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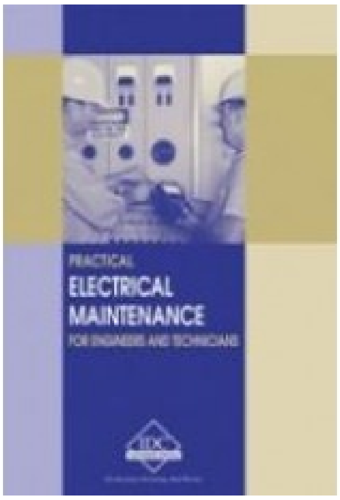
RC-E - Electrical Maintenance for Engineers and Technicians



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Short Description

This manual will update you with the latest information on cables, substations and switchgear, transformers and circuit breakers. You will become familiar with the latest techniques in control and maintenance and safety operations of the above-mentioned electrical equipment.

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First Chapter

Electrical Preventive Maintenance

1 Electrical Preventive Maintenance

In this chapter we will learn about Electrical Preventive Maintenance (EPM). We will discuss objectives and benefits of EPM. Planning an effective EPM program, record keeping, personal safety, equipment maintenance, production economics and energy conservation are covered in this chapter.

Learning objectives

- Elements of preventive maintenance
- Benefits of EPM
- Planning an EPM
- Production economics
- Energy conservation
- Record keeping

1.1 Introduction

Preventative maintenance (PM) is a program of routine equipment inspections, maintenance tasks and repairs which are scheduled to ensure that degradation of equipment is minimized. A well planned and designed preventative maintenance program keeps equipment/facilities in satisfactory operational state by providing for systematic inspection, detection, and correction of incipient failures either prior to their occurrence or prior to their development into major failure.

Predictive maintenance is the technique of regularly monitoring selected parameters of equipment operation to detect and correct a potential problem before it causes a failure. This is done by trending measured parameters which allows a comparison of current parameters to historical data. From this approach ensures that the right maintenance activities are performed at the right time.

The main objectives of PM are to:

- enhance capital equipment productive life
- reduce critical equipment breakdowns
- allow better planning and scheduling of needed maintenance work
- minimize production losses due to equipment failures, and
- promote health and safety of maintenance personnel

If maintenance is carried out reactively, in response to interruptions, breakdowns and other unfortunate events, then this kind of approach can be severe, especially at operations such as processing plants, assembly lines and power plants, where the failure of a relatively minor component can disrupt the entire facility. The total cost of downtime and emergency around-the-clock repairs can be overwhelming. Where as a preventive maintenance program ensures continuity of operation and reduces the danger of unplanned outages. Planned shutdowns during periods of least usage, helps in detecting troubles in the early stages and corrective action taken before extensive damage is done.

Table 1.1 shows results of the survey conducted by the IEEE Industrial Commercial Power Systems Committee.

Deterioration of electrical equipment is inevitable whereas the equipment failure is not inevitable. The deterioration process can cause malfunction or an electrical failure. An effective EPM program identifies and recognizes these factors and provides measures for coping with them.

Other potential causes of equipment failure can be detected and corrected through EPM, such as load changes, voltage conditions, improperly set protective relays and changes in circuits.

Table 1.1

Effect of EPM frequency of inspection on overall costs

Number of failures versus maintenance quality for all equipment classes combined

	Number of failures		
Maintenance Quality	**All causes**	**Inadequate Maintenance**	**Percent of Failures due to inadequate maintenance**
Excellent	311	36	11.6%
Fair	853	154	18.1%
Poor	67	22	32.8%
Total	1231	212	17.2%

1.1.1 Elements of preventive maintenance

The following are the seven elements of preventive maintenance (seen in Figure 1.1):

- Inspection: Periodically inspecting materials/items to determine their serviceability by comparing their physical, electrical, mechanical, etc., characteristics (as applicable) to expected standards.
- Servicing: Cleaning, lubricating, charging, preservation, etc., of items/ materials periodically to prevent the occurrence of incipient failures.
- Calibration: Periodically determining the value of characteristics of an item by comparison to a standard; it consists of the comparison of two instruments, one of which is certified standard with known accuracy, to detect and adjust any discrepancy in the accuracy of the material/parameter being compared to the established standard value.
- Testing: Periodically testing or checking out to determine serviceability and detect electrical/mechanical-related degradation
- Alignment: Making changes to an item's specified variable elements for the purpose of achieving optimum performance.
- Adjustment: Periodically adjusting specified variable elements of material for the purpose of achieving the optimum system performance.
- Installation: Periodic replacement of limited-life items or the items experiencing time cycle or wear degradation, to maintain the specified system tolerance.

Figure 1.1

Elements of preventive maintenance

1.1.2 Benefits of EPM

AS per NFPA 70B (National Fire Protection Association) standard, benefits of an effective EPM program fall into two general categories:

- Direct, measurable economic benefits – derived from reduced cost of repairs and reduced equipment downtime.
- Less measurable but very real benefits – result from improved safety.

Direct, measurable economic benefits can be documented by equipment repair cost and equipment downtime records after an EPM program has been implemented.

- A well-administered EPM program reduces accidents, saves lives, and minimizes costly breakdowns and unplanned shutdowns of production equipment.

- Improved employee morale — reduces injuries and property loss. Improved employee moral, comes with employee awareness of a conscious management effort to promote safety by reducing the likelihood of electrical injuries or fatalities, electrical explosions, and fires.
- Reduced personnel injuries, better workmanship and increased productivity, reduced absenteeism, reduced interruption of production, and improved insurance considerations.
- Equipment lasts longer and performs better
- Investment in EPM is small compared with the cost of equipment repair and the production losses associated with an unexpected equipment shutdown.
- With proper planning, maintenance costs can be held to a practical minimum, while production is maintained at a practical maximum.
- An effective EPM program satisfies an important part of management's responsibility for keeping costs down and production up.

Maintenance costs can be placed in either of two basic categories: preventive maintenance or breakdown repairs. The money spent for preventive maintenance will be reflected as less money required for breakdown repairs. An effective EPM program holds the sum of these two expenditures to a minimum. Figure 1.2 is a typical curve illustrating this principle. According to this curve, as the interval of time between EPM inspections increases, the cost of the EPM diminishes and the cost of breakdown repairs and replacement of failed equipment increases. The lowest total annual expense is realized by maintaining an inspection frequency that keeps the sum of repair/replacement and EPM costs at a minimum (Refer NFPA 70B Recommended Practice for Electrical Equipment Maintenance).

Figure 1.2

Effect of EPM inspection frequency on overall costs

1.2 Planning an EPM

The purpose of an EPM program is to reduce hazard to life and property that can result from the failure of electrical systems and equipment. A preventive maintenance program can only be effective if it is both well planned and regularly carried out. Planning involves understanding the electrical system, identifying and prioritizing equipment maintenance requirements and then establishing a maintenance schedule.

AS per NFPA 70B standard, the following basic factors should be considered while planning an EPM program:

- Personal safety
- Equipment maintenance
- Production economics

1.2.1 Personal safety

Personal safety should be given prime consideration in system design and in establishing maintenance practices. Safety rules should be instituted and practiced to prevent injury to personnel who are performing tasks and others who might be exposed to the hazard.

Maintenance should be performed only by qualified personnel who are trained in safe maintenance practices and the special considerations necessary to maintain electrical equipment. Employees who face a risk of electrical hazard should be trained to understand the specific hazards associated with electrical energy. The qualified personnel are expected to know the proper personal protection equipment (PPE) to avoid or mitigate electrical shock or burn exposure. The qualified person should determine if the hazard exposure is limited and restricted.

All employees should be trained in safety-related work practices and required procedures as necessary to provide protection from electrical hazards associated with their respective jobs or task assignments. The training should include information on the type of tools to be utilized. Instruction should be given in selecting the proper tool for the job and the limitations of the tool.

Electrically safe work condition should be established before performing maintenance of electrical circuits or equipment. According to 29 CFR 1910.333, “Occupational Safety and Health Act” (OSHA), circuits or equipment should be disconnected using proper de-energization means, also should be locked and tagged.

Article 130 of NFPA 70E, *Standard for Electrical Safety in the Workplace*, requires that electrical conductors and circuit parts that have not been de-energized or that have been disconnected [but not under lockout/ tagout, tested, and grounded (where appropriate)] not be considered to be in an electrically safe work condition and that safe work practices appropriate for the circuit voltage and energy level be used. All insulating tools and PPE should be tested periodically.

Switchboards, panelboards, industrial control panels, and motor control centers that are likely to require examination, adjustment, servicing, or maintenance while energized should be field marked to warn qualified persons of potential electric arc flash hazards. The marking should be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment.

In spite of all precautions, de-energized circuits can be inadvertently reenergized. When this occurs, adequate grounding is the only protection for personnel working on those circuits. For this reason, it is especially important that adequate grounding procedures should be established (Refer *NFPA 70B Recommended Practice for Electrical Equipment Maintenance*).

The following safety precautions should be observed:

- Personnel should wear personal protective equipment (PPE) such as goggles, gloves, aprons, and respirators when working with solvents.
- Care should be exercised in the selection of cleaning agents for any particular task, following all applicable environmental regulations.
- Adequate ventilation should be provided where cleaning agents are used, to avoid fire, explosion, and health hazards.
- A metal nozzle used for spraying flammable cleaning agents should be bonded to the supply drum and to the equipment being sprayed.
- Screens, ropes, guards, and signs should be provided to prohibit access to persons other than those necessary to perform the task.
- A procedure should be established to leave the test site in a safe condition when unattended.
- Employees should be trained to identify and understand the relationship between electrical hazards and possible injury.

1.2.2 Equipment maintenance

Many maintenance tasks require equipment to be shut down and de-energized for effective results. Other maintenance tasks might specifically require or permit equipment to be energized and in service while the tasks are performed. Examples include taking transformer oil samples and observing and recording operating temperatures, load conditions, corona, noise, or lamp output.

Coordinating maintenance with planned production outages and providing system flexibility such as by duplication of equipment and processes are two recommended means to avoid major disruptions of operations. An example of flexibility is a selective radial distribution system incorporating double-ended low-voltage substations. This system permits maintenance and testing to be performed on equipment such as the primary feeders, transformers, and main and tie circuit breakers during periods of light loads. Duplication of equipment enables maintenance to be performed economically without costly premium time and ensures continuous production in the event of an accidental breakdown.

Good quality equipment, appropriate for the task should be properly installed and maintained. Selection of quality equipment that is adequate for the present and projected load growth is a prime factor in reducing maintenance cost.

Scheduling maintenance

Effective maintenance program requires a positive mechanism for scheduling and recording the work that has been accomplished. Maintenance outages, particularly in plants that operate 24 hours a day, 7 days a week, are difficult to schedule. For example, low-voltage power circuit breakers should be inspected on an annual basis and tested under simulated overload and fault conditions every 3 to 5 years.

Many plants schedule shutdowns of 1 to 3 weeks duration to perform needed periodic maintenance on vital production apparatus that cannot be taken out of service at any other time. A total plant shutdown resolves the problem of scheduling partial outages around limited production operations. Even so, some difficulty might be encountered in providing power requirements for maintenance operations and still performing the needed maintenance on the electrical system. The distribution system should allow for maintenance work without load interruption, or with only minimal disturbances for critical loads. Table I.1 in *NFPA 70B Recommended Practice for Electrical Equipment Maintenance Annex I* gives an initial guideline for maintenance intervals for equipment.

Equipment safety

The protective device should be capable of immediately sensing an abnormality and causing it to be isolated with the least destruction and minimum disturbance to the system. The degree of sensitivity and speed of response is vital to the effectiveness of the protection. Applying the settings and periodic testing of the protective devices, relays, series and static trip elements, checking the proper type and ampere rating of the fuses used in the system is part of maintenance.

Rework, remanufacturing, or retrofitting process can be conducted by the original manufacturer or by another party with sufficient facilities, technical knowledge, and manufacturing skills. Safety certifications should be sought for repaired or rebuilt equipment.

Equipment cleaning

The cleaning method used should be determined by the type of contamination to be removed and whether the apparatus is to be returned to use immediately. Drying is necessary after using a solvent or water. Insulation should be tested to determine whether it has been properly reconditioned. Enclosure and substation room filters should be cleaned at regular intervals and replaced if they are damaged or clogged. Loose hardware and debris should be removed from the enclosures (new or unusual wear or loss of parts occurring after the cleaning can be detected during subsequent maintenance).

Methods of cleaning

Dirt should be cleaned with clean, dry, lint-free cloth or soft brush if the apparatus is small. Waste rags should not be used as the lint will stick to the insulation and collects more dirt. Care should be used to avoid damage to delicate parts.

If the dirt cannot be removed by wiping or vacuuming, compressed-air blowing can be used. Care should be taken while cleaning with compressed air as contaminants as compressed air can cause contaminants to become airborne which can foul the mechanical operation of nearby equipment. Therefore, other equipment should be guarded from the cross contamination. Air should be dry and directed in a manner to avoid further blockage of ventilation ducts and recesses in insulations.

Accumulated dirt, oil, or grease might require a solvent to remove it. A rag barely moistened (not wet) with a non-flammable solvent can be used for wiping. Solvents used for cleaning of electrical equipment should be selected carefully to ensure compatibility with materials being cleaned. Equipment might require cleaning by nonconductive sandblasting. Devices containing radioactive materials can require special precautions.

1.3 Production economics

Maintenance costs are usually due to manhours, materials and indirect costs. Preventive maintenance should be done when production is least effected. Assessing the costs of equipment downtime is an important step in the determination of costs of preventive maintenance.

A system in general is a complex configuration of different units, which may imply that downtime of one unit, does not necessarily halt the full system. It is important to identify which unit is most vital to production, and analyze the effect of repair or replacement of the unit on the production.

The failure of one component often is an opportunity to preventively maintain other components. Especially if the failure causes the breakdown of the production system it is favorable to perform preventive maintenance on other components. In such cases, only a little or no production is lost above that resulting from the original failure.

Maintenance scheduling in line with the production can reduce the good maintenance plan, one that is integrated with the production plan, can result in considerable cost savings. This integration with production is crucial because production and maintenance have a direct relationship. Any breakdown in machine operation results in disruption of production and leads to additional costs due to downtime, loss of production, decrease in productivity and quality, and inefficient use of personnel, equipment and facilities.

Selection of quality equipment that is adequate for the present and projected load growth is a can reduce the maintenance cost. Too often, installation cost without sufficient regard for efficient and economic maintenance influences system design. Within a few years, the added cost of performing maintenance plus production loss from forced outages due to lack of maintenance will more than offset the savings in initial cost.

1.4 Energy conservation

Equipment that is well maintained operates more efficiently and utilizes less energy. Energy management incorporates engineering, design, applications, operation and maintenance of electrical power system to provide for the minimum overall use of the electrical energy. Optimized use of electrical energy involves factors such as comfort, healthful working conditions, the practical aspects of productivity, aesthetic acceptability of the space, and public relations.

Any process requires a certain minimum consumption of energy. Energy additions beyond this minimum consumption require an evaluation of the incremental cost of more efficient or techniques versus the resulting energy savings or costs. Energy conservation can be obtained by proper maintenance and operation as follows:

- Shutting off unused equipment, eliminating steam, compressed air and heat leaks, proper lubrication of equipment, proper cleaning and replacement of filters in equipment
- Equipment and process modifications should be taken into considerations

during designing and planning, such as using more durable or more efficient components, more efficient design concepts or replacement of an existing process with an energy efficient process.
- Better utilization of equipment can be achieved by properly examining the production processes, schedules, and operating practices.
- Energy survey and energy balances identify energy wasting situations and differentiate between identify energy corrected by maintenance and operation actions from those that require capital expenditures.
- Power quality improvement – Energy savings can be achieved by improving the quality of the power supply to the utilization equipment.
- The I2R losses in electrical conductors can be reduced by selecting an increased wire size in cabling and by using a heavier cross section in busbars.
- Energy savings can be achieved by specifying and purchasing efficient transformers and operating the transformer efficiently.
- Provide zoning capability to shut down unused areas.

1.5 Record keeping

Records should be maintained by the management; analysis of the records should guide the breakdown repair and evaluate the results. They should contain accurate and vital information. Excessive record keeping will disrupt the EPM program. Usually records are classified into four categories:

- Maintenance work records
- Maintenance cost
- Inventory
- Maintenance files

Maintenance work records contain documentation of all the repairs and maintenance performed during the equipment service life to date. Cost records contain chronological records of profiles, labor, material costs by item. Figures should be kept to show the total cost of each breakdown. Inventory records contain information of equipment number, size and type, cost, date of manufacture or acquire, manufacturer, location of the equipment, etc. Other files include drawings, operating manuals, service manuals etc.

Record keeping is a practice and useful to determine operating performance trends, troubleshooting breakdowns, replacement or modification decisions, investigating faults, performing reliability and maintainability studies.