

# Maintenance Management Practices in Electricity Industry in Arab World : Case Study in Jordan

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## ABSTRACT

Nowadays, power plants, generators, substations, and equipment are becoming technologically more sophisticated and difficult to control besides that any interruption in power supply will cause losses to the industry and economy. Therefore, the importance of maintenance with enhancing availability, performance efficiency, on-time deliveries, safety necessities, and overall plant productivity become more necessary.

In this context, the electricity industry in Arab countries is increasingly realizing the importance of the maintenance role. The main objective of this paper is to assess the maintenance management (MM) practices, operational performance, and issues faced by maintenance functions in Jordanian power companies as a representative case study for all Arab countries.

To collect data in this study, a comprehensive survey methodology was developed, implemented, and presented.

To achieve this goal, a questionnaire was developed to analyze the requirements, and service difficulties, namely, maintenance planning, automation implementation, maintenance barriers, productivity measurements, staff training needs, and assessment. We then distributed the questionnaire to a selected sample of Jordanian electricity companies which has been filled out mainly through text surveys and personal interviews.

The main obtained results of this study, related to maintenance practices and procedures that promote equipment availability, are summarized as increased use of predictive, intensive maintenance, computerized maintenance management systems (CMMS), and maintenance troubleshooting techniques. Additionally, more understanding of the development strategy and maintenance automation in the company.

Thus, a more comprehensive maintenance program has to be implemented, so that the enhancement of performance in the equipment availability can be attained.

*Keywords: Maintenance management (MM), Electricity industry in Arab World, Jordan.*

## 1. INTRODUCTION

With the huge increase in power demands and the importance of electricity in our life and its continuity, many companies become realized the need for the use of proper maintenance of electric facilities and systems. In accordance, "MM is the activities of planning, organizing, implementing, monitoring, and controlling to sustain a certain level of availability, value, and reliability of the system and its components (assets) and its ability to operate to a certain standard level of quality". Therefore, MM is vital in ensuring the long-term success of maintenance programs with many benefits, which greatly affects the performance of the company by choosing the optimum maintenance practice and strategy. It is very important to measure the operational performance of the company; this can be done by the measure of reliability, maintainability,

productivity, efficiency, availability, and production per unit cost, among others [1-4]. Normally, a company's maintenance costs are high, because of that, any reduction in cost due to applying the optimum strategy and practice of maintenance can increase the performance of the company [5, 7]. Therefore, MM practices implemented in Jordanian electricity industry companies are studied and evaluated, as a representative case study for other countries in the Arab world.

Arab World is a region known to be an energy reservoir—producing 30% of the world's oil, has 41% Of the world's known reserves of gas, its most important export is hydrocarbons - they barely meet domestic electricity demand, in part due to many political and technical reasons such as poor management and lack of maintenance.

Jordan, like many Arab countries, does not have enough electricity, which leads to reduced industrial activities and slower economic growth. This situation pushes outside investors to find other countries that have sufficient energy supplies to establish their investments and companies. Therefore, Jordan's power plants play a significant role in the country's economic and industrial growth. Power plants must keep generators running, especially in compliance with specific power purchase and sale contracts. The availability target is above 85% to support the industry and its growth. However, these generators may fail from time to time, so it is difficult to reach this final set value. In addition, routine maintenance of the generator must be carried out to ensure reliable operation [8]. Therefore, the power plant maintenance practice must be strategically controlled to achieve its operational goals and commitments.

This paper provides a method to determine the impact of the implementation of MM practices and the level of management support in different electric companies in Jordan on business performance [6].

In this research, seven hypotheses have been formulated based on the advanced study and literature review, which have been positively demonstrated via an appropriately designed research methodology.

Based on the obtained results in this study, the main findings relating to the maintenance proceeding, and approaches that contribute to the enhancement of tools availability are summarized as follows: better application of proactive maintenance, assertive maintenance, CMMS, and maintenance troubleshooting procedures.

Additionally, the result shows that the primary problem faced by the maintenance department is related to the challenge of maintenance staff, which is due to the absence of experience, motivation, and competencies. These may be gotten over via, a workman development strategy, which leads to the enhancement of the performance of the works. These are up-to-date knowledge and can give a new understanding of the existing circumstances and policies for the maintenance department as far as Irish and Malaysian automated fabrication industries are engaged.

Therefore, by holding good preparation, planning, and realization, an enhancement in equipment presence can be predictable. On the other side, it may be seen from the results that "on-the-job training and training with internal staff", are the most suitable and effective procedures for the maintenance staff to improve their competencies

and knowledge in performing the maintenance work.

According to the obtained results in this research, the main conclusions linked to the maintenance working and procedures can be utilized as a good background for electricity industry companies in all Arab countries.

## 2. BASIC MAINTENANCE PHILOSOPHIES

### 2.1. MAINTENANCE TRIGGERS:

Maintenance must be performed at the facility level when a maintenance trigger occurs. These triggers are utilized to notify technicians of maintenance requirements.

**1. Breakdown maintenance (PM) trigger:** As its title suggests, a BM trigger happens as a part of the installation is damaged and can be utilized no longer. The instant an asset stops functioning, an alarm is triggered, and maintenance is planned to improve the issue and produce the equipment to work.

Breakdown triggers commonly occur in positions at pointed assets, which can be replaced or fixed fast with little spending or influence on manufacturing with scheduled reserve presence.

Types of maintenance that used breakdown triggers: corrective, reactive, run-to-failure.

**2. Usage Trigger:** Maintenance triggers occur based on usage if any asset needs maintenance after a certain period. A belt needs to be replaced after 100 work hours, tires must be replaced after 10,000 km, and the installation sealing kit strength needs maintenance after 20 production cycles. Whatsoever the case, when the asset fulfills its lifespan, a maintenance order is triggered and scheduled.

Types of maintenance that used breakdown triggers: corrective, reactive, run-to-failure.

**3. Condition Trigger:** When any component of the apparatus is not operating as required, it means that something wrong is happening. When a maintenance trigger is in place, it determines the location of the problem and alerts a technician about maintenance that is needed. For example, an overheated or highly vibrated engine caused by internal parts of the equipment is break-down. If these conditions are discovered, a maintenance order is triggered, the engine cools down, or compressed the bearing.

Maintenance types that used condition triggers: condition-based, predictive

**4. Trigger Time:** Trigger time is the most frequently used maintenance [7]. Here's how it works, scheduled maintenance on a predetermined schedule, such as the first day of every month. When is the appointed time coming? a maintenance order is triggered, a machinist is alerted, and the maintenance job is finished. Triggered times come in many different forms and extents, from hourly to seasonal ones.

Types of maintenance that used breakdown triggers: corrective, reactive, run-to-failure.

**5. Trigger Event:** This maintenance trigger type boils down to one phrase: If such an event occurs, it triggers that kind of maintenance. Only add a particular strategy and related maintenance duties. If the happening is added to a digital maintenance system, such as a CMMS, a sequence of tasks is triggered to support the minimization of the negative effect of the circumstance or confirm that assets are operating correctly during the event. For example, if the building basement floods, the electric systems must check, or if audits are scheduled, certain assets must inspect.

Types of maintenance that used breakdown triggers: corrective, reactive, run-to-failure.

## 2.2. MAINTENANCE STRATEGIES:

Different strategies can be used in maintenance depending on different factors related to the organization, to which it is applied. All these strategies distinct or combined are mentioned and discussed below:

### 1. Run to failure (BM)

This is the basic principle that allows a machine to run without preventive maintenance (PM) until a failure occurs [9]. If the equipment fails, this maintenance will be performed. A team assigned this maintenance strategy, such as in the event of a failure (repair, overhaul, or replacement of parts), is limited until simply ordering a replacement kit becomes more practical. This strategy is acceptable. It is used for equipment with the lowest service value (characteristics of other equipment that are rarely used or reused) or equipment with the lowest cost [10].

### 2. Preventive (scheduled) maintenance (PM)

PM is a planned or scheduled maintenance that is carried out at the beginning of a failure, to prevent or delay failure and to minimize the consequences of failure. This MM practice is based on the principle that prevention is better than cure. It includes maintenance work performed before equipment failure to maintain normal operation and minimize the possibility of failure [12, 13].

Dillon (2001) mentioned the characteristics of companies that require PM:

- Low equipment utilization due to failures.
- Large amounts of scrap and waste products due to unreliable equipment.
- Increase in equipment maintenance costs to repair and replace worn parts/components Due to negligence in routine lubrication, inspections, etc.
- Long-time operator downtime due to equipment failures.
- Reduction of fixed assets. Life expectancy due to poor maintenance.

### 3. Predictive maintenance (PdM):

In this strategy, maintenance is initiated in response to specific conditions or equipment degradation [14].

Check the health of the equipment for signs of wear that could cause any component of the equipment to fail. The purpose of a predictive maintenance strategy is to track component wear to ensure that imminent failure is detected. Predictive maintenance is widely used in automotive, aerospace, manufacturing, defense, and other industries [15].

### 4. Reliability-centered maintenance (RCM):

Reliability Centered Maintenance (RCM) is an enterprise maintenance strategy that can optimize a company or site maintenance plan. The result of the RCM program is to implement a defined maintenance strategy for the assets of each property. Formulating a maintenance strategy consists of selecting the correct combination of corrective maintenance, planned or PM, and CBM to fully support system reliability in a given operating environment [12-15].

### 5. Risk-based maintenance

Risk-based maintenance (RBM) first allocates maintenance resources to provide maintenance for the equipment with the highest risk of failure. This strategy determines the most economical way to use maintenance resources to minimize the risk of failure [16].

The risk-based maintenance strategy has two main stages:

- i. Risk assessment.
- ii. Risk-based maintenance planning.

## 2.3. MAINTENANCE MANAGEMENT

The wellhead management system provides equipment and facilities; Once available, the production team can order and receive anything as needed, such as light, electric, air, gas, heating, cooling, or machine tools. The well-prepared Maintenance Management System helps reduce downtime and waste of time and money [17].

So far, the literature on maintenance management is very limited. The concept of maintenance varies from organization to organization. Regarding the general

business framework, there is no unified solution or published literature. The main management steps identified are expropriation, approval, planning, planning, work execution, data recording, cost accounting, development management knowledge, updating equipment history, and providing management notifications.

The effective management of maintenance elements contains:

1. Policy of Maintenance.
2. Control of Materials.
3. Order Work System.
4. Records of Equipment.
5. Corrective and Preventive Maintenance.
6. Planning and Scheduling Tasks.
7. Control and Priority of Backlog System.
8. Measurement of Performance.

#### **2.4. MAINTENANCE CHALLENGES IN ELECTRICITY INDUSTRY**

The industry alone has problems and worries. However, compared with electricity producers, electricity producers may face more obstacles, because electricity is an essential and important part of our lives. If we lose electricity in a short period, everything will stop. The level of control in this industry is higher. As a result, system operators and maintenance teams face many major challenges, including strict standard regulations, hard working conditions, a huge grid with a variety of equipment, and complicated equipment that is hard to keep the system running. There are several challenges in achieving effective service delivery in an organization. Phogat and Gupta highlighted the main issues and obstacles that face maintenance [14-17].

Marquez and Gupta attribute the complexity of MM to the lack of an MM model, which may improve the understanding of the basic parameters of the service. Visser (1998-2015) further pointed out that there is not enough knowledge to manage maintenance. This makes it difficult to decide which service strategy to adopt [18-20].

By Marquez and Gupta, maintenance consists of a series of activities, and it is difficult to find procedures and information support systems in one place to facilitate the improvement process [14]. Hipkin and De Kock classified the obstacles to the implementation of the maintenance system. They classify the obstacles that managers, supervisors, and operators face in managing maintenance as ignorance of facilities and processes, lack of historical data, lack of time to perform the required analysis, lack of management support, and worry about production and business interruptions [21].

Marquez and Gupta also pointed out that the increase in automation and the reduction of storage buffers put

pressure on the maintenance system. Electricity cannot be counted, so there is greater maintenance pressure. Utilities love generators more than manufacturing companies. In addition, Buchanan, and Besant (1985) found that in highly automated organizations, the computational constraints of roles, the integration of teams, and the increase in knowledge requirements make it difficult to diagnose and solve hardware problems [14].

In nutshell, maintenance costs are usually high. Cost is indeed a matter of maintenance and management. Hennequin and Arango pointed out some MM methods, such as total productive maintenance and total quality maintenance, require a lot of investment in manpower and information resources. Many companies may not have enough funds to make this investment. It is also worth noting that because maintenance is mistakenly regarded as a non-strategic function, the support of MM practices by top managers has been rarely used in organizations [6, 22].

#### **3. SUMMARY AND GAPS FORM LITERATURE**

The maintenance must consider all factors to adjust them to the needs of the relevant company. This means that the "best" maintenance concept is unique to each company. With the rapid development of industrial systems, maintenance concepts must also be checked regularly to adapt to changing systems and environments.

Many maintenance principles are discussed in the literature. They provide promising and useful ideas, most of which require many resources in terms of personnel and management. Applying standard concepts found in the literature is not always the optimal solution. This also makes it difficult to formulate and implement maintenance concepts in practice. Part of the organization's total cost of ownership.

According to Wilson, some business processes which should be used for optimizing operational performance are minimizing maintenance costs, adopting optimal maintenance practices, maximizing plant utilization and capability, and maximizing performance efficiency [7]. Furthermore, Ben-Daya had also identified equipment availability as a measure of a firm's operational success [23].

This is the basic principle that enables a machine to operate without PM until a failure occurs. If the equipment fails, this maintenance will be performed. A team assigned this maintenance strategy, such as in the event of a failure (repair, overhaul, or replacement of parts), to be limited until simply ordering a replacement kit becomes more practical. This strategy is acceptable. It is used for equipment with the lowest

service value (features of other equipment rarely used or reused) or for equipment with lower cost [9, 10].

#### 4. RESEARCH METHODOLOGY

The purpose of the research methodology is to address the objectives of the research. Preliminary research and literature research will help identify areas that require consideration when designing the implementation framework. The next is the most important stage in the research methodology of gathering information to clarify the research results. Hence, it is important to own good knowledge of the concerns linked to the fieldwork method before starting the survey.

Therefore, an in-depth overlook methodology for acquisition evidence (Figure 1) was created, utilized, and introduced in this research. By the standard approach of vocational survey bodies, this research has observed with the greatest care all the well-established principles and guidelines, particularly on the strategy of the survey design and methodology, also the data processing investigation procedures utilized.

#### 5. POPULATION OF SURVEY AND PROFESSIONAL QUESTIONNAIRE LIST

The population of the research includes all maintenance departments in electric companies located in Jordan. A total of 257 questionnaires were sent out and only 55 questionnaires with the required answers were returned, with a response rate of 25%.

This low level of feedback stems from the fact that a large number of employees were off work during the preparation of this research work and questionnaire due to COVID 19 circumstances in Jordan and around the world. Table 1 shows the names of the main companies that participated in this research work.



Figure 1: Research Methodology

Table 1. Electricity companies participating in the research work and questionnaire.

Central Electricity Generating Company (CEGCO)
Samra Electric Power Company (SEPCO)
Amman East Power Plant (IPP1)
Korean company KEPCO Qatraneh (IPP2)
Amman Asia Company (IPP3)
Amman East Power Plant (IPP4)
Zarqa'a Electricity Generating Company
National Electric Power Company (NEPCO)
Irbid District Electricity Company (IDECO)
Jordan Electric Power Company (JEPCO)
Electricity Distribution Company (EDCO)

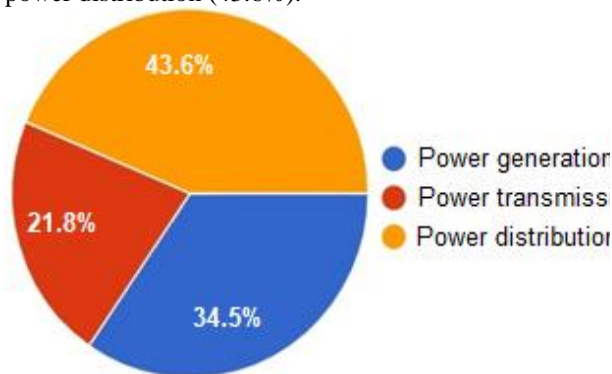
#### 6. RESULT, DATA PROCESSING, AND ANALYSIS

After receiving the response from the participants, the results were edited and electronically saved. The data processing stage mainly comprises 4 steps:

1. Establish a database
2. Data entry
3. Data analysis
4. Generate a report and documentation.

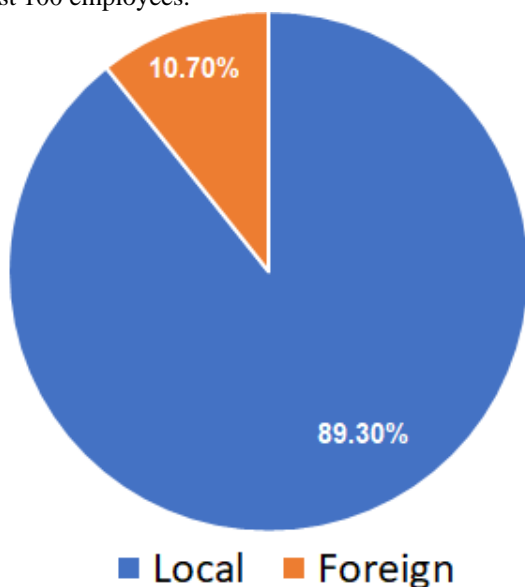
Windows version 12 with the Statistical Software Package for Social Sciences (SPSS) is used for data entry and processing.

Based on the results obtained, Figure 2 shows the distribution of the electricity categories of the companies questioned. The results show that the companies belong to three functional groups: power generation (35.5%), power transmission (21.8%), and power distribution (43.6%).



**Figure 2: Type of electricity Industry**

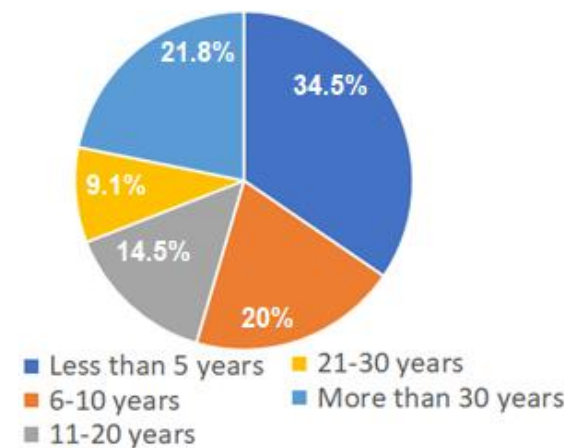
As Figures 3 and 4 show, most businesses and companies involved in this research are “local” businesses and subsidiaries of large companies. In terms of years of work and number of employees, Figure 5 shows that most of the Jordanian companies that shared this questionnaire have been in business for less than 10 years and Figure 6 shows the number of employees where most of these companies have at least 100 employees.



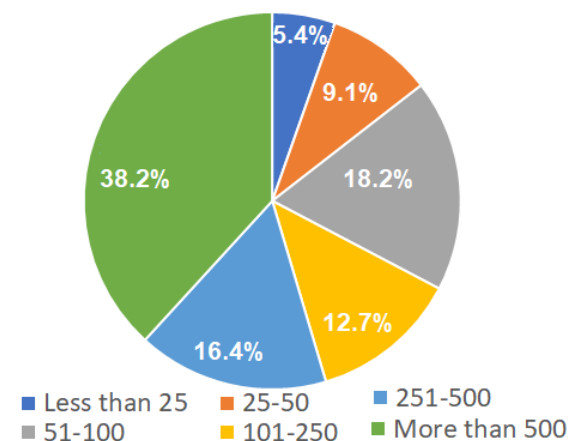
**Figure 3: Firm’s ownership status**



**Figure 4: Firm’s subsidiary status**



**Figure 5: Number of years in operation**

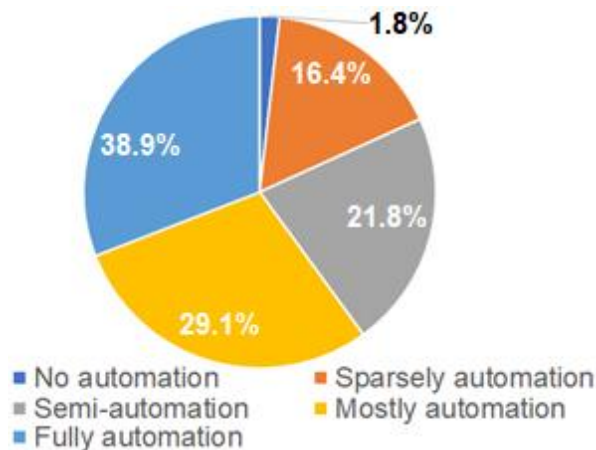


**Figure 6: Number of workers**

## 7. AUTOMATION AND INTEGRATION LEVELS

Jordanian electricity production companies can be classified, based on the method used in their operation,

as manual, semi-automatic, or fully automatic. From this perspective and as shown in Figure 7, most of the companies involved in this research are fully automated. Hence, this is followed by the fact that most of the production is automated.



**Figure 7: Automation and integration degree**

Furthermore, the necessary operations in electric power generation companies and stations that require starting and stopping electrical machines when required by the system need adequate and automatic protection for these machines. The design and development of PLC controllers and automatic relays with a high degree of accuracy, sensitivity, and reliability made such automation possible.

Table 2 shows that the type of controllers utilized depends on the degree of automation. This table also shows that the most used control unit for fully automated electrical systems is the PLC controller.

**Table 2: Degree of automation related to the type of controller used**

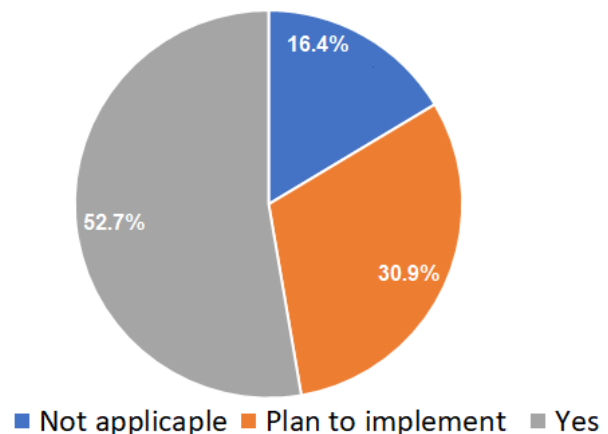
	Sparsely automated	Semi-automated	Mostly automated	Fully automated
Rely	Moderate	Extensive	Minimal	Minimal
PLC	Extensive	Extensive	Extensive	Extensive
DCS	N/A	N/A	Moderate	Extensive
Microprocessor	Moderate	Moderate	Moderate	Extensive
SCADA	N/A	N/A	Moderate	Extensive

Automatic relays are also found to be implemented in semi-automatic electrical systems. The latest generation of control systems, DCS and SCADA systems are widely used in fully automated systems. Meanwhile, the correlation analysis (CA) between the degree of automation and the type of control in production illustrates that the higher the degree of automation, the more complex the type of control utilized, such as DCS and SCADA systems.

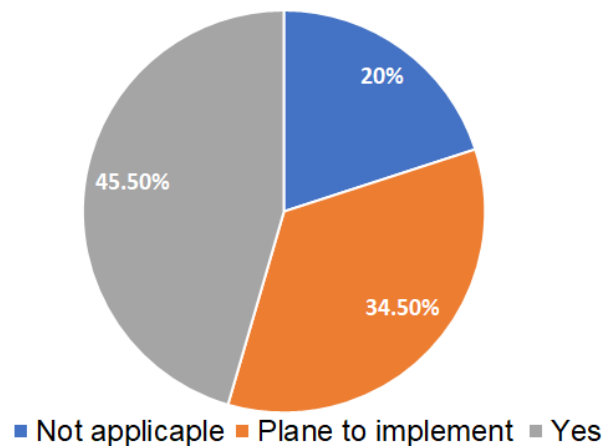
## 8. MAINTENANCE TYPES USED

Table 3 shows the types of maintenance implemented and their scope of application. The results show that "PM" has the highest average value and is often classified as "extensive or quite extensive", followed by "BM" and then "corrective maintenance".

The results in Figures 8a and 8b also illustrate that many respondents have implemented "Total Productive Maintenance" (TPM) related to "Reliability Centered Maintenance" (RCM).



**Figure 8a: Practice of TPM program**



**Figure 8b: Practice of Reliability Centered Maintenance (RCM) program.**

Table 4 shows the main obstacles that face the maintenance of the automation system. The results in Table 4 indicate that there are two elements: "lack of motivation" and "lack of supervisory skills" that represent the highest average. Most of the problems identified as obstacles fall into the soft skills category. On the other hand, "hard skills" categories such as

“insufficient manpower” and “insufficient training” are classified as secondary obstacles.

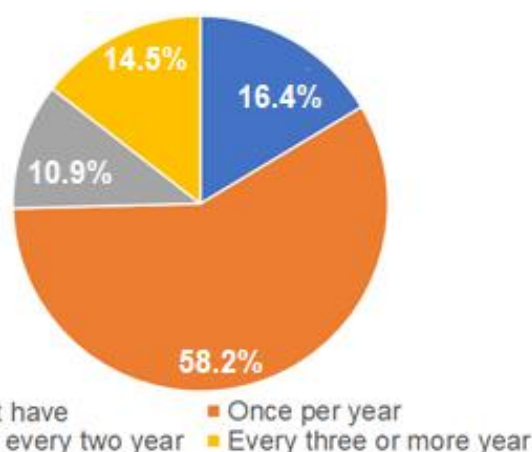
**Table 3:** Maintenance strategies implemented in this research.

Mean value	extensively	quite extensively	3: Used moderately	2: Used quite moderately	1: Used minimally	not have	
3.27	49.09%	12.73%	16.36%	7.27%	5.45%	9.09%	A - Breakdown
3.18	18.18%	18.18%	29.09%	7.27%	5.45%	9.09%	Corrective
3.29	38.18%	16.36%	14.55%	9.09%	14.55%	7.27%	C - Preventive
2.91	36.36%	9.09%	18.18%	10.91%	12.73%	12.73%	D - Predictive
3.04	21.82%	29.09%	20.00%	7.27%	3.64%	18.18%	E - TPM
3.02	20.00%	34.55%	14.55%	5.45%	9.09%	16.36%	F - RCM

### 8.1. PLANNING AND IMPLEMENTATION OF TRAINING

Figure 9 shows the results of using Training Needs Analysis (TNA) to determine the company's maintenance training needs. Based on these results, we can find that most respondents conducted TNA once a year. Meanwhile, the survey results also showed that (16.4%) of respondents did not conduct TNA exercises in their company.

Table 5 shows the ratio of “in-housed maintenance” to outsourcing maintenance. The average result shows that most respondents use suppliers and manufacturers to outsource maintenance services and qualify as “full participation”.



**Figure 9:** Analysis of training needs.

### 8.2. USAGE OF OUTSOURCING MAINTENANCE

Table 4 shows the ratio of “in-housed maintenance” to outsourcing in maintenance. The average result shows that most respondents use suppliers and manufacturers to outsource maintenance services and qualify as “full participation”.

**Table 4.** The use of “in-house and external maintenance” in maintenance.

	A-In housed	B – Consultant	C-Vendor & Manufacturer
0: No involvement	12.73%	16.36%	12.73%
1: Minimal involvement	25.45%	29.09%	36.36%
2: Quite moderate involvement	20.00%	10.91%	9.09%
3: Moderate involvement	10.91%	21.82%	10.91%
4: Quite fully involvement	9.09%	5.45%	18.18%
5: Fully involvement	21.82%	16.36%	12.73%
Mean value	2.63	2.67	3.33

Figure 10 shows that the majority of respondents see that the role of the company in maintenance needs to be reviewed. Table 5 shows that for those companies whose management does not regard maintenance functions as investments and

important support functions, the company's role in maintenance should be reviewed.

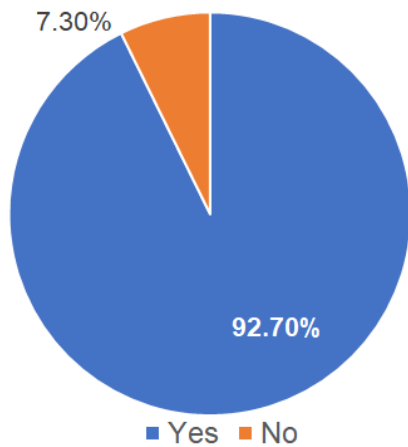


Figure 10: Maintenance role required to review.

Table 5. Top management opinion about maintenance function.

	A- Overhead	B- Investment	C- Supporting function
1: Strongly disagree	7.27%	5.45%	5.45%
2: Disagree	10.91%	12.73%	5.45%
3: Moderate	38.18%	45.45%	34.55%
4: Agree	25.45%	16.36%	21.82%
5: Strongly agree	18.18%	20.00%	32.73%
Mean value	3.40	3.13	3.60

Table 6 indicates maintenance work contributes to productivity. The average results show that maintenance expenditures contribute the most to "improving production cost reduction", followed by "improvement of equipment availability" and "the improvement of product quality".

### 8.3. USAGE OF CMMS

Regarding the use of a CMMS, as shown in Figure 11, 41.8% of the respondents used CMMS.

Table 7. Contribution of maintenance effort to performance improvements.

	A- Product Quality	B- Equip Availability	C- Reduce Prod Cost
Less than 20%	12.73%	14.55%	21.82%
About 35%	27.27%	18.18%	14.55%
About 50%	12.73%	21.82%	16.36%
About 65%	9.09%	12.73%	16.36%
More than 80%	38.18%	32.73%	30.91%
Mean value	2.50	2.82	3.06

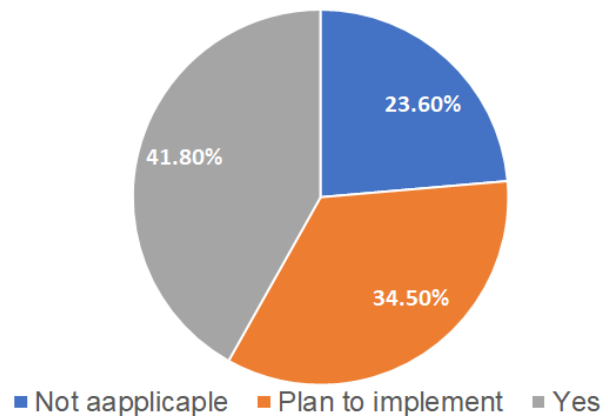


Figure 11: Usage of CMMS.

From the perspective of the level of CMMS used, as shown in Figure 12, most companies use the system extensively. The Pareto analysis technique is used to determine the level of CMMS and the most extensive modules used. Modules are classified according to frequency distribution data and average value from the most frequently used module to the least frequently used module.

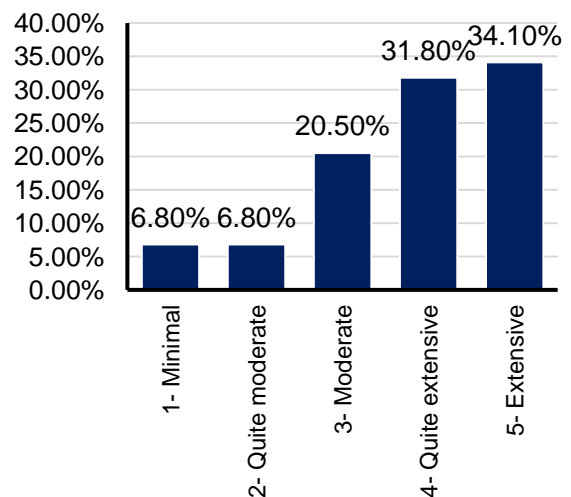


Figure 12: Level of CMMS usage

## 8.4. MM MODEL

Figure 13 shows the proposed MM Model, including corrective and PM management.

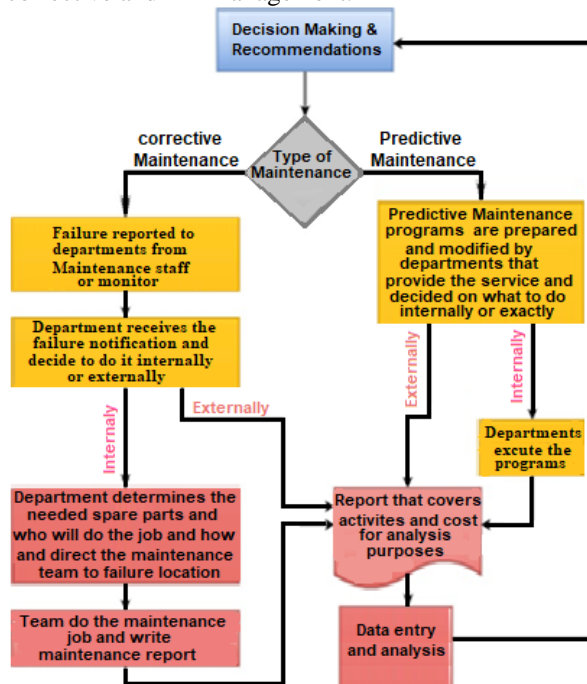


Figure 13: Proposed MM model

In addition, the model takes into consideration the possibility of outsourcing maintenance services and explains the role of different management levels in executing it. The relationship between the various departments of the public utility, such as procurement, branch offices, and information technology departments. The MM model takes into account the need to record the location and cost of maintenance work for analysis and decision-making. Although the model can be adopted by any electric utility company, regardless of its level, the researcher recommends starting with the implementation of the MMM in power distribution because it is more feasible.

## 9. Conclusions

This research paper conducts a study on the application of maintenance practices in electrical power companies in Jordan. From the perspective of the technologies used, it can be found that the higher the degree of automation in power plants, the more maintenance practices are implemented.

In this study, a comprehensive data collection method is developed, applied, and introduced. In compliance with the practice of professional investigation agencies, this study strictly follows all established principles and guidelines, especially in the design and

investigation process and the data processing and analysis methods used.

Moreover, to achieve the main objectives of this research, a questionnaire was conducted to study how necessary the maintenance is for the companies participating in the research and other things related to the maintenance such as planning, spare parts, equipment calibration, and training of maintenance personnel.

The survey results reveal that most of the respondents had not once regarded a maintenance consultation, discussion, workshop, or conference. The obtained results show lower involvement, although the presence of such a maintenance seminar is supposed to be a forum for the maintenance staff to debate the maintenance problems and disseminate knowledge with other maintenance staff in other companies.

The results of this research clearly show that management commitment is critical to successful maintenance performance. Furthermore, according to the stated purpose of this research, the maintenance strategy formulation process leads to the formulation of the development strategy of the maintenance personnel of the utility company and incorporates it into the company maintenance strategy.

Relied on the results provided in this paper, the main findings of maintenance practices and methods that help improve plant availability are summarized as follows: Increasing use of proactive maintenance, CMMS, and troubleshooting during maintenance. This practice and procedure can be summarized as follow:

- Utilization of a higher degree of proactive maintenance procedures such as predictive and preventive maintenance.
- Utilization of a higher degree of aggressive maintenance procedures such as TPM.
- Utilization of a lesser degree of reactive maintenance procedures such as BM.
- Utilization of a higher degree of CMMS.
- Higher degree of utilization of maintenance troubleshooting techniques such as Failure Modes Effects & (Criticality) Analysis, System Analysis Design Techniques, Fault Tree Analysis, and Pareto Analysis.

The results show that the maintenance effort donates the utmost rate to the enhancement of installation availability, followed by a decrease in production cost and product quality. Additionally, the correlation analysis shows that the higher the enhancement of equipment availability, the better the enhancement in the product quality and the lowering of production cost. Another correlation result shows that the higher the performance improvement, the higher the level of satisfaction with the maintenance attainment.

The research work highlighted in this paper suggests that the maintenance staff should be composed of multi-purpose and multi-task personnel. According to

the application field and technology of the power plant, they can solve any problem that can meet such requirements with the help of maintenance personnel training. From the point of view of personnel development, proper analysis of training needs, planning, and implementation of training courses are expected to improve equipment availability.

### Consent

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

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