LECTURE NOTES

INTRODUCTION OF ELECTRICAL MAINTENANCE AND REPAIR

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EDITION 2021

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ABSTRACT

This ebook is designed to assist students in performing theory task for topics Introduction of Maintenance and Repair. This book is organized according to the course Electrical Maintenance And Repair (DET50093) as an elective course to choose for Diploma in Electronic in Electronic Engineering (Computer), Diploma in Electronic Engineering (Communication) and Diploma in Electric & Electronic Engineering students in semester 5 under the Department of Electrical Engineering, Politeknik Sultan Mizan Zainal Abidin, Dungun Terengganu. This ebook contains brief notes, diagrams and sample questions. It is hoped that this ebook can help students to understand more about the topic of electrical maintenance.

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1.0 INTRODUCTION

Maintenance is an activity that has been designed so that equipment and machines are always in perfect condition. If this management is well implemented, maintenance objectives will become a reality for every industry. Maintenance management is based on the PDCA concept.

Figure 1.0: Flow and plan of maintenance work

Figure 1.0 shows the flow and plan of maintenance work can be launched and evaluated from the aspect of efficiency in using power and replacement items so that they are in optimal condition.

These rules and safety must be observed while performing the work.

In carrying out maintenance work, safety regulations relating to the work carried out shall be followed. The existence of safety rules can educate and discipline employees and can also curb the symptoms of accidents occurring during maintenance work is done.

Employees will be exposed to the requirements of self-related regulations, workshops, tools or machines, electric shock, precautionary and safety measures.

2.0 SAFETY REQUIREMENTS

Safety requirements in electrical wiring works shall complied to prevent any accidents which may result in physical injury, loss of life or property. Failure to follow safety regulations may result in electric shock to employees, consumer or general public. In addition, the practice of these safety measures can also cultivate disciplined employees or electrical users and always prioritize safety.

The purpose of electrical safety for consumer is:

1. Consumer must be proficient with the basic concepts of electricity
2. Knows the effects of electricity on the human body
3. Able to detect the dangers of electric shock
4. Users have skills to use protective electricity devices

The importance of electrical safety measures on the following:

1. Rules and personal safety
2. Safety in the workshop
3. Safety wear
4. Stairs

Rules and personal safety

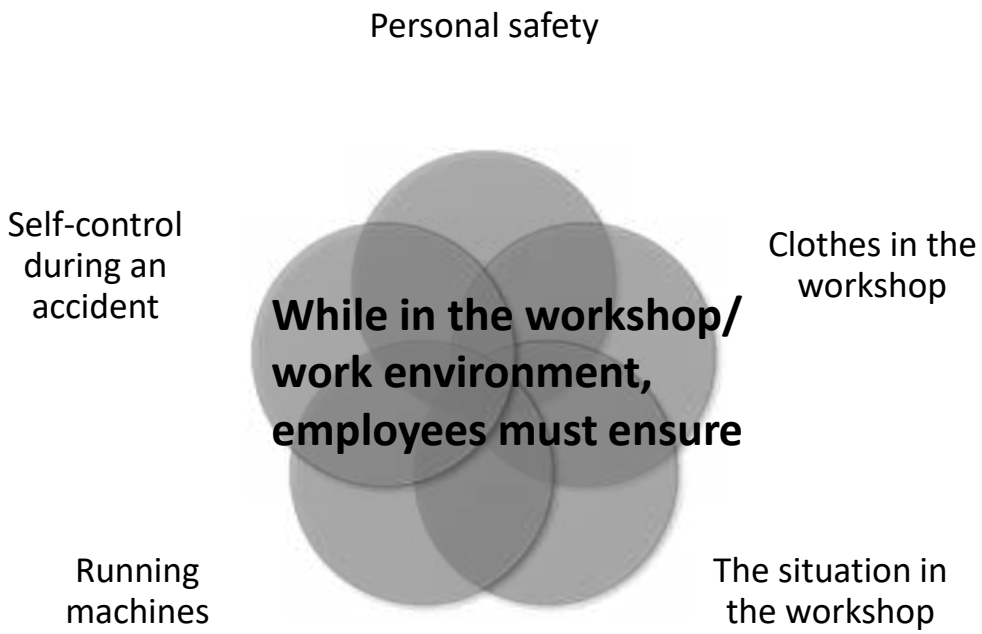
For employees, they should always,

1. Dress neatly and have short hair.
2. Wear safety shoes such as rubber shoes and appropriate apparel when in the maintenance area, for example at the TNB substation and motor maintenance.
3. Have appropriate personal protective equipment (PPE) such as safety shoes, safety helmets or other necessary when at work.
4. Wear appropriate safety clothing according to the work to be done.
5. Do not wear jewelry or ornaments such as rings, watch, chains, etc while carrying out electrical work.

2.1 SAFETY IN THE WORKSHOP

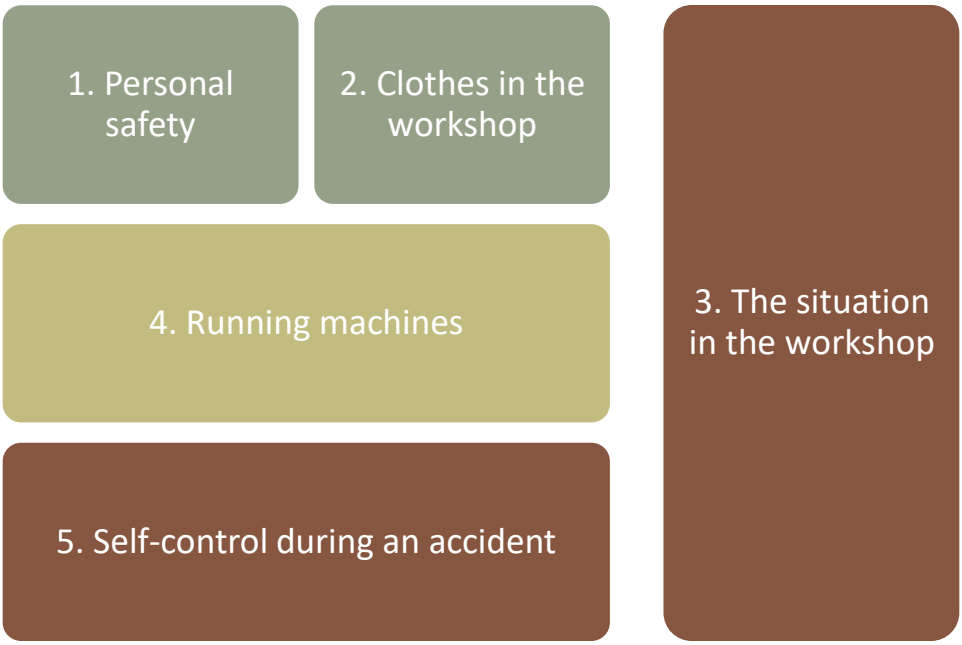
Several safety measures need to be adopted to ensure a safe work area for workers. One of the safety measures is to conduct inspections in the work area. Among the appropriate inspection practices for the work area are:

- Unsafe work environment
- The bar wire is stored
- Open areas exposing wires
- Screw fasten are loose or missing

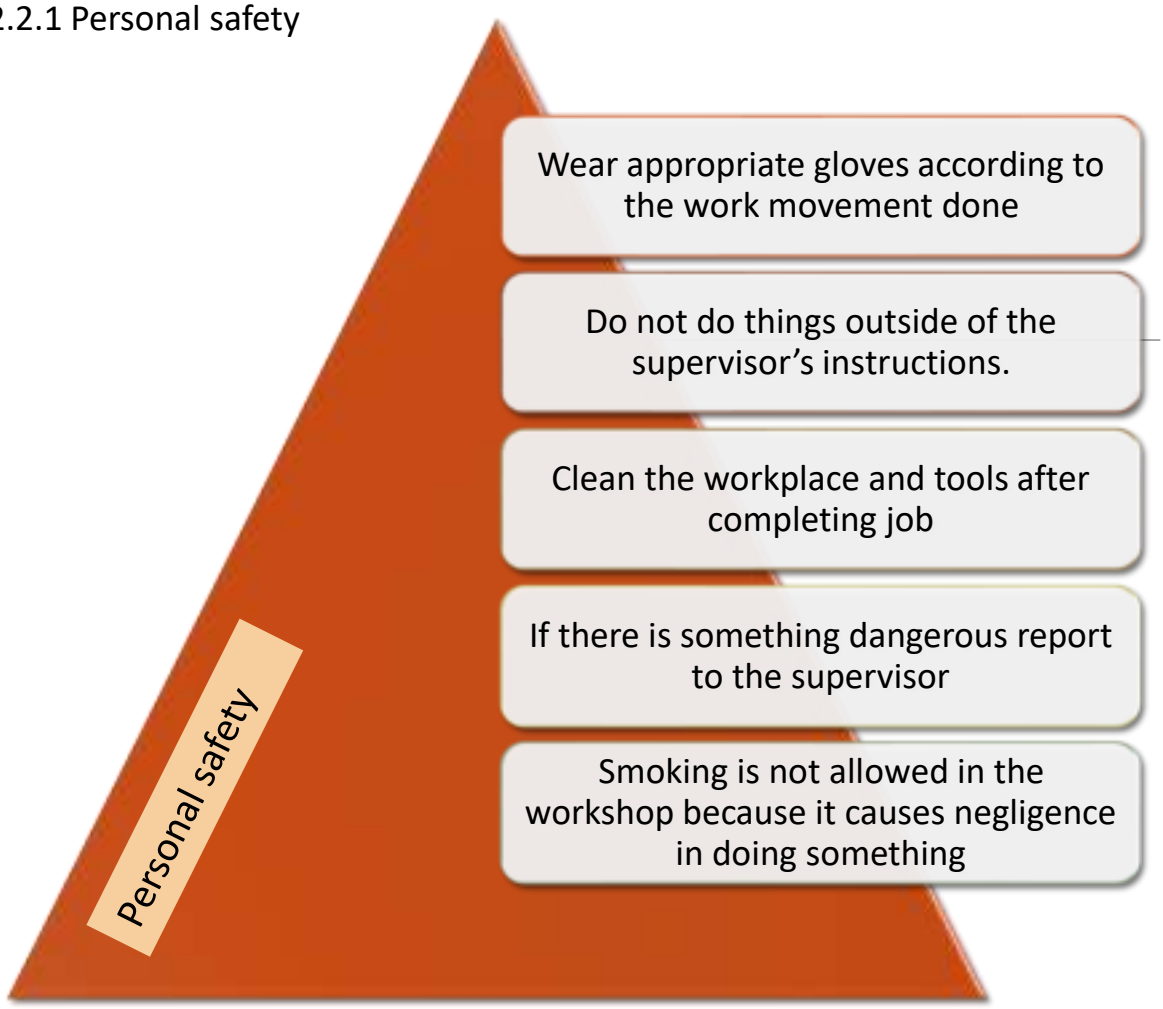


2.2 SAFETY MEASURES & OBJECTIVES MAINTENANCE

These rules and safety must be observed when electrical maintenance is performed. With the rules set, students become disciplined employees in addition to carrying out orderly and smooth work. This can prevent accidents while carrying out work.

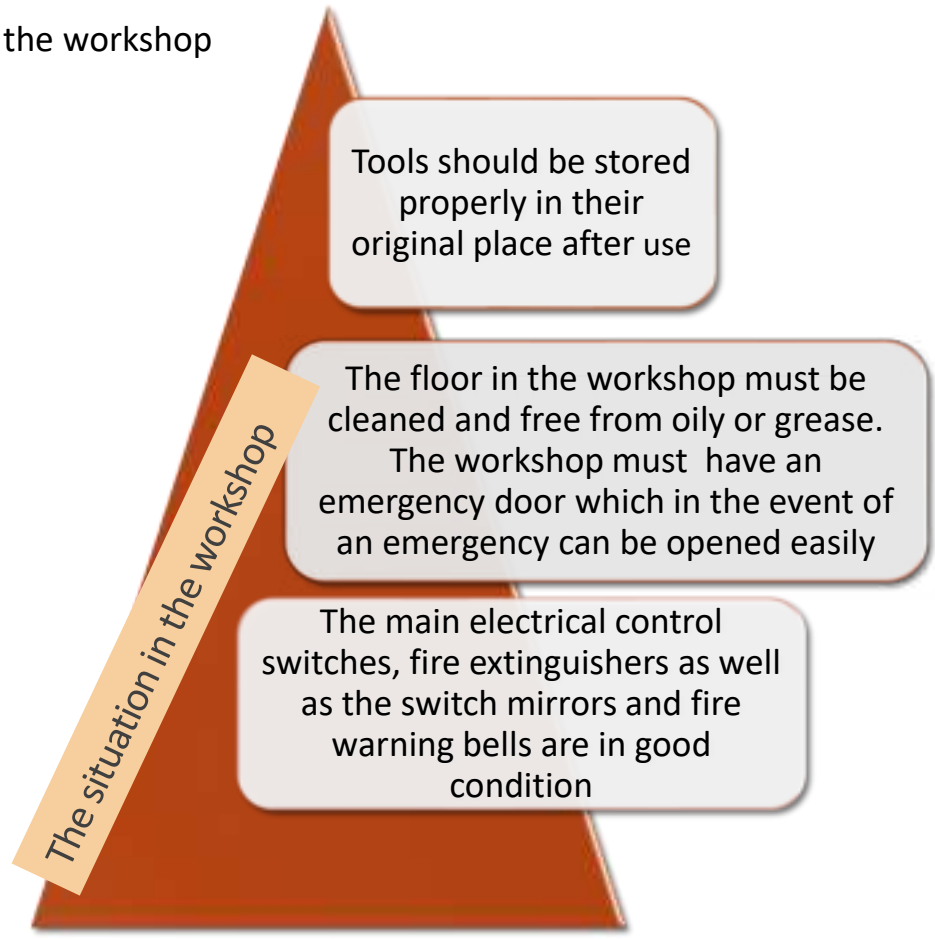


2.2.1 Personal safety

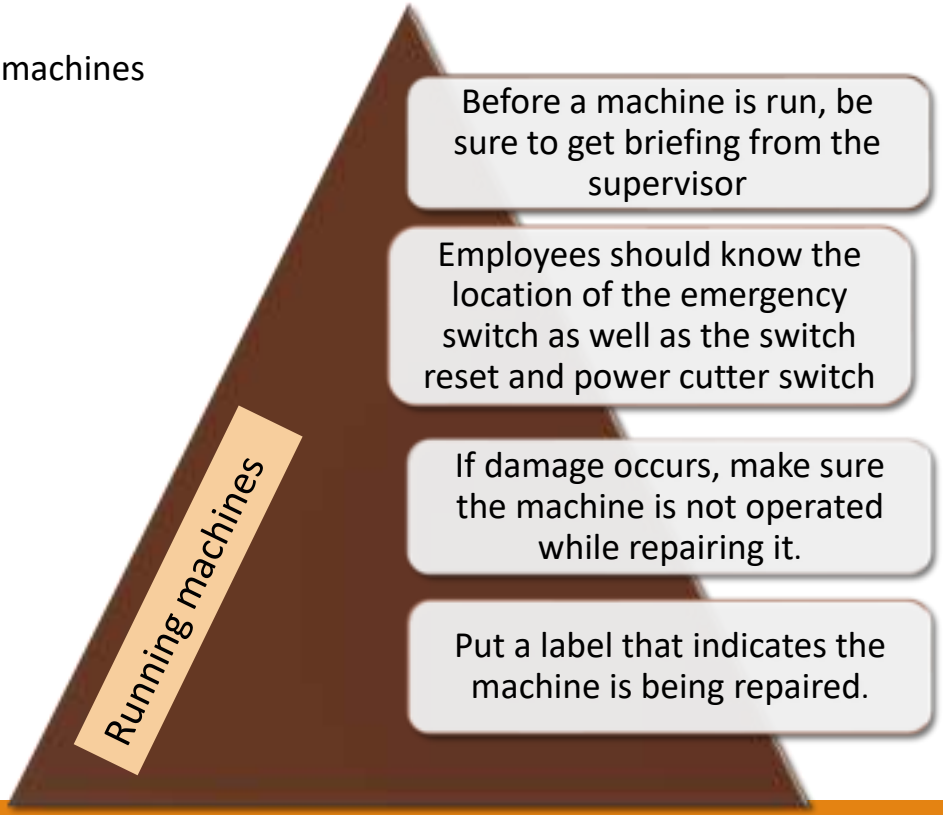


2.2.2. Clothes in the workshop

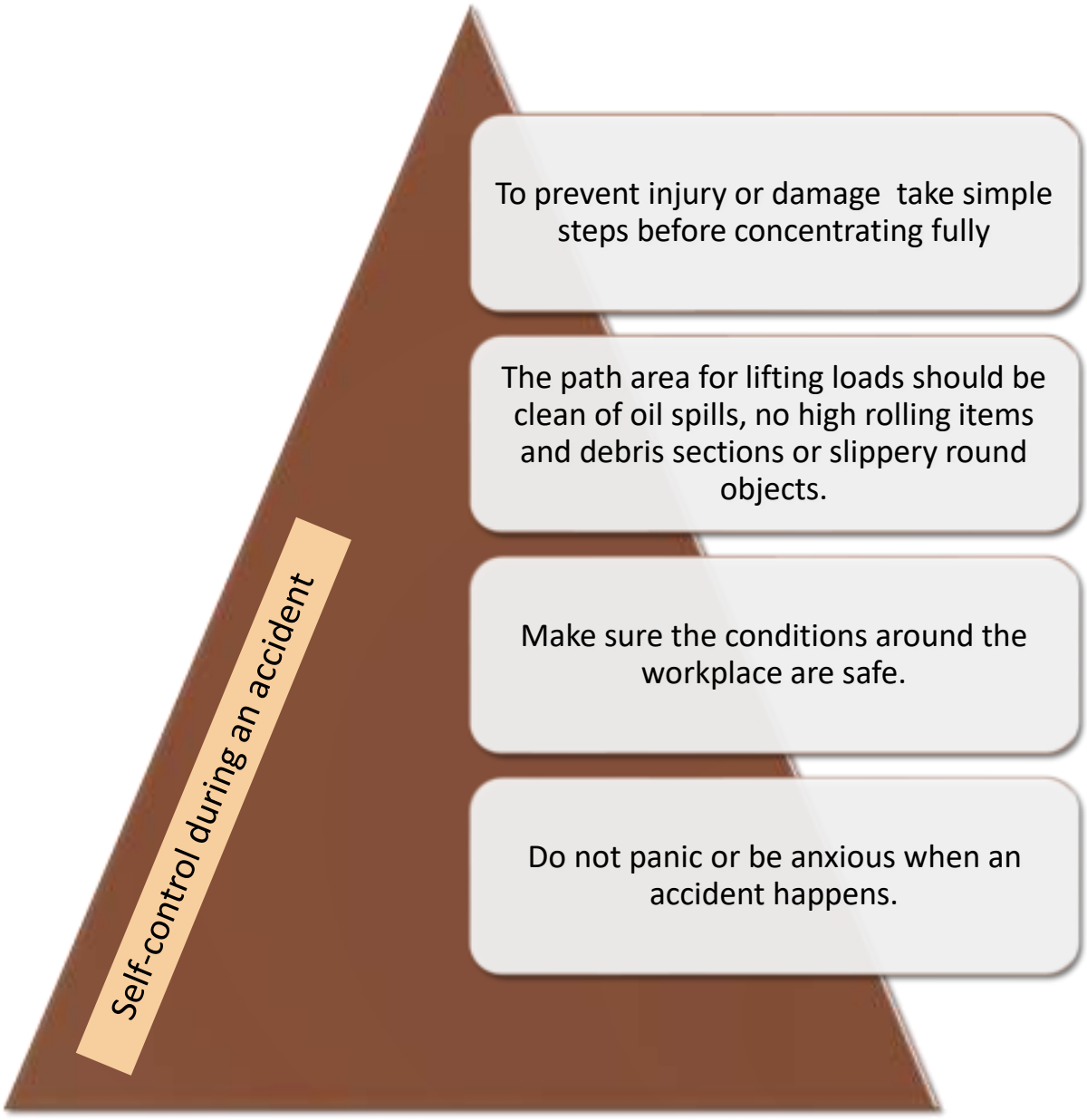
2.2.3. The situation in the workshop



2.2.4. Running machines



2.2.5. Self-control during an accident



2.3 SAFETY WEAR

While in the workshop/work environment, employees must adhere to dress code such as:

1. Do not wear jewelry such as rings, watches, necklaces, bracelets etc, while working with live electrical circuits.
2. Wear safety clothing such as insulating gloves, safety shoes, safety helmets, face shield should be worn where needed.
3. Do not wear long and dangling such as tie that can interfere and endanger the safety of workers.

2.4 SAFETY WHILE USING TOOLS @ MACHINES

To ensure safety when using tools and machines, the following steps must be followed:	Do not use a tools or machine without knowing the correct method of how to use it
	Do not use a tool or machine without permission from the teacher or supervisor.
	Damage or slightly damaged tools or machines are necessary repaired before use.
	Work tools need to be stored in the right place so that they are easy to find when needed.
	Clean the tools after use and store it in its original place.
	Do not leave a running engine unattended.
	Use goggles, face, ears or nose in workplaces that require PPE
	Follow the SOP (standard procedure) of the machine even if you are used to using it
	Do not close or remove instruction or warning signs found on devices or machine as other users may not be aware of them
	Do not attempt to repairs tools or machine without the knowledge of the supervisor

2.5 STAIRS

A ladder is an example of a tool that used to reach a higher place. Stairs should always be in good condition and as far as possible unpainted. Whenever using the ladder, it should be fastened to the building with ropes or chains or tilted. In slippery places, ladder shall be supported by additional supports to prevent it from slipping or may also be erected by using the base of the support which is at 1/3 of the length of the ladder. The user must know how to work on the stairs by dangling one leg between the stairs. So, when the ladder slides the ladder will not harm the user.

3.0 CLASSIFICATION OF TYPES OF ELECTRICAL INJURIES

The main injuries caused by electricity are:

1. Electric shock
   Electric shock occurs when a person is touched or exposed to an electrical source. The electric current that passes through the body, since human body is an electrical conductor, has the potential to cause the individual suffer thermal burns, internal injuries to muscles or organ and disorder of heartbeat that can cause shock (cardiogenic shock).
2. Electrocution (Death due to electric shock)
3. Burning
4. Fell down

The danger of electric shock depends on the following factors:

1. High current (the higher the current , the higher risk of death)
2. Duration (the longer the shock, the higher the risk of death)
3. Direction of current travel. If current flows through the heart, risk of death is most likely.
4. Voltage (the higher the voltage, the lower the resistance and the high risk of death).

3.1 THE CAUSE OF THE ELECTRIC SHOCK

Most cases involving adults occur due to exposure to electrical sources during work. Accidents involving teenagers occur due to curiosity and risky activities that expose these teenagers to the dangers of electric shock. Babies and children are exposed to electrical sources at home because they consider electrical appliances as toys or materials to be eaten (bites). The factors that cause electric shock are:

1. Negligence
2. Leakage Current
3. Broken/Exposed Conductor Or Cable
4. Direct Touch
5. Indirect Touch

1. Negligence

If the work is done without full concentration, negligence in handling the work is bound to occur. For example, maintenance work or testing is done without disconnecting the supply.

2. Leakage Current

Leakage currents can cause the metal frame to come to life and can pose a danger of electric shock when the user holds the metal frame.

3. Broken/Exposed Conductor Or Cable

Conductors or cut off cables and live or exposed cable is dangerous. Avoid holding the cable and must report to the responsible parties immediately.

4. Direct Touch

Direct touch means the user gets a shock by touching the live conductor directly. For example, holding a damaged cable (without insulation), touching an exposed part of the live conductor.

5. Indirect Touch

An electric shock that occurs due to contact of something connected to an electrical installation but not direct contact with a live conductor, is likely due to equipment or installation damage. This shock may occur due to contact that occurs between the user with installations or equipment that are not directly connected to the electrical supply but become a source of life when the damage happen. Refer to Table 3.1, Table of current ratings and received shock levels.

Table 3.1: Table of current ratings and received shock levels

Current ratings	Danger to the user who touches it
1mA	No danger
10mA – 15mA	Stiff and numb
25mA – 30mA	More pronounced stiffness to paralysis
50mA keatas	Stopping a potentially fatal heartbeat

Competent People

The 1994 electrical regulations require all electrical work to be carried out by or under the direct supervision of a competent person registered with the Suruhanjaya Tenaga. In addition, the electrical contractor who carries out the electrical work must also be registered with the Suruhanjaya Tenaga.

Therefore, the owner of the installation must ensure that the appointed electrical contractor is registered with the Suruhanjaya Tenaga and his registration is still valid.

4.0 MAINTENANCE

4.1 DEFINITION OF MAINTENANCE

According to the technical dictionary, maintenance is a combination of all technical processes and things that connect the movement of a maintenance system (equipment or machine) that aims to make the equipment in a system to function according to the implementation of the required planning.

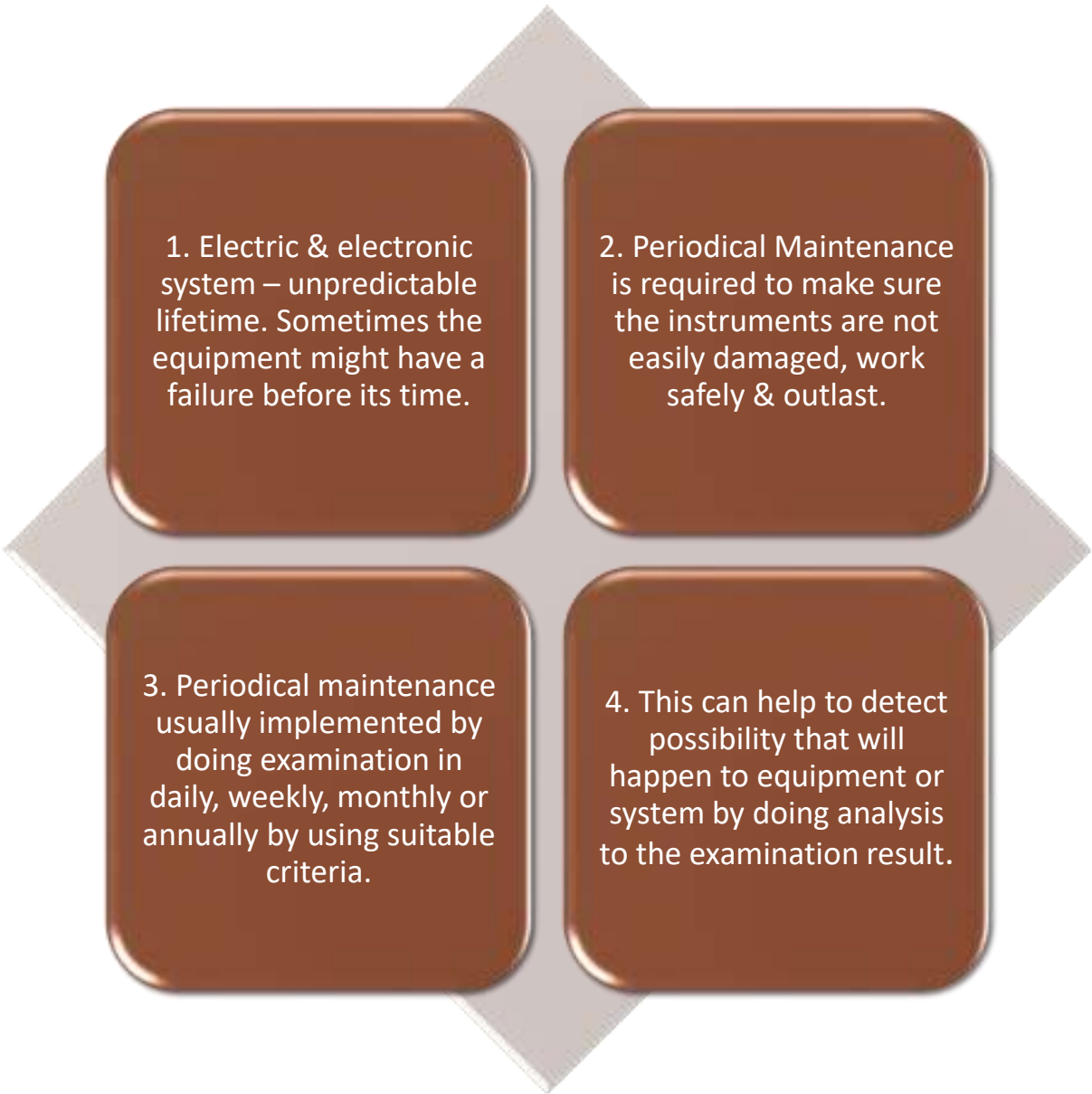
4.2 OBJECTIVES OF MAINTENANCE

The main objective of maintenance is the combination of tasks that need to be performed to maintain and repair any equipment so that it is in satisfactory and good condition.

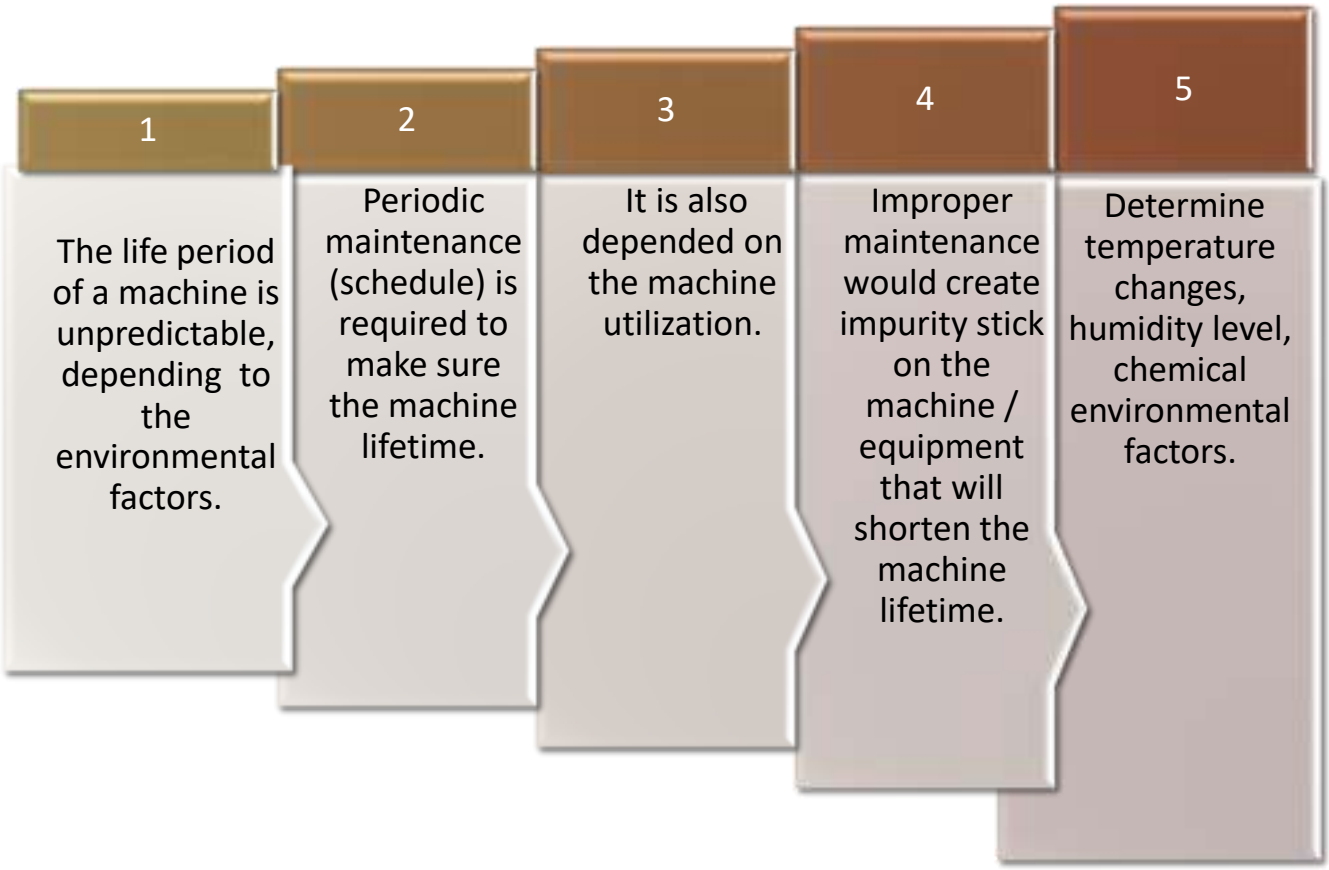
On The following are the Maintenance Objectives:

1. Able to update the equipment system or a machine.
2. Able to reduce the risk of damage to equipment maintained.
3. Able to improve the quality and value of equipment to the opitmum level.
4. Improve the durability and toughness of the equipment maintained.
5. Able to easily identify damage to equipment that is maintained.
6. Able to minimize the maintenance cost

4.2.1 Able to reduce the risk of damage to equipment maintained.



4.2.2 Improve the durability and toughness of the equipment maintained.



4.2.3. Able to minimize the maintenance cost

1. Maintenance should be planned properly.

2. Made before a system or equipment is produce or operate.

Maintenance Planning

where all the maintenance process arrangement were made. In this period all information is produce and future plan is prepared. Without Maintenance Planning No maintenance plan determination to an equipment maintenance.

Preventive Maintenance

The purpose of this maintenance is to determine the condition of an equipment by referring to the observation data or by using a criteria that has been prepared in order to reduce failure in the system that is plan to be made.

Repair Maintenance

Maintenance that is made after a failure happened to the equipment that is maintain . Also to keep the item where the maintenance can be made for the equipment to operate according to the function that is needed.

4.2.4 Able to minimize the maintenance cost

Emergency Maintenance	Term & Regulation	Maintenance schedule
• This maintenance is needed to repair a machine immediately to avoid serious effect to the machine. • Normally this maintenance need a long period of maintenance; more than one day. This failure are affected by the environment effect.	• Maintenance that are more to preventive action where it starts with the discussion result. • This is followed by the term & regulation which all the result item should be done routinely or by using a process that connected to the monitoring system.	• Complete schedule system that contain with the maintenance schedule, preventive activity that are covered with date, time, operation number & etc.

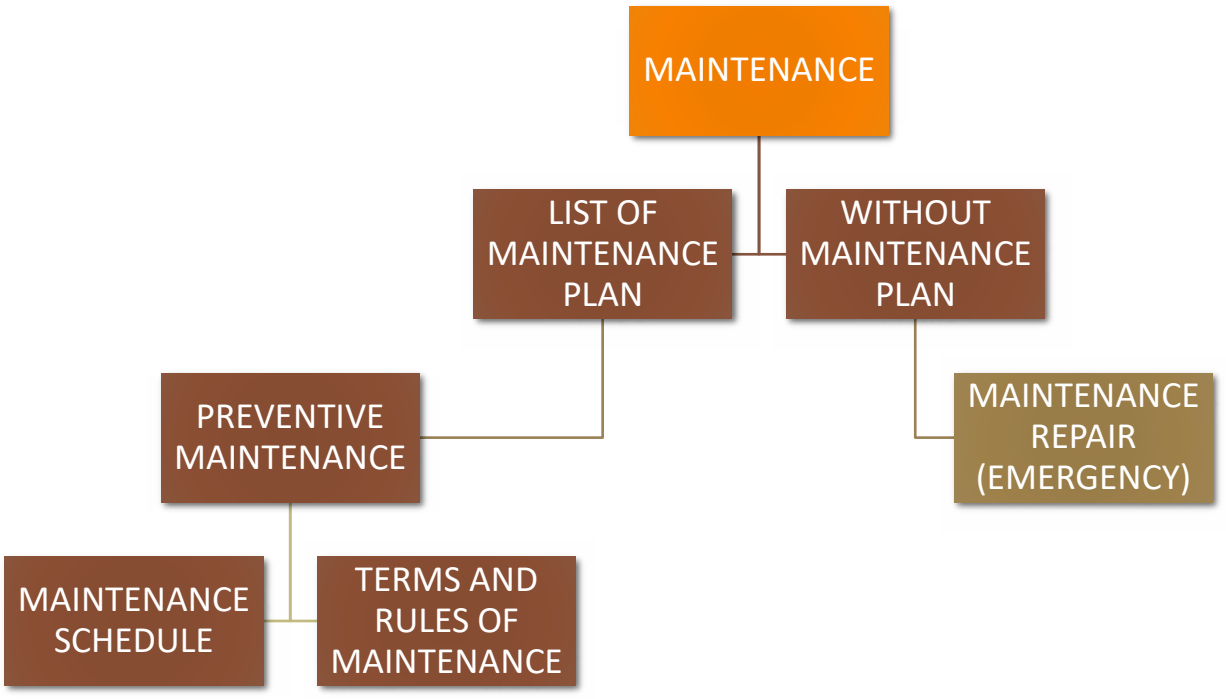


Figure 4.1 shows the relationship between the minimum cost of plan. The initial cost for planned maintenance is higher compared to the cost required for unplanned maintenance. These costs will increase slightly due to regular maintenance activities performed and due to the increasing age of the machine used.

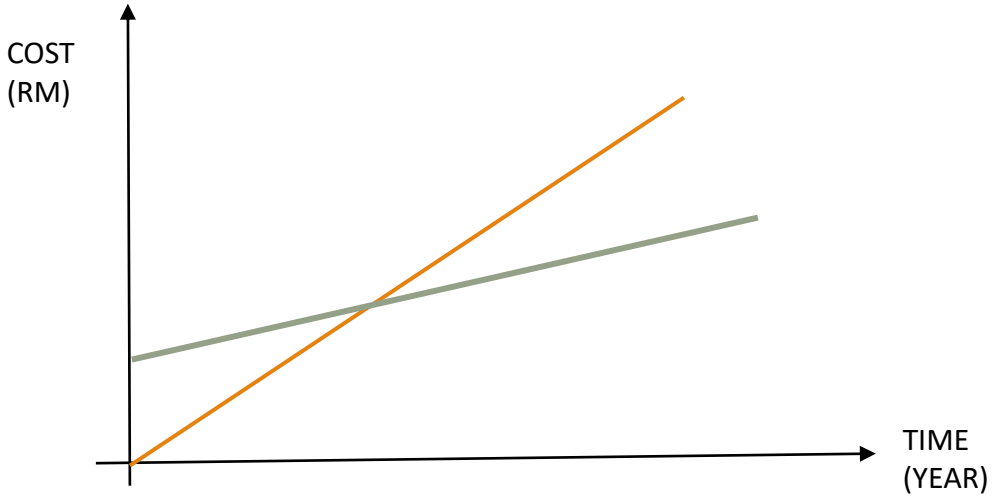
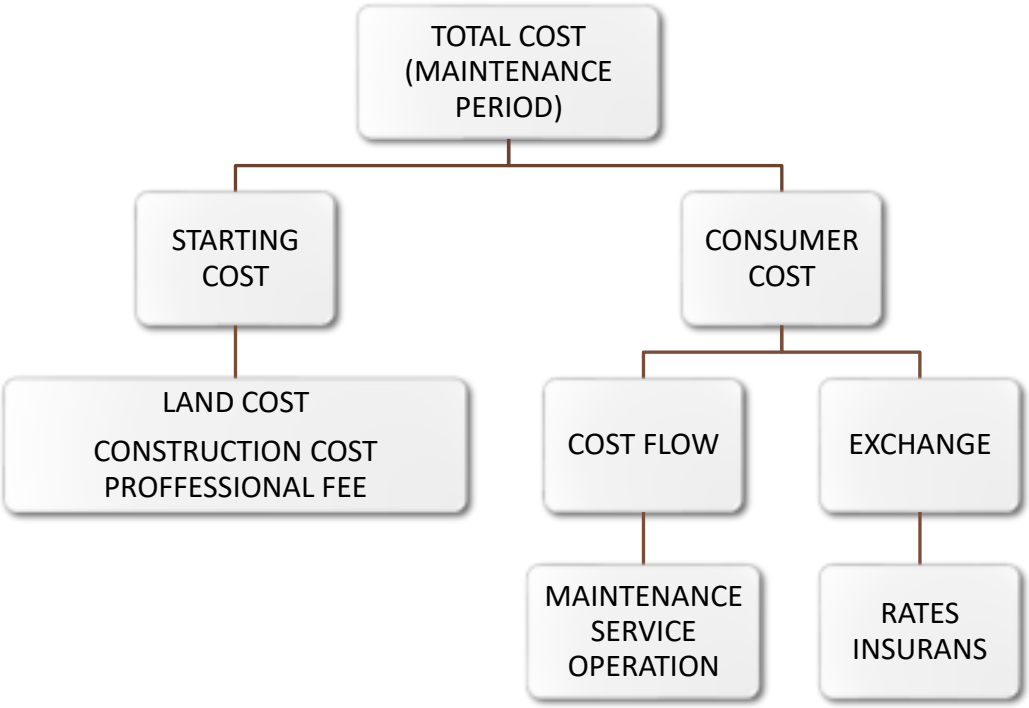


Figure 4.1: Relationship between the minimum cost of plan

BREAKDOWN OF TOTAL COST



5.0 THE FUNCTIONS OF MAINTENANCE

5.1

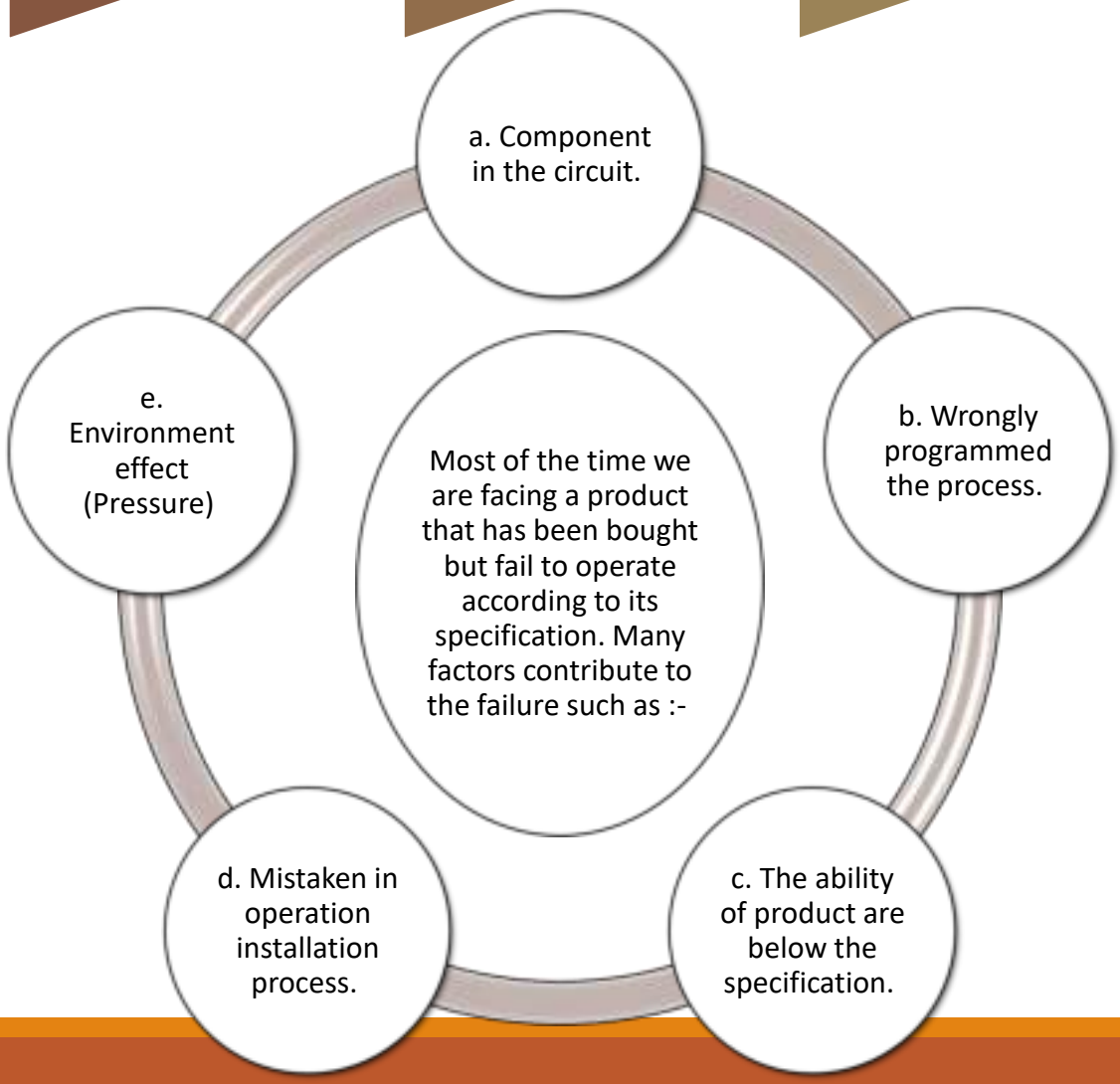
- To ensure items or components met the specification.

5.2

- **To ensure cost of the item produced is reasonable.**

5.3

- **To ensure machines or equipment can be used optimally**



5.1.1 To ensure items or components met the specification, full maintenance should be implemented.

Full Maintenance. Figure 5.1 shows that the Process of Full Maintenance.

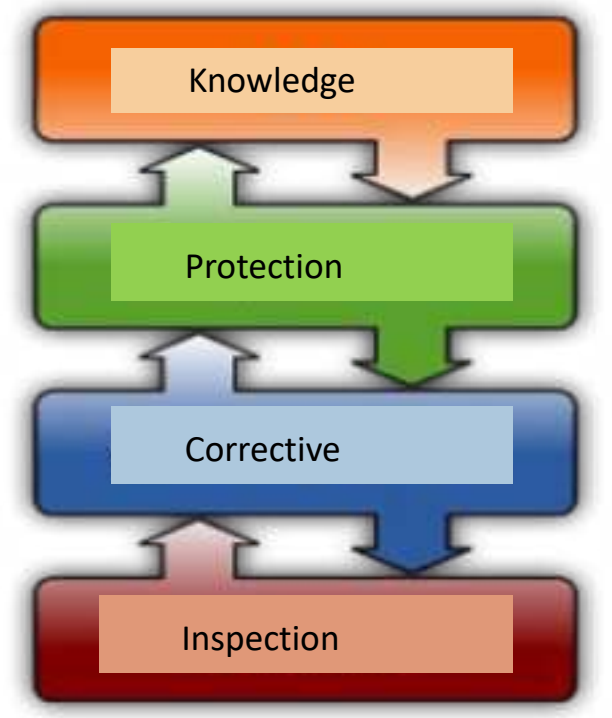


Figure 5.1: Process of Full Maintenance.

5.1.1.1 Knowledge

Knowledge here means what are the ability and the disability of the product or equipment. It includes the ability of product resistance to temperature, vibration & absolute maximum range of product. In additional, it is important to understand below terms if we want to know whether the product follow the specification or not.

In addition to durability, other things that need to be considered to ensure that the goods meet the specifications are:

1. Sensitivity
2. Accuracy
3. Precision
4. Linearity
5. Hysteresis

5.1.1.2 Protection

Based on the knowledge, for sure maximum protection can be given to the equipment @ product. As example, if the equipment cannot operate in high temperature, the equipment should be placed at room temperature.

5.1.1.3 Corrective

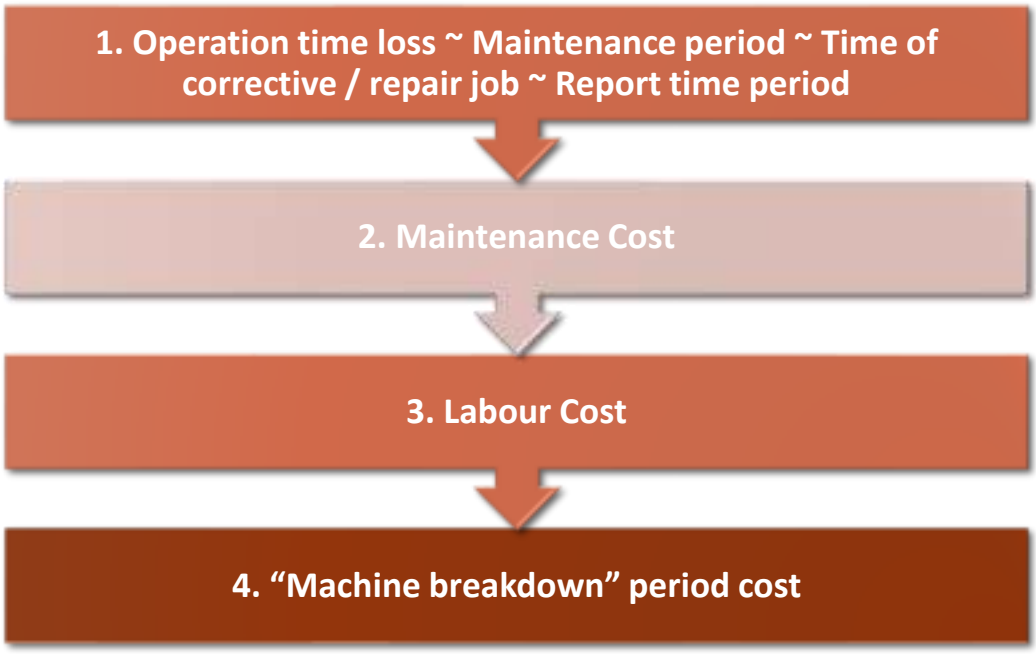
To make sure the product constantly operate in the specification limit, corrective maintenance should be routinely implemented. No matter major @ minor failure occur, the corrective maintenance should be urgently implemented.

5.1.1.4 Inspection

This is the most important procedure in the process of full maintenance. Logbook/form need to be prepared to make sure the checking/examination follow the procedure. The best examination/checking that is include with the daily , weekly, monthly and also yearly checking maintenance.

5.2.1 To ensure cost of the item produced is reasonable.

- Analysis is made to the cost of time, labour and financial (profit/loss)
- As an example , in a firm (industrial), the analysis is included with :-



- For individual responsibility – to make sure the product is reasonable compared to the price, check the ability & disability of the product.

5.3.1 To ensure machines or equipment can be used optimally

Below maintenance should be implemented :-

Fault/Breakdown Maintenance	• implement after the machine or equipment breakdown
Protective/Preventive Maintenance	• implement before the machine or equipment breakdown to avoid a major failure.
Service List/Predictive Maintenance	•The maintenance method also known as Preventive maintenance. •Implement by doing an analysis to detect problem at the equipment or machine without disturbing the production schedule.
Modification/Condition-Based Maintenance	• Should only be done when the machines have continuity with other work of system. It is performed by using PLC systems where the system will be connected to the computer machine monitoring operating conditions. If problems occurred, the computer would do the alignment automatically or the computer will issue a warning and let maintenance personnel whether do the service manually or not. Very effective but very high initial cost but provide long-term returns are very high.

Ensuring the Cost of Goods Produced is Reasonable

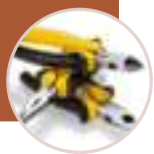
To ensure that the cost of the goods produced is affordable, the main thing that needs to be considered is to make an analysis. Regardless of anyone whether it is an individual, a group or even a large company, analysis needs to be done so that the cost of the goods produced can give them a reasonable return. The cost meant here is in terms of financial cost (Profit/ Loss), manpower, time and so on.

For a large firm such as an industry, the analysis includes the following costs:

- Time during maintenance.
- Time to do repairs/overhauls.
- Time when reporting any problems.

1. Cost lost operating time (operation time lost)

2.Maintenance cost.

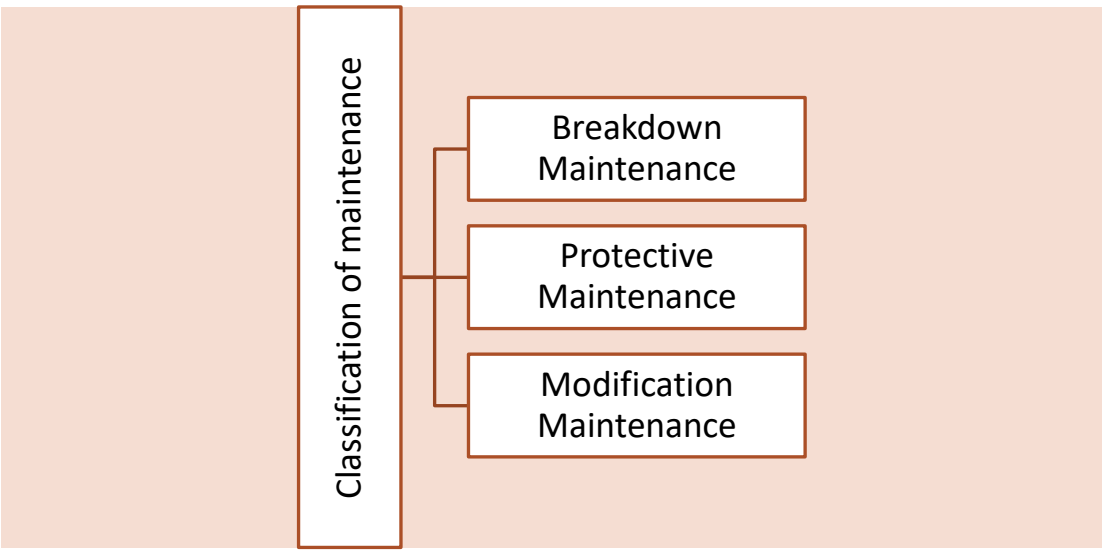


3. Labour costs.

4. Cost when machine breakdown

6.0 CLASSIFICATION OF MAINTENANCE

Costs are very important to be analyzed for the firm so that the goods produced can provide a reasonable profit to them. For individuals or consumers, to ensure that the goods obtained or purchased are reasonable with the price offered then the thing to do is to do an inspection. Inspection means an examination of the capabilities and deficiencies found in the goods.



6.1 FAULT (BREAKDOWN) MAINTENANCE

- It is implemented when a machine or equipment breakdown in operation period.
- Usually, the technician will do service activity to the machine. This method can save time but not effective in reduce cost for some machine.
- Normally an electric equipment failure are cause by the parts or components in the equipment because of too long operation period.
- Without a good maintenance planning, the component in the circuit will easily broken.

As an example, this is a type of failure that usually occur in a radio :

1. Failure in Power supply Circuit.
   Power Transformer Failure
   - Cause by the “open circuit” at the transformer coil.
   - This will cause the radio power supply interrupted, where the primary coil will not induce the secondary coil which contribute to the power supply failure. Short Circuit
2. Input Filter Capacitor Failure

6.1.1 Short Circuit

- ✓ Filter capacitor is in a parallel condition with the high voltage of positive & negative point.
- ✓ This capacitor act as charger & discharger to get a constant & linear direct current (dc).
- ✓ If the capacitor is not in good condition, it will easily break.
- ✓ i.e. when C1 short circuit, the current load that crossing the rectifier diode will become high & will affect the diode to be in a high temperature & broken.

6.1.2 Open Circuit

- ✓ Electrolytic capacitor is made from an electrolytic substances.
- ✓ This substances are easily dry that will make the capacitor to loss its capability & the cap value is decreased.
- ✓ This will affect the radio to produce a buzz sound.
- ✓ The DC voltage also will become lower because of the ripple & sometimes it is caused by a capacitor that is not properly assemble where sometimes the inner part of the capacitor will detach.

6.1.3 Leakage

Electrolytic capacitor have an acceptable range of leakage. For every micro Farad that is assemble to a 300-dc voltage, the leakage current is approximately 0.1 – 0.25 mA. And for a good capacitor, the leakage is below 10 mA. If the leakage is greater, the chemical substances will flow out.

To check the capacitor condition, adjust the meter to the ohm scale. If the meter pointer swiftly increase to the higher range, then turn slowly downward, this shows that the capacitor is in good condition and if there is no response to the meter pointer, this shows that it is broken. This capacitor acts as charger & discharger to get a constant & linear direct current (dc).

6.2 PROTECTIVE MAINTENANCE

- ✓ Covered the process of supervise the equipment in the aspect of checking & re-calibrate the equipment.
- ✓ This is a practical method because every equipment will be corrected in time-to-time base on the checking processes. This will increase the life period of the equipment & avoid it from breakdown in operation period.
- ✓ With this knowledge, maximum protection can be given. i.e., strength of temperature.
- ✓ If the component cannot stand to high temperature & strong vibration, so we need to locate it at low temperature & weak vibration area. So, we'll protect the equipment effectively.

- We need to do the maintenance routinely to guarantee the life period of an equipment.
- To make sure the component that is used in the equipment in a good condition & long lasting, take off the casing & clean up all the equipment in the circuit with a dry & clean cloth.
- This is to make sure there is no dust that can generate electrostatic that can damage the component. To clean the area that are out of sight, don't use high pressure air nozzle instead, use a gentle brush. This is to avoid the dust from going to other area.
- To avoid failure from occur, make sure all the wire connection arrangement in the equipment is orderly tied. Make sure the wire is not touching the component that emit heat because it can damage the wire. If there is a minor failure occur to the wire, the wire should be replaced as soon as possible.
- To make sure all the adjustable button operate effectively, use cleaner degreaser. Spray it to the moving area. For an equipment that are using battery, make sure replace the weak battery to avoid acid that is produced by the battery so as not to damage other equipment.

6.2.1 How to protect an electric equipment.

6.3 MODIFICATION MAINTENANCE

It is implemented to a machine @ equipment based on conditioned or it cannot be repaired to be functioned as before. This might be happened to an old machine or equipment where the spare part were difficult to find.

6.4 ENERGY MANAGEMENT SYSTEM IN MAINTENANCE ORGANIZATION

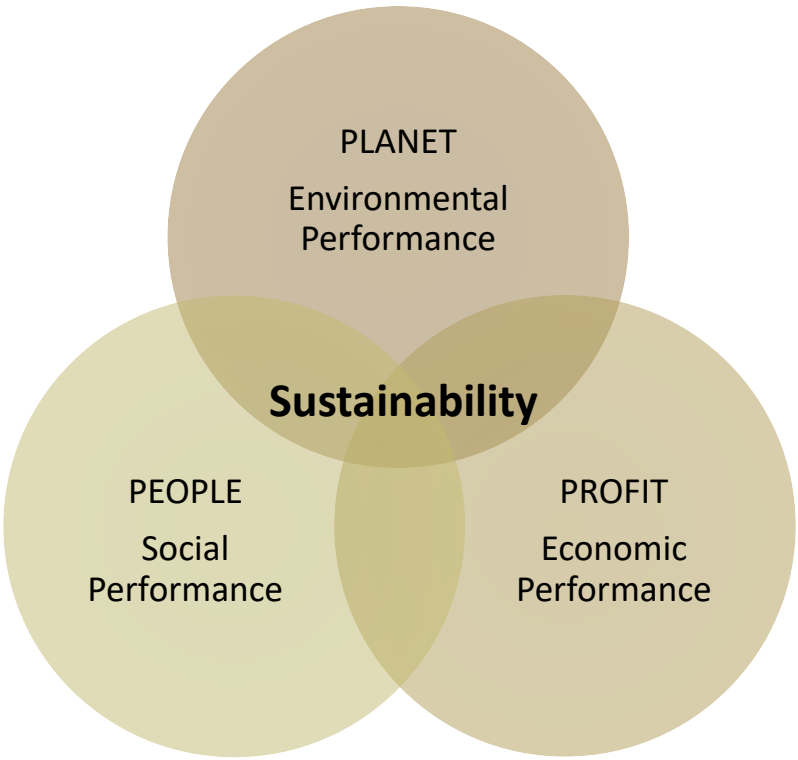


Figure 6.0: Triple Bottom Line

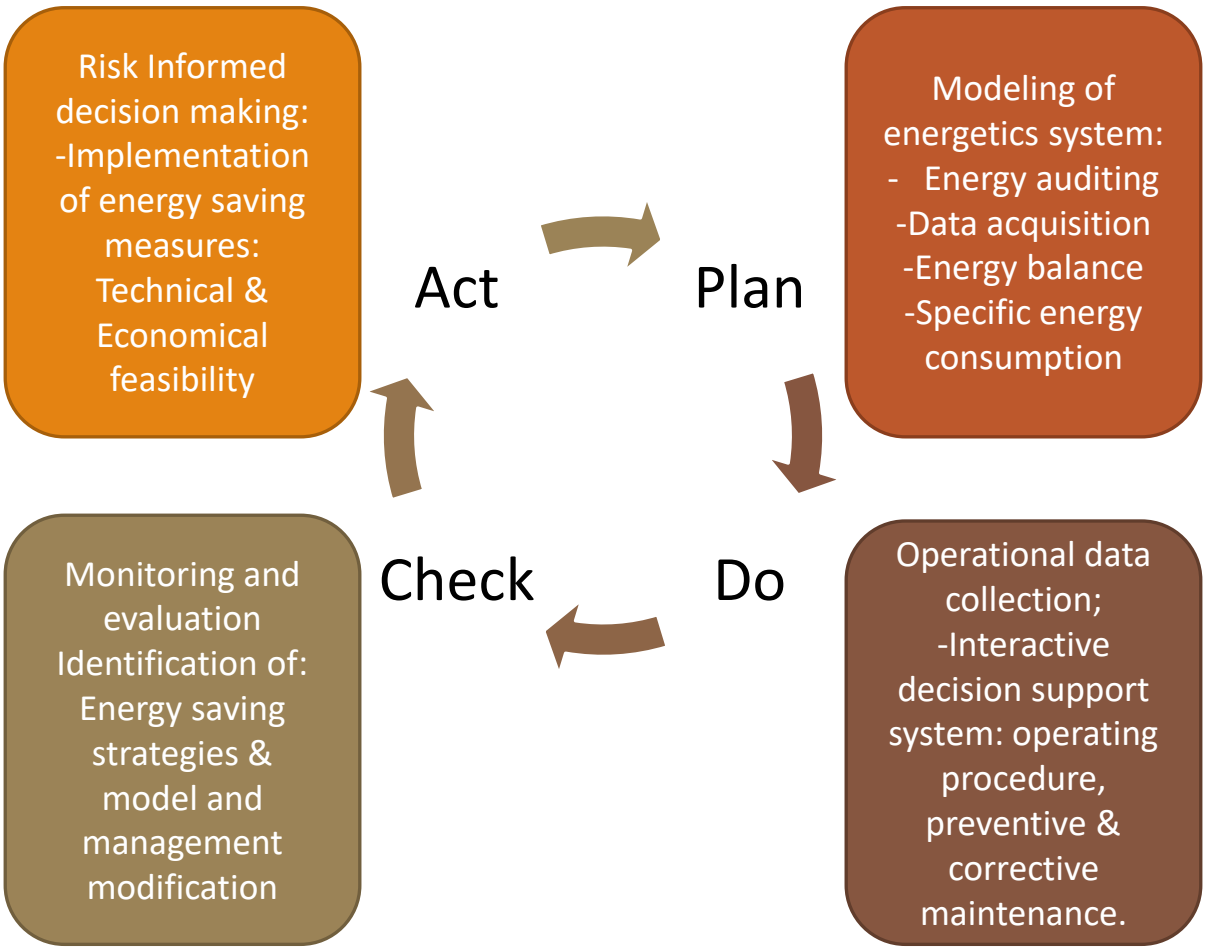
6.4.1 Maintenance, An Energy Efficiency Opportunity

In great energy consuming industries with high carbon dioxide emissions, various energy saving strategies are practiced such as energy saving by management, technologies and policies.

The importance of energy efficiency in manufacturing industries is to reduce energy cost and consumption also environmental impacts (CO_2 emissions, wastes).

Many energy efficiency measures in industry consist of improving purchasing, maintenance practices and procedures. These measures often have positive implications other than just energy savings. They can also reduce maintenance costs and increase the productivity benefits of the site, and vice versa.

- To achieve these results, an Energetic Efficiency Management System (EEMS) is needed, that will require a structure like all other industrial management systems.
- An EEMS scheme has been developed which also includes the decision-making procedure that allows the selection of an optimum set of maintenance and operating procedures, to achieve high performance of the system that it is shown below:


Risk Informed decision making: -Implementation of energy saving measures: Technical & Economical feasibility
Act
Plan
Modeling of energetics system: - Energy auditing -Data acquisition -Energy balance -Specific energy consumption
Check
Do
Monitoring and evaluation Identification of: Energy saving strategies & model and management modification
Operational data collection; -Interactive decision support system: operating procedure, preventive & corrective maintenance.

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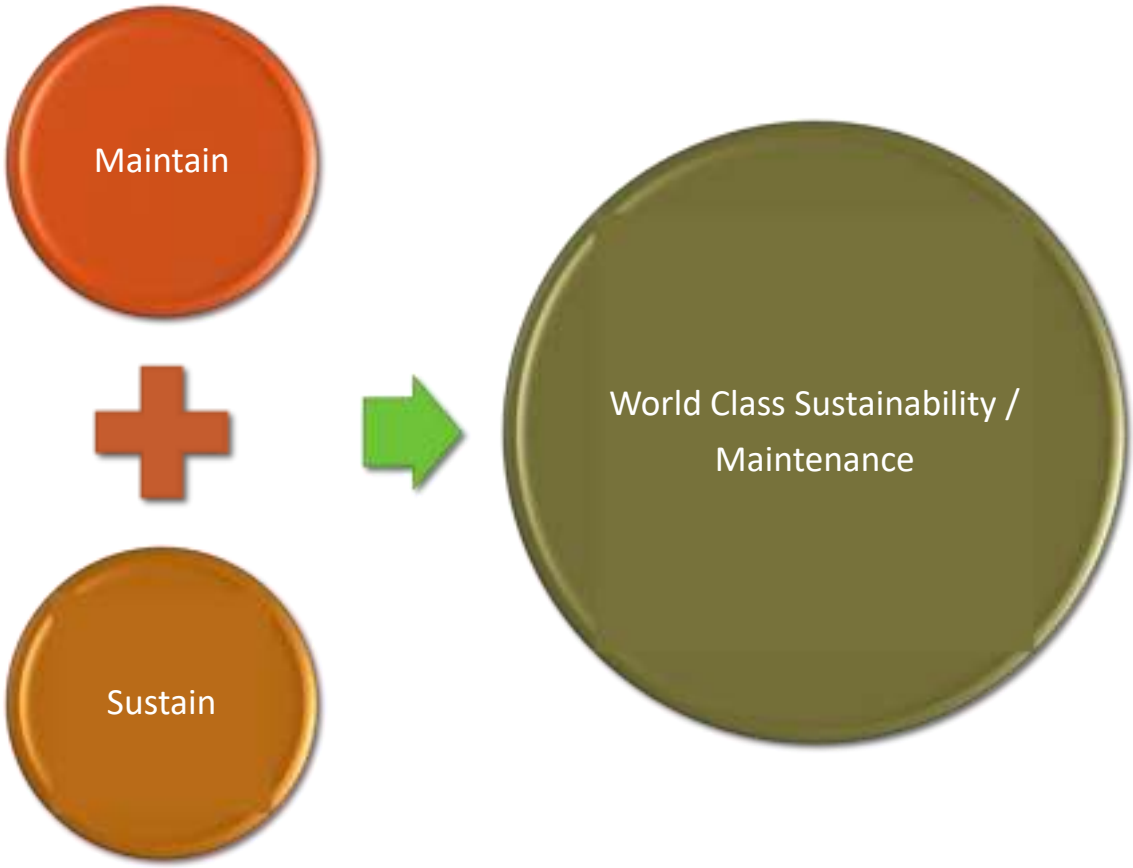
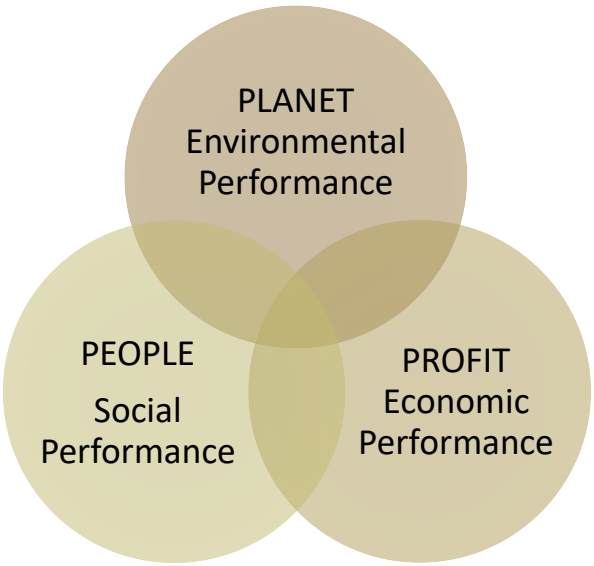


- ✓ Organizations that established enterprise preventive and predictive maintenance programs find that maintenance costs can be reduced by >40% and energy consumption by >10%.
- ✓ Properly maintained equipment also produces less waste and environmental impact.
- ✓ Safety is dramatically increased when equipment is properly maintained because it improves employee morale and public perception of the organization.

- Energy conservation is critical to sustainability because it heavily impacts all three areas of the Triple Bottom Line.



Triple Bottom Line

- Many people outside of the maintenance function fail to recognize that performing world-class preventive maintenance (PM) and predictive maintenance (PdM) provides more than just equipment reliability; it also helps to:
  i. save energy
  ii. extend equipment life,
  iii. reduce system downtime and
  iv. increase the overall safety of the facility.

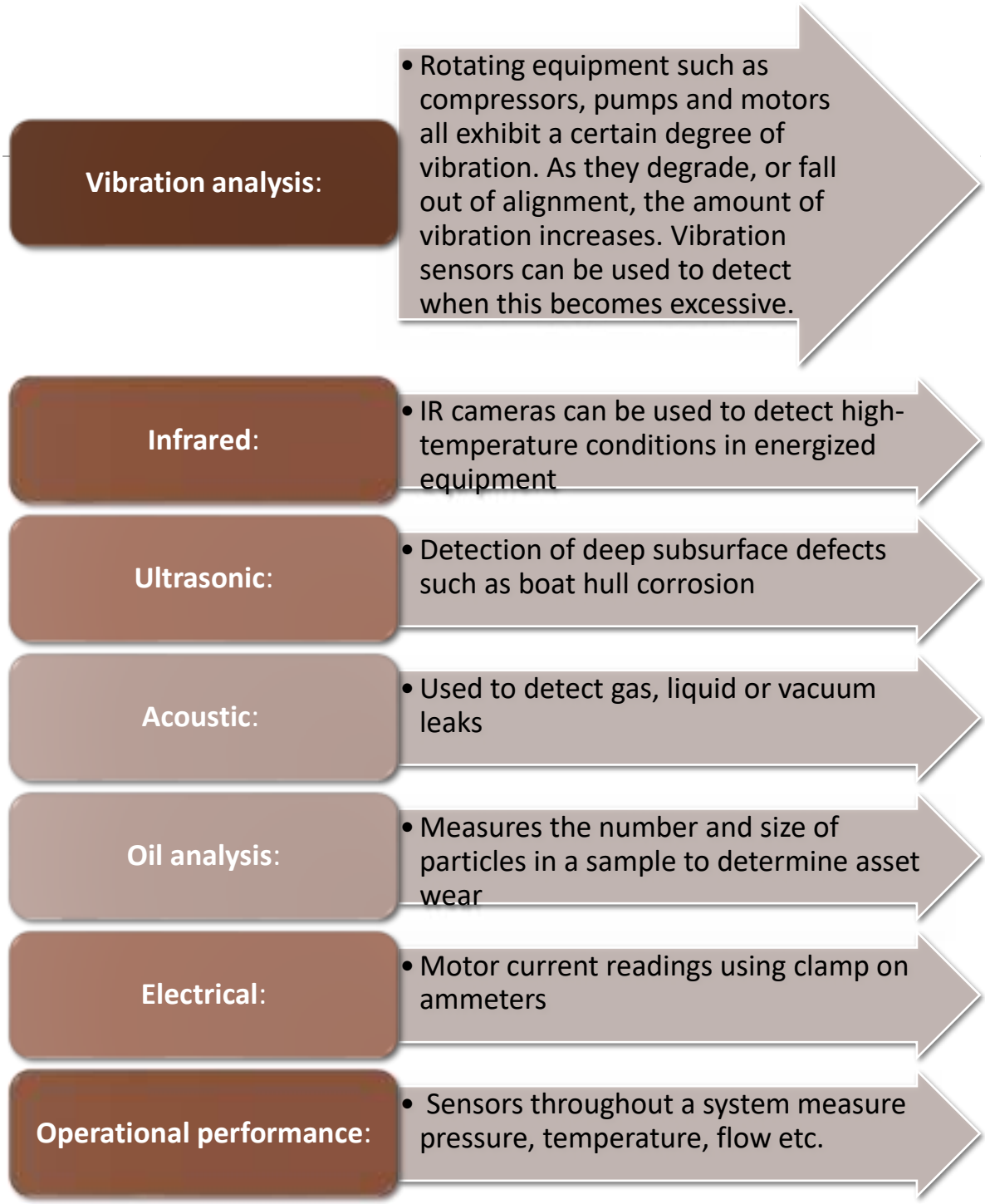
- There are many characteristics of World Class Maintenance practices, but effective planning is the most influential.

- Planning is best with the detailed tasks and well-defined equipment hierarchy; AND sufficient notice. This is where Condition Based Maintenance is the ultimate driver of effectiveness.

- The idea behind condition-based maintenance is to replace the oil only when a replacement is needed, and not on a predetermined schedule.

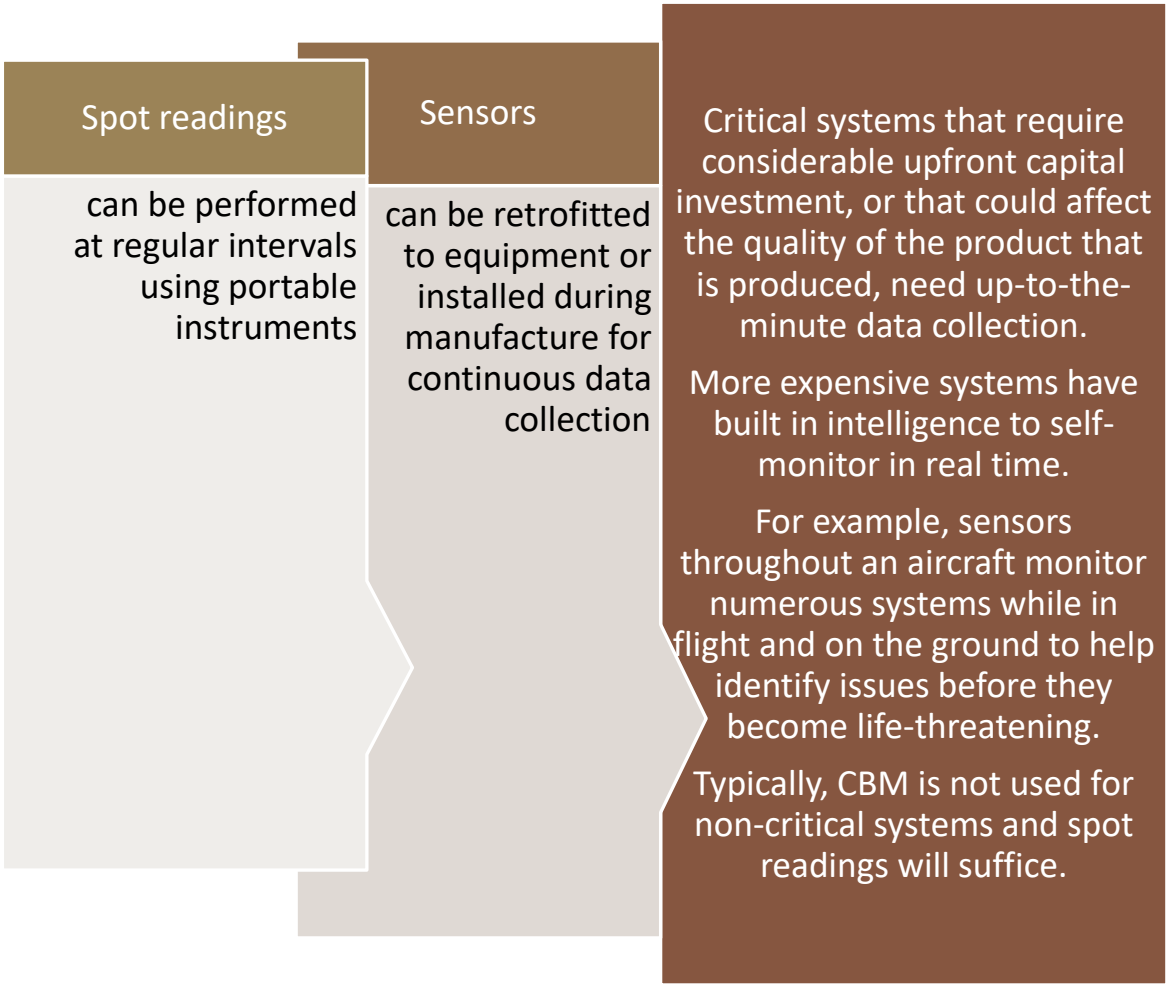
In the example of industrial equipment, oil analysis can perform an additional function too.
By looking at the type, size and shape of the metal particulates that are suspended in the oil, the health of the equipment it is lubricating can also be determined.

There are various types of condition-based monitoring techniques as below:



Data collection

Data can be collected from the system by two different methods:



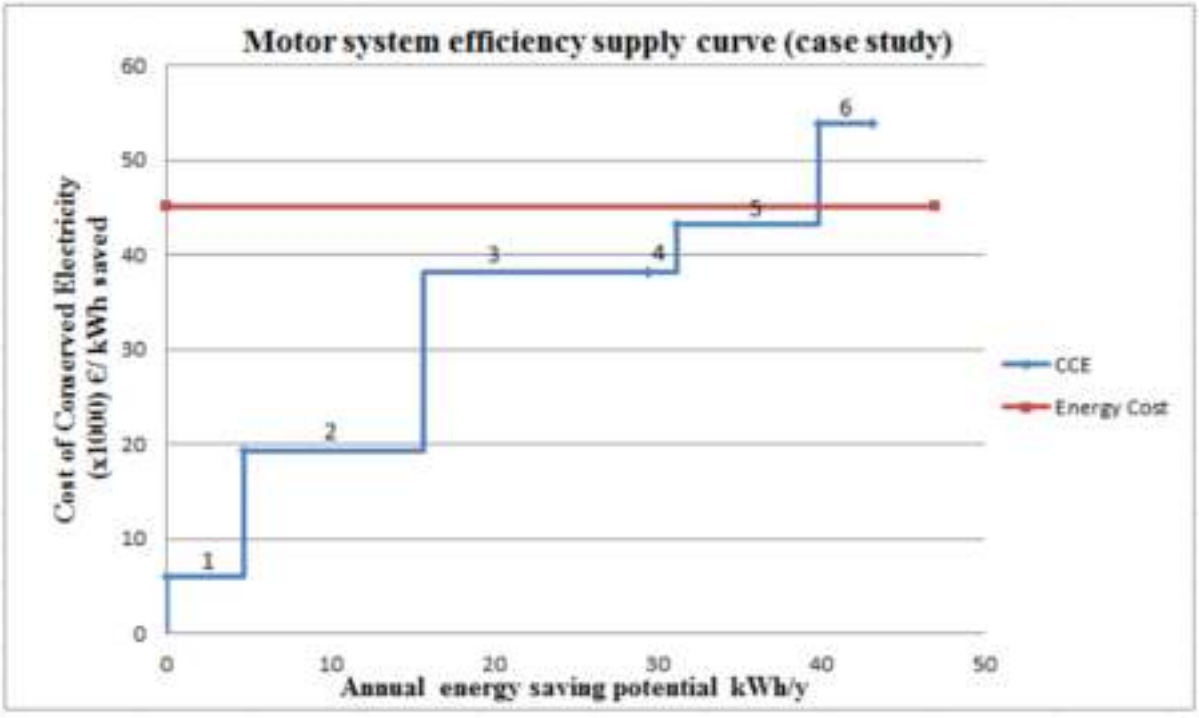
Energy efficiency measures for the motor system (case study) Table 1

Energy efficiency measures for motor system	Base case efficiency scenarios: Low (Up to15%)	Med. (Up to 10%)	High (Up to 15%)	Cumulative annual energy saving kWh/y	Cumulative annual potential CO_2 reduction $kgCO_2/y$
	Possibility of energy recovery %			For Med. level	For Med. level
Upgrade system maintenance					
1. Fix leaks, damaged seals and packing	3.0	2.0	1.0	4.696	2.348
2. Remove sediments from mixer	7.0	5.0	3.0	15.668	7.834
3. Replace Motor with more energy efficient type	14.0	7.0	5.0	29.413	14.706
4. Use of new technologies and more efficient devices, like: New belts(higher power transition and maintenance free)	1.0	1.0	1.0	31.240	15.620
5. Initiate predictive maintenance program (maintenance optimization)	7.0	5.0	2.0	39.917	19.959
6. Use of inverter (o Variable speed drive)	*not economical convenient for the case study.			43.189	21.595

*Management consumption of the motor, to minimize peaks during start of the work is economic alternative for measure 6, by starting motor only one time a day, and turned off motor only at the end of the daily work.

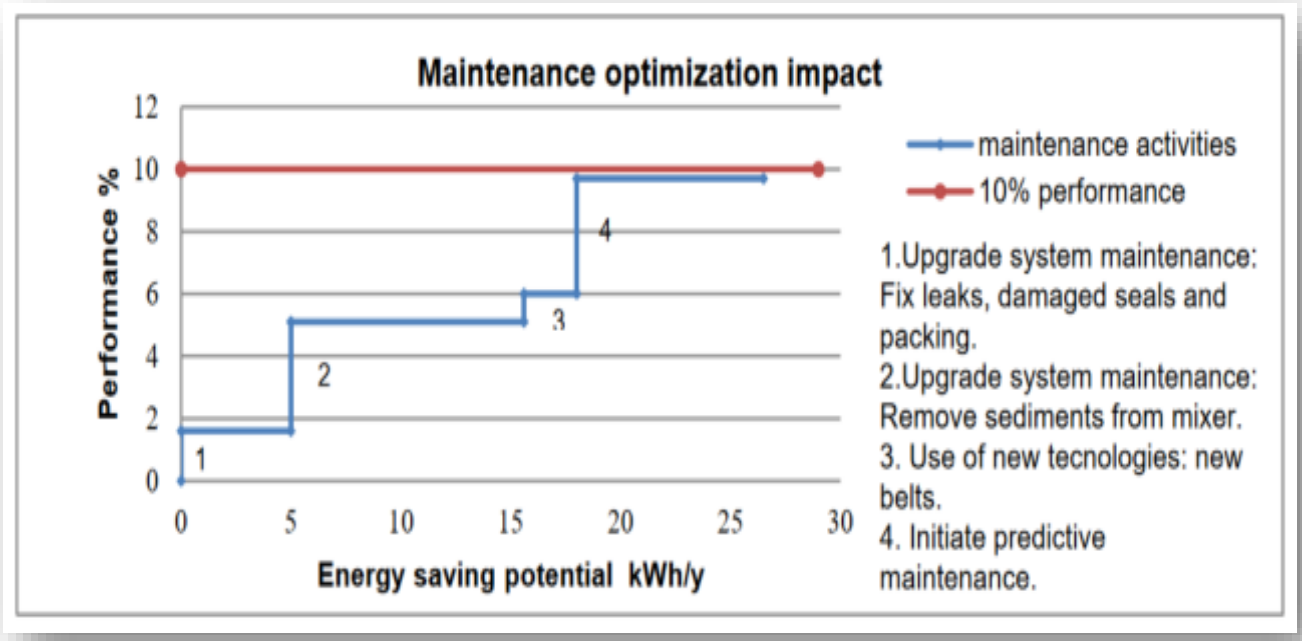
Figure below shows the conservation supply curve for the electric motor system (presented case study), that presents the energy saving potential as a function of the marginal Cost of Conserved Energy CCE, which accounts for the costs associated with implementing of each measure (Table 1) that includes maintenance and operation costs M&O.

Must be mentioned, the energy efficiency measures that are below the energy cost line (in this study the energy price is 0.15 RM/kWh, so annual electrical energy cost is about RM45000), are both technical and economic feasible so are cost-effective and the efficiency measures that are above the energy cost line are not cost effective, so in this study measure 6 is technically feasible, but is not economic.



The conservation supply curve for electric motor system

Results have also demonstrated that even only through maintenance optimization like; upgrade system maintenance, use of new technologies and initiate a predictive maintenance program, it is possible to increase the performance of the system up to 10%, for a medium base case scenario, as is shown in Figure below.



Maintenance optimization impacts

- ✓ In an integral compressor for gas transmission, the Specific Fuel Consumption (SFC) is the energy required to generate horsepower to compress the gas for delivery to the pipeline.

- ✓ When the SFC goes up, it indicates increased energy consumption that could be an equipment issue.

- ✓ With CBM, a maintenance task would use SFC with component measures to indicate the area to inspect or repair.

- ✓ If the degradation is in the second stage cylinder, a maintenance action for that cylinder would include safety information, tools and parts required, available properly trained technicians, and permit/tag out instructions that are generated directly between the equipment and the Maintenance Management Software to be sent to the responsible person.

QUESTION

1. Explain the definition of maintenance.
2. Describe the objective of maintenance.
3. Refer the Figure of 3.1, explain the graph

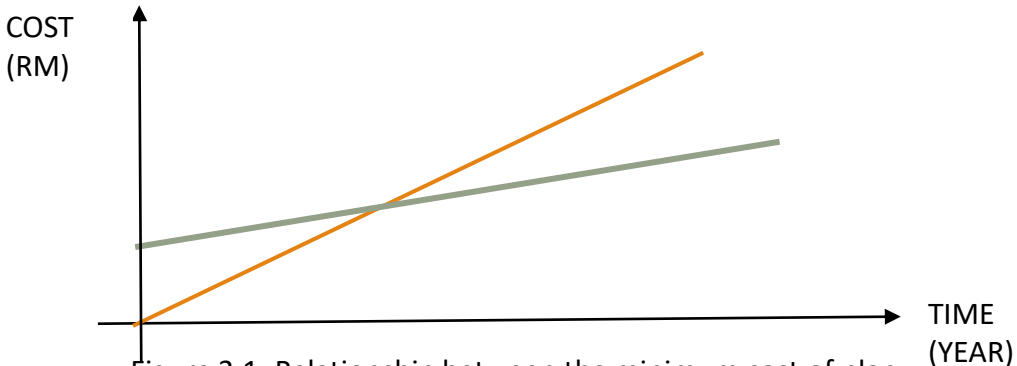


Figure 3.1: Relationship between the minimum cost of plan

4. What is the meaning of prevent to produce failure in maintenance?
5. Explain briefly how the course of maintenance can be reduced.
6. What is the factor that reduce the life period of the machine that are using electronics components?
7. Give 3 factors that contribute to the failure of a product.
8. State 4 basic methods that are needed to implement full maintenance.
9. Why there is always exist a product that is bought not fulfill its specification and customer needs?
10. Why do we need to implement the full maintenance to an equipment?
11. State the basic requirement to do the full maintenance.
12. State the knowledge that are required to determine whether a product follow its specification.
13. What is the meaning of protection in a full maintenance?
14. What are the cost type that is needed to make sure the product have a reasonable price?
15. List the maintenance that is needed to make sure the machine or equipment can be used optimally.

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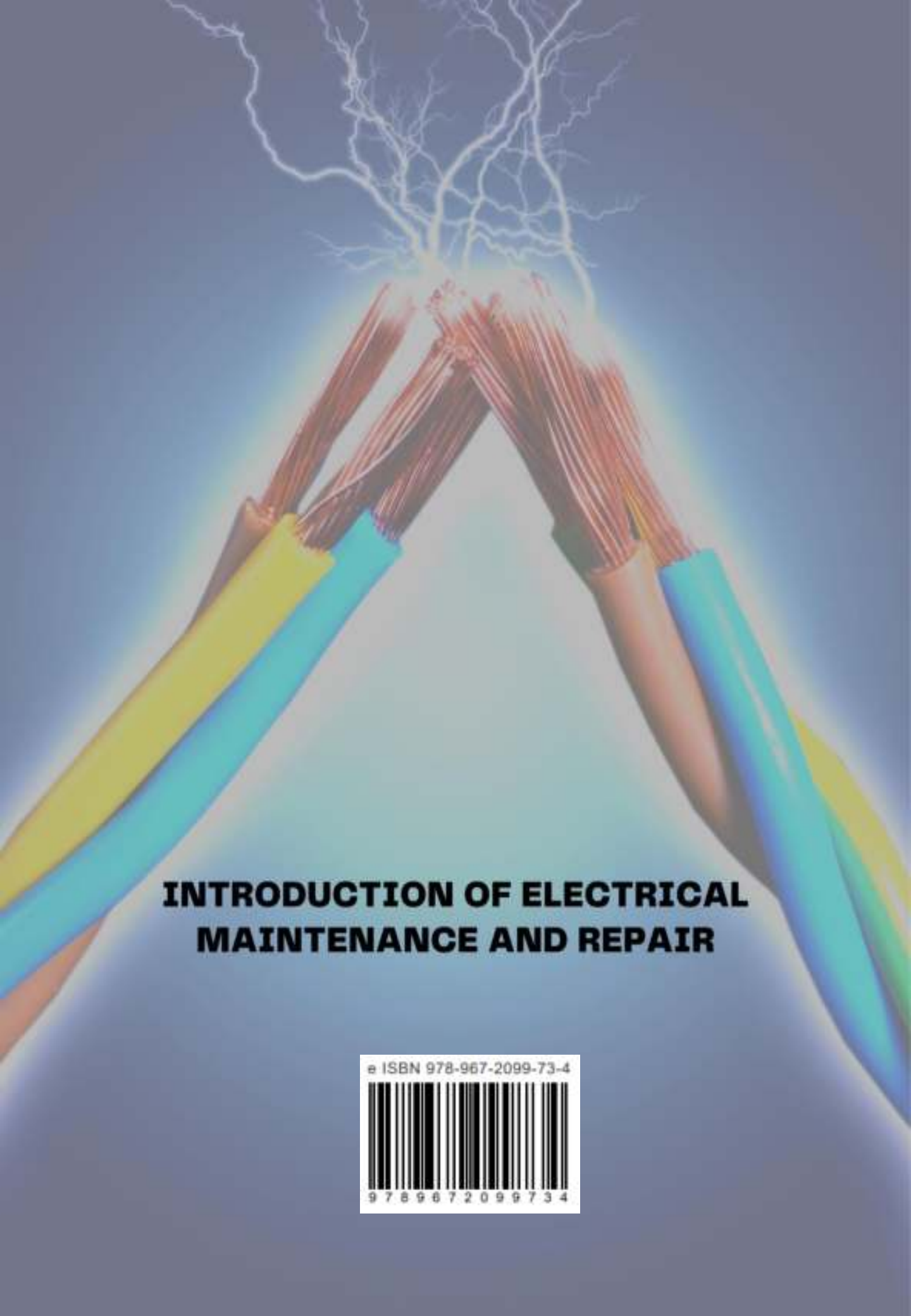

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