MAINTENANCE OF ELECTRICAL EQUIPMENT

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ABSTRACT

This paper highlights the significance of maintenance of electrical equipment and machinery, which plays a vital role to improve their efficiency, extend their useable life and retain their functionality intact. It defines various types of maintenance and discusses the ways to perform these types regularly and meticulously. It emphasizes that all electrical installations should be regularly inspected, maintained and tested in order to keep them safe, secure and sturdy. Visual and precise inspections of all running equipment should be made and the external conditions should be recorded. If damage is identified or if the degree of protection is found impaired or if an abnormality is expected, then the situation should be carefully assessed and remedial actions should be taken, either immediately as forced maintenance or gradually during scheduled preventive maintenance. Simultaneously predictive maintenance should also be carried out to foresee an impending failure and to adopt a corrective action plan ahead of it. This is achieved through condition monitoring of important parameters of the equipment or plant during its on-going operation. The paper gives some practical maintenance and operation checklists and guidelines. An exhibit shows in the form of flow charts, what should be done at what time and at which locations to avoid undesired results of unwanted environmental or operational features. Cost benefit ratio of maintenance has also been discussed, explaining how maintenance offsets the loss of equipment and the resulting loss of revenue, in the long run.

PHILOSOPHY OF ELECTRICAL MAINTENANCE

Electricity has become the lifeline of today's industrialized world. Operation of all industrial, commercial, institutional and residential sectors, nowadays, entirely depends on electric power. Whole country comes to a standstill if power supply fails, as both homes and businesses have become so reliant on constantly available electricity sources. One cannot now imagine living without electricity. A variety of electrical equipment and installations are found everywhere, which make our life easy, convenient and comfortable. The proper upkeep and timely maintenance of these equipment and installations prolong their design life, ensure their safe working, guarantee their optimal availability, improve their efficiency, reduce their renewal costs and minimize the risks due to their extended use. A prudent and effective maintenance plan helps reduce possibilities of sudden downtime of equipment and production loss in industrial plants.

All electrical installations deteriorate because of a number of factors such as wear, tear, corrosion, excessive loading, ageing and environmental influences etc. If no proper attention is paid, this deterioration will continue and may reach to an alarming point. Ultimately the affected equipment, apparatus and installations will not only cease to function, but may explode, burst or burn, endangering the surroundings to a great extent. In that case, electricity becomes like a jinn out of bottle, who will tear apart whatever comes in its way. So every effort should be made to confine this jinni within the bottle and get maximum use of his relentless working powers.

GOOD MAINTENANCE: A KEY TO REHABILITATION

There cannot be a second opinion to the crucial importance of regular and periodic maintenance of electrical equipment, machinery, systems and installations. All of these must be regularly inspected, checked and maintained in order to keep their performance in tune to the highest degree of safety, reliability and functionality. A carefully employed maintenance program helps detect deterioration before it becomes danger and then disaster. Such program facilitates us to adopt appropriate remedial measures, well in time, to rehabilitate the system. This **rehabilitation** involves **repair, replacement** or **renovation** of the respective equipment or system, as defined below:

Repair: is the rectification of local damage due to failure of a part or parts.

Replacement: means installation of new parts without changing the fabric of existing system.

Renovation: means total or partial modification of original fabric of existing system by means of which its current performance is improved.

It thus goes without saying that an effective and well-planned maintenance plays a pivotal role to keep systems healthy and ready to work round the clock. This is the key to achieve the highest industrial productivity and profitability. Timely repairs, overhauls, fault-rectifications and retrofitting are the key factors to guarantee maximum plant efficiency at minimum costs.

Let us see what different types of maintenance are and how these are performed to secure oft-repeated electrical workability.

TYPES OF MAINTENANCE

Generally speaking, there are four types of maintenance:

- Outline Inspection
- Corrective (or Breakdown)
- Preventive
- Predictive

These types are briefly described hereunder:

OUTLINE INSPECTION

This consists of two parts: **visual inspection** of electrical facilities during their normal working and **precise (or detailed) inspection** during their off-working periods. In the visual inspection, the responsible person patrols the specified check points regularly, confirms the exactness of operating states by using his five senses and monitors / detects the presence of any abnormality. For example, hearing some abnormal sound, sensing extreme hotness by touching or observing something unusual. This is a routine data collecting activity, conducted during daily, weekly, monthly and quarterly cycles. The data collected so far, serves as a guideline to do the requisite restorative or regenerative actions during the next phase of inspection i.e., precise inspection.

The precise or detailed inspection is carried out, in two phases, after stopping the operation of facilities. Firstly as a small recovery measure, such as general cleaning, lubricating, oiling etc, without disassembly of equipment. In second phase, certain measurements and tests are conducted to verify the exactness of actual state-of-affairs of the facilities. Generally, this takes place over 1 to 3 years.

CORRECTIVE (FORCED OR BREAKDOWN) MAINTENANCE

Corrective or breakdown maintenance, also called as forced or 'fire-brigade' maintenance, takes place when a sudden failure or breakage occurs, making the equipment or system non-functional, either totally or partially. In other words, this is a crisis-management measure, which involves man and material resources, to make the defective systems re-workable, through the rehabilitation cycle, defined in Item-1 above. Here economical aspects are mostly sidelined, because the abnormality is corrected and normal functions are restored, irrespective of the cost impact. Everyday examples of this type of maintenance are replacement of a fused bulb of a lamp, repair of a ceased water pump, or re-winding of a burnt motor etc.

PREVENTIVE MAINTENANCE

As the name suggests, the theme of this type of maintenance is to prevent possibility of failure, malfunctioning or breakdown of any running equipment and machinery. This is performed on the basis of:

- Manufacturer's recommended instructions, service intervals or running hours.

- Initiation of a red alert signal or appearance of a sign of abnormality, noticed during *visual inspection.*
- Data collected during second phase of *precise inspection.*

Preventive maintenance is planned in a specified sequence and scheduled at pre-determined intervals. To carry out this maintenance, the equipment is taken out of operation and is put back into service only after its completion. During this maintenance, some critical parts are also changed, which are otherwise still in running condition, but are prone to any malfunctioning in near future. This is done to minimize risk of breakdown and achieve a greater degree of reliability of the plant. A common example is change of a motor-belt, which is working all right but is found uneven, jerky, loose or withering out. If this kind of belt is retained after completion of preventive maintenance, it will soon become non-operational, causing stoppage of motor and subsequent loss of relevant industrial or commercial process. So it will be wise to replace it during preventive maintenance and to save such a big loss.

PREDICTIVE MAINTENANCE

The objective of predictive maintenance is to predict or foresee an impending failure, which helps to adopt a corrective action plan, well in time. It consists of ways and means, employed in a plant, system, equipment or machine to tell us:

- What has happened inside it during its prolonged use?
- What is happening inside it and how it is behaving during its normal use?

The first method comprises diagnostic techniques, mostly used during preventive maintenance, such as insulation check-up of motors or cables, Capacitance and Dissipation Factor (C&DF) testing of current transformers, dielectric testing of insulating oils or timing test of breakers etc. The second one is based on continuous or on-line monitoring and evaluation of important parameters or conditions of the equipment such as temperature, pressure, sound level, speed or vibration. This is commonly known as *condition monitoring* or *condition based maintenance* and is frequently employed in plants nowadays. It is, therefore, in the fitness of things, some details are discussed below:

Condition Based Maintenance

Condition based maintenance or condition monitoring continuously extracts information from a running system or machinery and indicates its prevalent condition or healthiness in quantitative terms. Condition monitoring apparatus stores the current values of important operating parameters and compares them with the corresponding past recorded values. These condition monitors are programmed to decide, on the basis of this comparison, whether the equipment or plant is operating properly or whether it is likely to develop a malfunction in near future. In the later case, the monitor can advise which remedial action should be taken to avoid expected faults. So maintenance menu and schedule can be planned, reducing maintenance downtime and assuring greater availability.

The condition monitoring of electrical equipment involves not only their mechanical well being but also their electrical state. Sometimes ancillary parts of an electrical system are also monitored to detect an unusual happening. For example, chemical state of cooling water systems in thermal power plants serves a good tool to predict unperceived faults like scaling, tube foiling, pitting or erosion etc. These faults may not be too rapid or fatal, but their effects like corrosion or scale formation reduce optimum performance, ultimately causing decreased functionality in the long run.

EFFECTIVE MAINTENANCE MANAGEMENT PLAN

A successful and effective maintenance plan helps reduce downtime of equipment and production loss in industries. Nevertheless, it requires a careful and thorough planning and management. Make a comprehensive list of what to do, where to do and when to do. Start independent segments of planned work in parallel. For interconnected and tied works, do first things first and arrange what is following next. Check the step-wise sequence for the works, which are permissively interlocked. This means think of nut when you are fixing a bolt. A stitch in time will save nine. After finishing the job, analyze its technicalities in broad perspective, whether next maintenance is economical or retrofitting is better or new equipment should be bought altogether. It applies, especially, to old equipment, apparatus and machinery.

Following are some useful tidbits, which should be taken care of before start of any type of maintenance:

Maintenance Check Points

- While purchasing any electrical equipment, get sufficient copies of operation and maintenance manuals from the manufacturers. Follow these manuals in letter and spirit, during all phases of operation and maintenance of the concerned equipment. Keep one or two copies in a safe place,

to be used only if other copies are misplaced or not immediately available.

- Major equipment should have its own logbook, which should contain all of the relevant historical information including nameplate data, previous maintenance record, parts replacement etc. If the need arises, consult the manufacturer and provide him all available information of the equipment.
- Ensure that all necessary tools, spare parts, supporting equipment etc are available in your warehouse in abundant quantities. Replenish warehouse stock periodically. Never underestimate small things like nails, bolts, lugs, tapes, glues, cotton rags etc, as these may stop big jobs. Remember an ant could kill an elephant.
- Work that can be done by machines, should be done by machines. Manpower should be used on the task that only humans can do. This will bring down equipment on line without any extra delay.
- Apart from outline inspection, a permit to work, signed by an authorized person, must be issued, prior to start of any maintenance work. The concerned electrical equipment must be de-energized, isolated and switched-off from the power supply. This will involve isolating the relevant breakers,

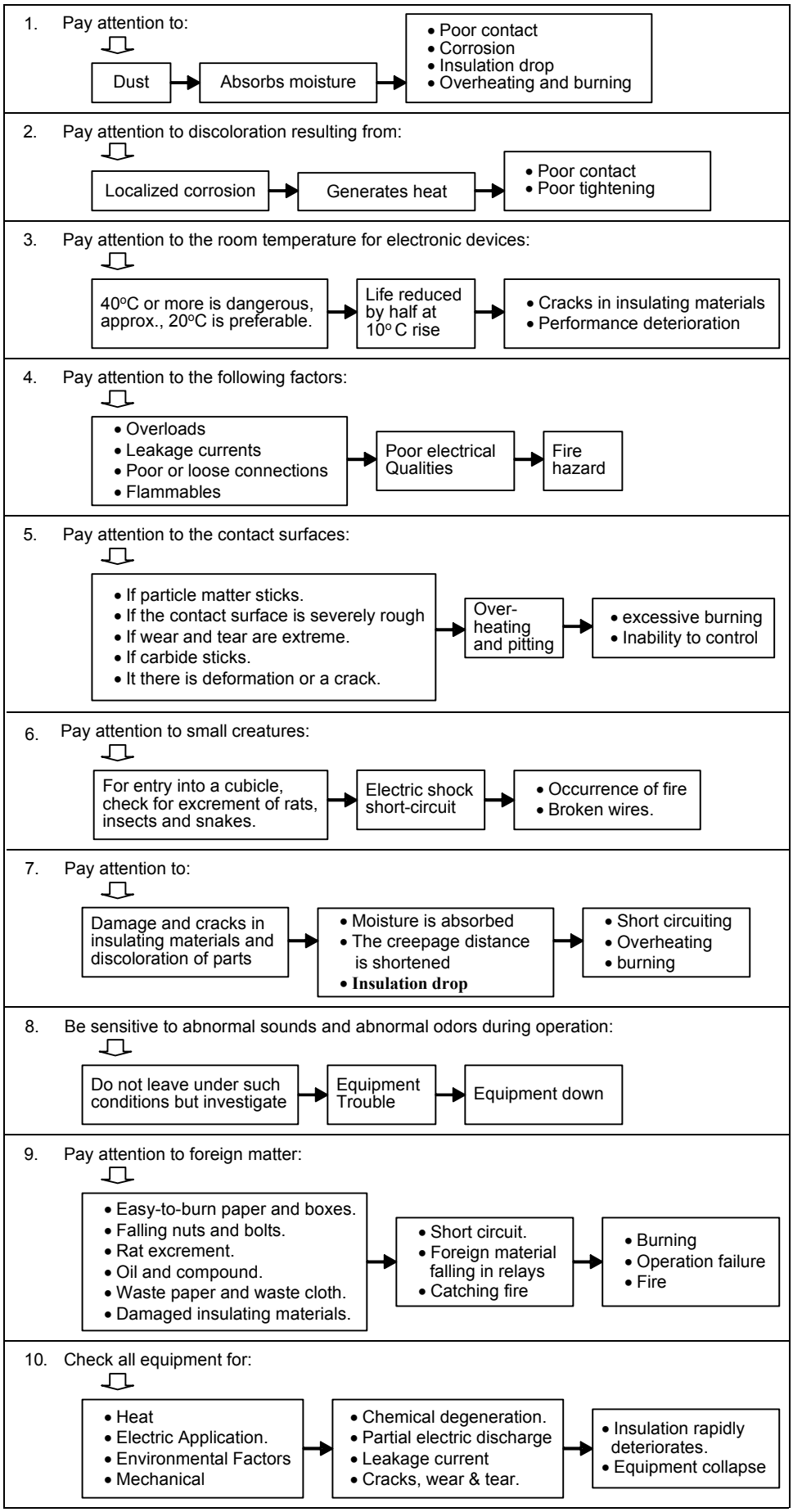

Exhibit 1: Maintenance Inspection Checklist

checking that the power is off by testing with the correct electrical detectors and ensuring that the switches / breakers are properly padlocked. Area of work shall be barricaded with protective barriers, safety signs or warning tapes etc.
- Always assume electrical circuits as LIVE until proved DEAD.
- Safeguard DEAD circuits from becoming electrically charged during work. Isolate from all points of supply, secure each point of isolation, and provide earthing where appropriate.
- Keep yourself abreast with modern trends and technologies. Get standard O&M handbooks or journals and develop a habit of reading them off and on. Try to implement the procedures and guidelines, given therein, wherever possible.
- Special attention should be paid to site and personnel safety as well as good housekeeping. After finishing the job, ensure the site is clean of debris, used pieces of wires, cables, tapes and all unwanted things.

Operational Check Points

Proper and meticulous operation minimizes chances of forced maintenance, costly repairs and downtime. Following guidelines should be observed while handling or operating any equipment.

- Never touch, catch or climb on any part of a transformer, motor, RMU, or likewise apparatus, while it is energized. Injury or death can occur from electrical discharges.
- Always pull the big equipment with pulling eyes supplied on it.
- When unloading heavy equipment or placing it in position, make sure the jack lugs or places designated for jacking are used.
- Do not open any valves or plugs of any oil-filled transformer, re-closer or breaker etc and any of their accessories, while being energized. This may cause the liquid to drop below the minimum level (the gas or oil sampling valves are the exception). An internal flashover may occur if the oil is lowered below the minimum oil level. Oil level gauges must be constantly checked.
- The control circuits, inside and outside the control cabinets, utilize voltages that can pose safety hazards. Be careful while operating any of the switches, breakers or control devices. If work on these circuits is necessary, the power source must be shut off before start of work.
- In case of energized transformers, proper cooling equipment (fans, pumps and selector switches) must be in operation under auto mode. Otherwise, dangerous pressures can occur inside the transformers. Check color of silica gel, it should be changed or regenerated, if its two-third quantity turns pink. Also level of sealing oil in oil cup should not fall below red line.
- The secondary circuit of any current transformer, not connected in auxiliary circuits, must be shortened and grounded.
- Operation of generators and power transformers under over excitation condition should be as minimum as possible. Always follow the limits prescribed by their excitation curves.

General Inspection Checklist

Exhibit-1 shows a general checklist or flow chart, which is applicable, to a variety of equipment. This flow chart identifies stress areas, accompanying symptoms and ultimate effects. It is a handy guide to

- perform recommended inspection of stress area.
- catch changes due to the imminent stresses.
- find symptoms of equipment malfunction at an early stage.
- provide early cure and treatment.
- investigate the cause of malfunction and help its elimination.

Each entry of this Exhibit has three blocks. First block indicates stress area. Second block shows what the ill effects of that particular stress area are. Third block shows the ultimate results of ill effects. There is a recommended action to be performed on the stress area block. The Exhibit explains what abnormality will happen and what will be the ultimate dangers in each, if the recommended action is not performed.

COST BENEFIT RATIO OF MAINTENANCE

The benefits of a well-in-time maintenance program are understandable, but the hard fact is that such programs put off the operation of machinery, resulting in a sudden loss of revenue, which, otherwise, could be gained had it been in operation. Moreover, maintenance accrues labor costs, overtimes and material costs. These factors adversely affect the cost benefit ratio of maintenance plans. In production plants, forced maintenance is a major source of expenditure, as it drastically increases running expenses with nil or very little production. Such possibilities could be minimized through an effective outline inspection and condition monitoring. Anyway, if forced maintenance has to be done, then every effort should be made to complete it as soon as possible and to bring the equipment back to normal operation. Maintenance crews should work round the clock, if the

need arises. In that way, equipment functionality will be restored and cost benefit ratio will improve.

Nevertheless, preventive maintenance should go as planned, because it offsets the risks of sudden breakdowns of equipment or accidental failures. Disallowing or delaying preventive maintenance schedules will have a negative effect on the cost benefit ratio, in the long run.

Let us consider a practical example. Suppose there is a serious electrical accident in a company, involving a heavy damage of machinery, major injury to workers and their consequent absence from work for some weeks. Likely costs to the company will be:

- Sick pay to injured workers and their treatment / hospitalization charges.
- Cost of replacing lost production e.g. overtime paid to other employees.
- Cost due to accident investigation and responding to the law enforcing authority.
- Cost incurred due to shut down of plant pending investigation.
- Cost associated with repair or replacement of damaged machinery / equipment.
- Cost arising from a possible civil action brought by the employees against the company for damage compensations.
- Future increased insurance premiums.
- Cost to redress lost company reputation.

All of these costs would be either eliminated or minimized to a great extent, had a regular visual / precise inspection, preventive maintenance and condition monitoring been undertaken. Costs associated to these maintenance plans would have been much lower compared to above-mentioned costs, which always appear at wrong times and leave no room for a second option. An easy question could be asked: whether a plant shutdown and resulting loss of revenue, is affordable for executing preventive maintenance plans? Contrary to this, a smart plant manager's question would be: whether a plant can afford non-execution of preventive maintenance for saving plant shutdown and resulting loss of revenue? This is because he knows that cost benefit ratio of executing preventive maintenance is ultimately higher than of its non-execution.

CONCLUSION

The preceding paragraphs have explained to the entirety, the necessity, significance and appropriateness of various types of maintenance of electrical equipment. All manufacturers of repute, deliver operation and maintenance procedures of their equipment. As mentioned elsewhere, every effort should be made to adhere to the plan, intervals and timings of maintenance given therein. The recommended visual inspections, operating precautions, duty cycles, condition monitoring and off-loading at specified checkpoints must be followed in letter and spirit. However, a brilliant maintenance manager will also keep an eye on the physical condition of the equipment. In view of that, he will ascertain whether it is economical to maintain and upkeep that equipment or replace it altogether. If the equipment is too old, if its physique and insulation is bitterly deteriorated, if its spare parts are obsolete or hard to find, if it has become incapacitated due to frequent repairs or if its maintenance costs are more than the benefits, then a wise decision will be to replace it with a new one. This is called equipment renewal plan and it should go side by side with the maintenance plan. Sometimes, technological innovations make the existing equipment either obsolete or less efficient compared to its new model. Equipment renewal plan, thus, suggests either replacing the old apparatus totally or upgrading it with change of important spare parts. In such cases, the maintenance manager has to decide what to do and guide the company management accordingly.

*** *Date: 22nd December 2002*

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