Technical)
- Planning department (15) person (specialists of planning). In addition, there are operation department employees.

The strengthening of trust and appear flexibility to accept the views of employees will work to increase the station productivity.

Also, we can benefit of time in the training of technicians and increase their expertise in the use of modern methods of maintenance and ensure the reliability of maintenance.

We can also exploit times shift of employees in the operating department to raise the efficiency of the operators in dealing with equipment. The general knowledge of all the employees of the station to its system and the nature of its work contributed to the success of the work dramatically.

A continuous development of personal skills for employees works at public higher productivity at the station and thus sustains competition and achieves more profits. The real benefit from the increased staff skills it is to keep the station in the work for as long time as possible and reduce the number of outages. Follow the multi-skills training program for each employee is the real solution to get to the high technical level and assists in the achievement of the technical and administrative stability to the station.

6.10.1. The training and development

The training and development considered one of the important stages of the administering of maintenance, also the development of knowledge and training of maintenance employees is the basis for increasing the opportunities of success. We can take advantage of training in the development of (all the following paragraphs will benefit the station):

- Scientific culture for employees
- The skill required to do the work
- The use of modern software
- The application of safety procedures and reduce accidents

- The spirit of cooperation among the members of one team

It must be multi-level training program to cover the varying percentages of skills among the staff. The focus is on level of the new employees at general vision of the station, and the right way to run the equipments and proper handling with it and the safety procedure. Successful management is work to ensure that a high level of training for its employees. The industrial facilities that spend money on manpower development programs will benefit from them by increasing the profitability of the facility. When applying the benchmark in industrial facilities there must be an integrated program for training and developing, this program includes the administrators and technicians. Contributes the ongoing development in the perpetuation of the momentum within the facilities and maintain good performance rate. On the other hand, the development and training programs that take advantage of the information available to arriving the station to good levels of technical and administrative efficiency. The continued development programs and training of staff on setting plans to work during the period of outages. It is the best way to stimulate the manpower administration to show their capabilities and skills.

6.11 The Mechanism of Coordination and Management of Work Orders

The work orders or (requests) in industrial facilities is the first step for maintenance the officials open the work orders for certain equipment and locate the fault type or the type of maintenance required to conduct. Planning officials could benefit from the work orders in determining the quality of the tools and spare parts we need in maintenance, number of technicians needed to finish the work, technical information required (schedules), maintenance expenses, and the time required to get the job done. The work orders supply the direct and official contact between the operation department and departments of maintenance. In Baiji steam power station it is received work orders by the planning department and in the department turn entered into the database after categorized by types of maintenance (preventive, predictive, urgent, and corrective). Planning department includes on the DMM (Dynamic Maintenance Management) and it mean a section of the administration dynamic and the objective of the employees in the DMM to monitor the results of the quality of the work systems at the station. It is responsible for to, the introduction of work orders and documenting the operations that are made, and the time of achievement irrespective of department or work team. Work orders provides the ability to monitor expenses and maintenance work efficiency and the delay in the completion of maintenance work and

provide full information about the nature of the equipment and the reasons for the outages. So it must be recorded the life cycle of work orders from the beginning to open to the moment of close them with recording all the notes and side things during maintenance work. Where they are allocated a team to follow all maintenance activities through work orders system and compare it with the maintenance operation on-site. The table 6.8 shows management system or (life cycle) of the work orders during benchmark application. In simplified shape after the completion of the work order typing it is handed over to the planning department, which in turn distribute it to the competent maintenance department. After recording all the information related to it (number of employees, the time of completion, and the critical degree) and work second version and added to the daily report that is submitted to the direct manager. The designated employee is to determine the type of problem in the work order. An example of this when a vibration occur in the electric motor 380 volts will be shown the number of actual working hours of the engine and the cause of vibration (mechanical or electrical). And the statement of the availability of spare parts is in the stores, and coordination with the maintenance supervisor at the speed of completion of work. The coordination between the planned and stores about the availability of spare parts and its quantity and after confirmation of availability the request is sent to maintenance work. The previous procedures developed by those responsible for planning to overcome the problems that arise as a result of hasty action, or lack of necessary materials for maintenance. So should choose employees competent in the planning and maintenance management. The early planning and analysis of the taken information from the sensors and measuring devices help to form an accurate picture about the equipment is working and coordinating with the stores to provide backup material without shortages in times of need or accumulation in stores.

Table 6.8 Work order management

Work order system	Baiji power station
acceptance procedure of request	2
the sections received	3
maximum time of cycle life of monitor (hours)	15

6.12. Warehouse Management and Organize Inventory

The availability of spare parts in the stores is one of the basic pillars of any maintenance operation, with attention to the time when you start the maintenance operations. Pick a good quality of spare parts in maintenance operations. It is very essential in maintaining work continuity systems in the station during the period of

operation and the reduction of outages and also in maintenance that high reliability. In the stores management system, there is an urgent need for the use of the comprehensive and modern software, in order to boost the maintenance operations. When is the benchmark application in Beiji Steam Station the stores management by (DMM).

Where is it has control available stock of spare parts, and the organization of internal and external purchasing process. Also set the rules the material pull from the stores and inserting it.

This contributed significantly to the control of the spending process on maintenance operations. Add to it is determined how much and the type and age of the stored material.

Identify deficiencies in materials and initiate purchase procedures. And the materials are classified and arranged according to the nature each item. Materials should be stored in a readily accessible when urgent case.

Prepare tables of to illustrate the status of stored materials and qualities and in coordination with the planning department. Prepare things needed to store spare parts in the standard conditions.

Creating the right places for the storage materials has dangerous nature in use or that need to special treatment of storage. The creation is of a standard storage conditions and balancing in the amount of spare parts so that the materials are available for maintenance without accumulation. And accuracy of work in the administrative matters of the stores works to facilitate the completion of maintenance operations on time with high efficiency. Thereby is increasing productivity in the station. In most industrial facilities found that 40% of the remaining waste after maintenance work, is the residual of the spare parts waste material for the plant and the materials had been replaced. This leads us to implement CMMS program and to provide the appropriate conditions for its success. Sometimes in the stations become 15% of the expenditure of spare parts waste. For this reason it is necessary to apply a strict system of control over the backup material and waste reduction (Wireman, 2005).

6.13. Conclusions

The benchmark in power stations is modern tool to diagnostic for performance and operations management. Doing general studies for the management of industrial facilities. Compared to the successful procedures at the station itself or with a similar stations, and which contributes to raising the efficiency of performance and provide solutions to reach the best level of performance in the station. In addition, benchmark

allows to the station share the perfect results with the competition stations and the exchange of ideas and experiences. Build strong relationships based on trust and honesty with competitors to exchange information and conduct benchmark completely. Preparation of the final reports of the benchmark process and record the results. Through this study, and as a result of the search in applied the maintenance managements at the power stations, and after taking Baiji steam power station as a case of the study was to reach the following results:

- The benchmark is of great practical benefit if it planned is executed thoroughly and committed workers. We will get the results in the efficient performance and financial profit of ultra-fine. The station gives full transparency and clarity to follow the business in which the operation, knowing it's the benchmark not simple and should work with by specialists.
- Determine the methodology to gather information at the station. Information gathering and analysis is an important factor in determining the various maintenance activities trends, because it gives objective and scientific overview of the performance of the equipment at the station. Therefore, the comprehensive database of the station is one of the most important stages of the measurement.
- The benchmark application at the station. Helped to understand the mode of action in the management of the station and finding reasons for failure and the determinants of the development work. And thus put the necessary solutions to get rid of restrictions that delayed the completion of the work and raise the level of performance.
- The benchmark work to avoiding the performance difference between the departments are works in a same station, by creating a state of balance in work and diagnosing the causes of variation in department and reasons of late performance. Or between the station and the rest of the competition stations.
- The benchmark application should not be the main goal of the station, but the main goal is the continuous development process. And raise the performance efficiency and thereby reduce the expenses of the station with the best performance.

- The benchmark philosophies is based on the self-criticism and confesses mistakes and try to benefit from the experiences of others, and create an environment of fair competition.
- One of the characteristics of Benchmark they can work simultaneously in several directions and in parallel in order to raise the level of performance of the station.
- And having the flexibility to change during the course of work.

We cannot pretend that this study was a comprehensive and integrated in all respects. But we are tried to study all departments relating to maintenance, and that there is sufficient information to evaluate station. It is advisable to continuing to work for the development of benchmark existing work and adoption it in wider field.

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APPENDICES

APPENDIX1. The maintenance model in benchmark.

Information attributive	5 years information of benchmark in Baiji power station, BPS					5 years rate	5 years rate outcome from good Perform Power
	year 1	year 2	year 3	year 4	year 5		
The maintenance information							
SH, operation hours							
gross power outage loss,in (MWh)							
Forced outage in power losses,in (MWh)							
Outage power loss maintenance, in (MWh)							
Unscheduled power Outage powerhours, FOH							
Maintenance outage power hours, MOH							
The frequency of outage power							
The frequency of outages in maintenance							
Gross of operation hour							
Gross of maintenance hour							
Gross Operation & maintenance man hour							
Steam space man hour							
Capacity and power							
Gross of units work or consuming, in GWh							
total ultimate ability							
total reliable ability							
total realistic generation (GWh)							
Net ultimate ability							
Net reliable ability							
Power outages and information classified							
gross maintenance in power outage losses, MWh							
unscheduled power outage MWh							
Unsheduled power outage in hour							
scheduled power loss due to classified, MWh							
scheduled classified, Hours							
Forced (unscheduled) classified, in MWh							
Forced (unscheduled) classified in Hours							
Size of lowering							

Unexpected (time-based) performance indicators							
FOR (%)							
EFOR (%)							
EAF(%)							
AF (%)							
MOH							
EMOF							
SOF, scheduled Outage Factor							
WF, work factor							

Maintenance expenses

Information attributive	5 years information of benchmark in Baiji power station, BPS					5 years rate	5 years rate outcome from good Perform Power
	year 1	year 2	year 3	year 4	year 5		
Station maintenance expenses							
Pollution removed expenses							
Technical consultancy expenses							
Catastrophes and repairs expenses							
Equipment maintenance expenses							

Additional maintenance expenses

Information attributive	5 years information of benchmark in Baiji power station, BPS					5 years rate	5 years rate outcome from good Perform Power
Spare parts or the consumables expenses							
expenses of maintenance time deviation							
special apparatus and programs							
Labor expenses							
taxes types							

APPENDIX-2 Indications and mathematical equations to assess the maintenance work in the steam power stations.

BROAD INDICATORS
This section presents three such indicators.
Index I
This is defined by

$$I1 = (TMC)/TS$$

Where
TMC =total maintenance cost,
TS =total sales, I1 = index parameter.

Index II
This is expressed by

$$I2 = (TMC)/TO$$

Where
TO =total output expressed in gallons, tons, megawatts, etc., I2 □□index parameter.
This index relates the total maintenance cost to the total output by the organization.

Index III
This is defined as follows:

$$I3 = (TMC)/TIPE$$

Where
I3 =index parameter,
TIPE =total investment in plant and equipment.
This index relates the total maintenance cost to the total investment in plant and equipment.

SPECIFIC INDICATORS
This section presents twelve such indicators.
Index IV
This is a useful index to control preventive maintenance activity within a maintenance organization and is defined by

$$I4 = TTPM/TTEM$$

Where
I4 =index parameter,
TTPM =total time spent in performing preventive maintenance,
TTEP =total time spent for the entire maintenance function.
As per the past experience, the value of I4 should be kept within 20 and 40% limits.

Index V
This index can be used to measure the accuracy of the maintenance budget plan and is expressed by

$$I5=TAMC/TBMC$$

Where
I5 =index parameter,
TAMC =total actual maintenance cost,
TBMC =total budgeted maintenance cost.
In this case, large variances indicate the need for immediate attention.

Index VI
This is a useful index for maintenance overhead control and is expressed by

$$I6=TMAC/TMC$$

Where
I6 =index parameter,
TMAC =total maintenance administration cost.

Index VII
This index is useful in scheduling work and is expressed as follows:

$$I7=PJCED/TPJ$$

Where
I7 =index parameter,
PJCED =total number of planned jobs completed by established due dates
TPJ = total number of planned jobs. The value of I7 should be high to keep backlogs down
Index VIII
This index is useful in material control area and is defined by

$$I8=TPJAM/TPJ$$

Where
I8 =index parameter,
TPJAM =total number of planned jobs awaiting material

Index IX
This index can be used to measure maintenance effectiveness and is defined by

$$I9=MHEUJ/TMMH$$

Where
I9 =index parameter,
MHEUJ =man-hours of emergency and unscheduled jobs,
TMMH =total maintenance man-hours worked.

Index X
This index can also be used to measure maintenance effectiveness and is expressed by

$$I10=DTCB/TDT$$

Where
I10 =index parameter,
DTCB = downtime caused by breakdowns, TDT =total downtime.

Index XI
This is an important index used to measure inspection effectiveness and is defined by

$$I11=NJI/TIC$$

Where
I11 =index parameter,
NJI =number of jobs resulting from inspections,
TIC =total number of inspections completed.

Index XII
This index relates material and labor costs and is expressed by

$$I12=TMLC/TMMC$$

Where
I12 =index parameter,
TMLC =total maintenance labor cost,
TMMC =total maintenance materials cost.

Index XIII
This index relates maintenance cost to manufacturing cost and is defined by

$$I13=TMC/TMFC$$

Where
I13 =index parameter,
TMFC =total manufacturing cost.

Index XIV
This index relates maintenance cost to man-hours worked and is expressed by

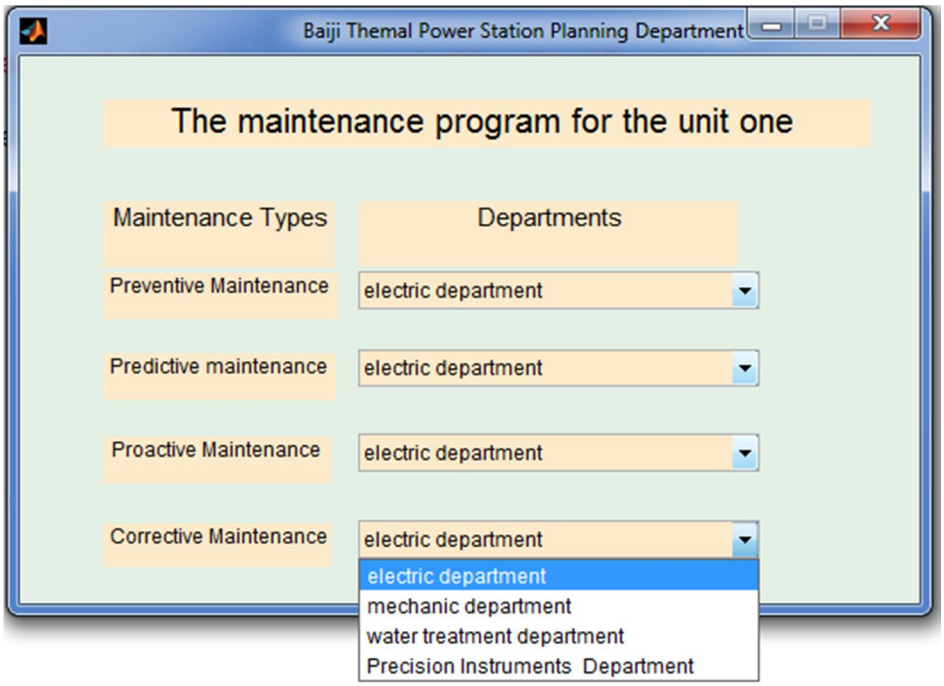
$$I14=TMC/ (TNMW)$$

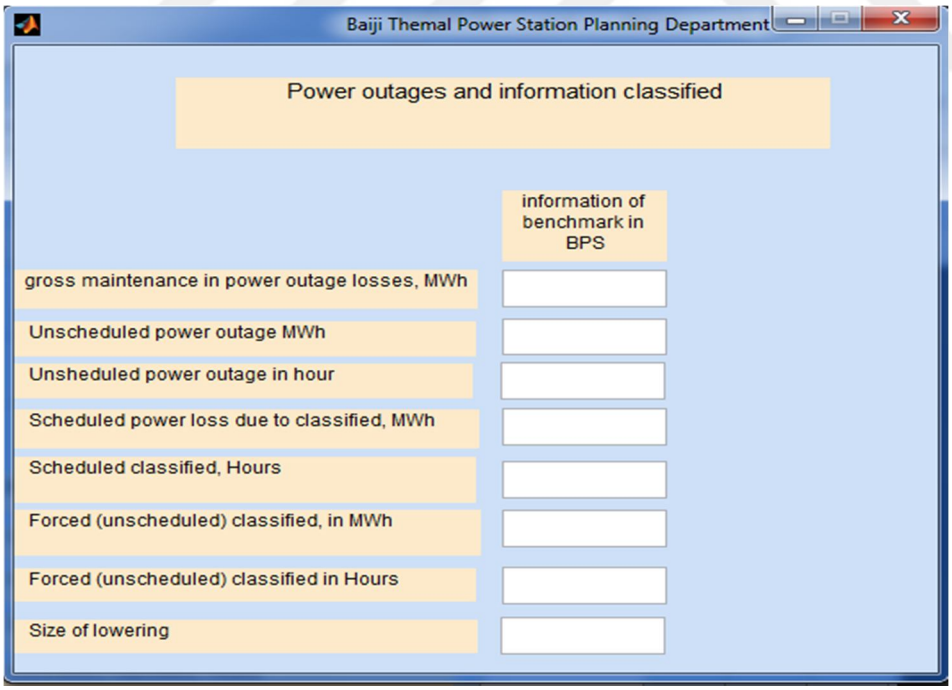
Where
I14 =index parameter,
TNMW =total number of man-hours worked.
Index XV
This is a useful index to monitor progress in cost reduction efforts and is defined by

$$I15=PMMSJ/ (MCPP)$$ Where

I15 =index parameter,
PMMSJ =percentage of maintenance man-hours spent on scheduled jobs,
MCPP = maintenance cost per unit of production.

APPENDIX-3


Baiji Themal Power Station Planning Department
The maintenance program for the unit one
Maintenance Types
Departments
Preventive Maintenance
electric department
Predictive maintenance
electric department
Proactive Maintenance
electric department
Corrective Maintenance
electric department
electric department
mechanic department
water treatment department
Precision Instruments Department


Baiji Themal Power Station Planning Department
Power outages and information classified
information of benchmark in BPS
gross maintenance in power outage losses, MWh
Unscheduled power outage MWh
Unsheduled power outage in hour
Scheduled power loss due to classified, MWh
Scheduled classified, Hours
Forced (unscheduled) classified, in MWh
Forced (unscheduled) classified in Hours
Size of lowering

ÖZGEÇMİŞ

KİŞİSEL BİLGİLER

Adı Soyadı : Muqdad Khaleel
Uyruğu : Irak
Doğum Yeri ve Tarihi : Tikrit – 14.9.1979
Telefon : 05365980390
Faks :
e-mail : muqdad_hammad@yahoo.com

EĞİTİM

Derece		Adı, İlçe, İl	Bitirme Yılı
Lise	:	**Tikrit Özel lisesi, Tikrit, Salahudin**	**1997**
Üniversite	:	**Teknoloji Üniversitesi, Bağdat**	**2002**
Yüksek Lisans	:		
Doktora	:		

İŞ DENEYİMLERİ

Yıl	Kurum	Görevi
2004-2009	Baiji buhar santrali	İşletme Mühendisi
2009-2014	Baiji buhar santrali	Bakım Mühendisi

UZMANLIK ALANI

YABANCI DİLLER
İngilizce, Türkçe

BELİRTMEK İSTEĞİNİZ DİĞER ÖZELLİKLER

YAYINLAR

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