

## SAFETY RISK MANAGEMENT OF ELECTRICAL POWER SYSTEM BY PROPER SERVICE MANAGEMENT ACTION PLAN

Sayandeep Bhattacharyya<sup>1</sup> and Saumya Singh<sup>2</sup>

**Abstract:** People involved in maintenance of electrical transmission and distribution lines and power systems are at extremely high risk of electrocution. The result of unintentional contact with high voltage power often is death or severe injury that involves damage to internal organs, musculoskeletal disorders, neurological damages and severe burns. Present global economic crisis has paralyzed every business houses and which forces organization to curtail their 'Capital Expenditure (CapEx)' for any new investment or major modification of the existing electrical power system infrastructure and 'Operational Expenditures (OpEx)' for maintaining the existing electrical power system infrastructure. As a result- budgets for proper maintenance, modification, up gradations have been curtailed. Absence of proper service management agreement with vendors/OEMs; as a result, no response time commitments from vendors/OEMs in case of emergencies - set the electrical system operation at risk in most of the industries. It's a gap in their electrical infrastructure maintenance practice. This is just compromising with safety. The goal of this study is to assess the control measures of electrical hazards using a outlook of hierarchy of controls (HOC) and evaluate the available options of proper service management plan (maintenance plan) as a risk mitigation practice. Maintenance plan for the electrical physical infrastructure should be considered as an important task under Engineering control of hierarchy of controls (HOC) standard to estimate a protection's effectiveness.

### 1. INTRODUCTION

'Life blood' that drives operations in most the industry is electrical physical infrastructure. The electrical infrastructure in a plant or business is often taken for granted. Electrical system is among the most reliable systems, it demands periodic inspection, maintenance for continuous supply of power in a safe and efficient manner. Favorable environmental conditions for the electrical equipments need to be maintained and proper service plans need to be worked out for any electrical power system network. Toady 'health', 'safety' and 'security' are major

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<sup>1</sup> Research Scholar, Indian School of Mines (ISM), Dhanbad, India. Email: sayandeep2006@gmail.com

<sup>2</sup> Associate Professor, Dept. of Management Studies, Indian School of Mines(ISM), Dhanbad, India. Email: saumya.ism@gmail.com

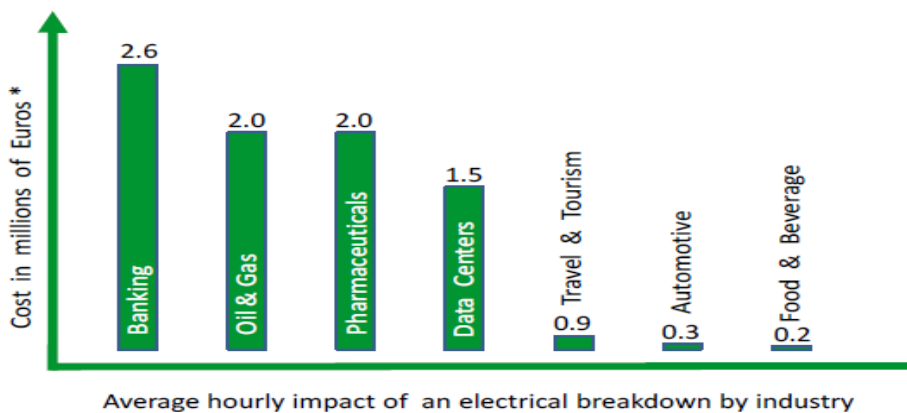
objectives of those maintenance managers who are assigned to ensure zero injury, uninterrupted, continuous, smooth operation of the plant.

However, people involved in maintenance of electrical transmission & distribution lines and power systems are at extremely high risk of electrocution. As per the Electrical Safety Foundation International (2010)-contact with overhead power lines accounted for an average of 43% of all electrocutions between 1992 and 2009. Some other key causes of occupational electrocutions are- contact with wiring, transformers, or other electrical components (27%) and contact with the electrical current of machines, tools, appliances, or light fixtures (17%).

Result of T&D electrical injuries are extensive. Electrical injuries are typically induced mainly through hazards such as shock, arc and blast (Cardick et al., 2005). In the case of an electric shock, the degree of the injury is a function of the current flow path, intensity of current, the duration of contact between the human body and the source, and the magnitude of the voltage (Lee and Dougherty, 2003). The result of unintentional contact with high voltage power often is death or severe injury that involves damage to internal organs, musculoskeletal disorders, neurological damages and severe burns (Lee et al., 2000). This causes long-term physical and emotional distress to workers and their families.

Beside the physical damage & emotional distress, these injuries and fatalities result in substantial economic expenses such as higher insurance premiums, medical cost, compensations, lost productivity, administrative costs, and others (Everret and Frank, 1996; Ferret and Hughes, 2007; Oxenburgh and Marlow, 1996; Tang et al., 2004). It has been observed in the research work that around two-thirds (67%) of breakdowns can be avoided by a routine preventive maintenance program only<sup>1</sup>.

**Figure A: Illustrates how much monetary loss results from an hour of loss of productivity across various industries<sup>(10)</sup>**



## 2. REASON FOR FAILURE OF ELECTRICAL INFRASTRUCTURE COMPONENTS

Over time, due to ageing of the existing electrical infrastructure- connections can loosen, resulting in a non continuous path for the electricity to follow and eventual arcing and potential breakdown and fire. On the other hand, there is a continuous increase in workload demands on the existing electrical physical infrastructure. Most of the time it has been noticed that the present electrical system might not had originally been designed to support such increased loads. In order to ensure smooth uninterrupted safe operation- all electrical equipment needs to be maintained regularly. This is not only reduces the possibility of breakdown, but also enhances safety of the entire electrical infrastructure. Environmental condition (ambient temperature, inappropriate ventilation, and humidity), overload and excessive duty cycle effect on the performance and life expectancy of any electrical system. A proper maintenance is necessary for any non operating instrument before it start functioning again. The principal reason for electrical system failure is lack of maintenance<sup>2</sup>.

### Impact of Harsh Environments

Speed of ageing and chances of malfunctioning of any electrical distribution is due the extreme temperatures, significant temperature changes, high humidity levels and high dust concentration. Well structured, proper planned maintenance program can tackle the majority of these factors, thereby helping organizations to avoid future financial losses, enhance safety to safeguard human life.

**Figure B: Malfunctioning of electrical distribution system due to impact of harsh environment condition <sup>(11)</sup>**

Maintenance	Normal environment conditions	Severe environment conditions
<b>Temperature</b>	Average annual temperature < 25°C outside the switchboard (TA)	Average annual temperature between 35°C - 45°C around the switchboard (see IEC 60439-1)
<b>Percent load</b>	< 80% of In 24/24 hours	> 80% of In 8/24 hours or 24/24 hours
<b>Relative Humidity</b>	< 70%	> 80%
<b>Corrosive atmosphere (IEC60721-3-3)</b>	Device installed in environment category 3C1 or 3C2	Device installed in environment category 3C3 or 3C4 without any particular protection
<b>Salt environment</b>	No salt mist	Installation < 10 km from seaside and device without any particular protection
<b>Dust</b>	Low Level. Device protected in switchboard equiped with filters or ventilated IP54 enclosure	High Level. Device not protected
<b>Vibration</b>	Permanent vibration < 0.2g	Continous vibration between 0.2g and 0.5g

As per the scope of service plan, all maintenance persons observe the basics- installation practices, cabling techniques, mechanical connections, load

types and immediately alert owner's maintenance team about the probable premature wear and tear of components. They make the people understand the factors that may have a harmful impact in near future on system availability - probable human error during handling the equipment, higher than ambient/ recommended temperatures, presence of harmful gases and lack of ingress protection (IP) issues.

### **3. ECONOMIC CRISIS AND NEGATIVE IMPACT ON SERVICE MANAGEMENT PLAN**

Global economic crisis has paralyzed every business houses and which forced organizations to cut down their 'Capital Expenditure (CapEx)' for any new investment or major modification of the existing electrical power system infrastructure. As a result- budgets for proper modification, up gradations have been curtailed. In this unfavorable economic scenario, every business houses are very much aggressive and are continuously hunting opportunities to reduce other variable costs. Target is to reduce 'Operational Expenditure (OpEx)' for maintaining the existing electrical power system infrastructure without decreasing productivity and also intend to increase bottom line as well. In reality it has been noticed that most of the medium and small organizations have gaps in their electrical infrastructure maintenance practices. Resulting to that, 'Total Cost of Ownership (TCO)' of equipment likely to be increased as instance of downtime increases. Proper service management action plan is needed to prevent all possibilities of electrocution, safety of human life, avoid sudden breakdown of electrical power system, protect productivity of the plant and minimize 'Man-Day' losses. Maintenance managers are concerned for zero injury, safety, security, equipment lifetime and uninterrupted smooth operation of the plant.

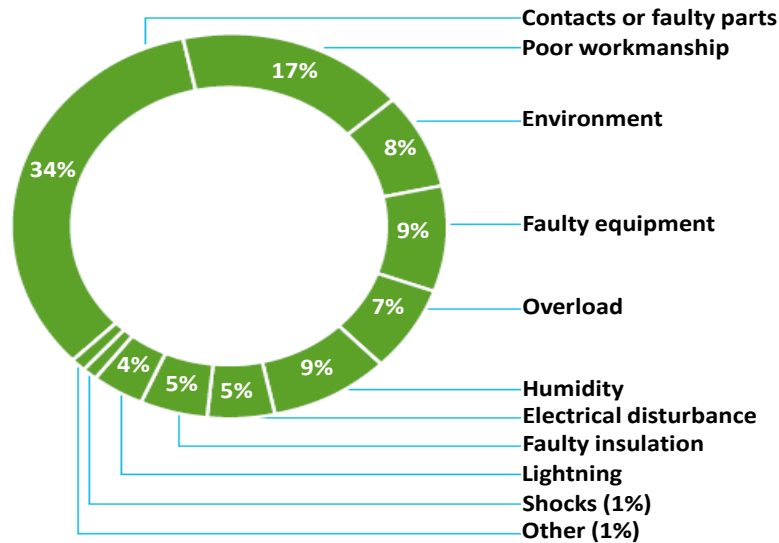
### **4. SAFETY RISK MANAGEMENT AND SERVICE MANAGEMENT**

As per the US Occupational Safety and Health Administration (OSHA) employer and the employee both are responsible for safety related issues in the work place. As per OSHA- employer has to provide the workforce with a place free from all recognized hazard (Wilson and Koehn, 2000), employer has to provide personal protective equipment, and train them in order to enhance safety performance (Spellman, 1998). All employees must abide by the rules and regulations set by the employer and relevant regulatory authorities.

The first step in safety risk management is to identify hidden and lively hazards which may exist or may be raised by worker behavior at the worksite

have been recognized by the employers (MacCollum, 2007). This can be achieved through in depth analysis of installed electrical power system equipments, their age, obsolescence of the technology, availability of the spare parts on failure, support availability from OEM, impact of unfavorable environmental conditions, and other relevant document to identify possible hazards. OSHA (2002, p. 11) says- most hazards in the T&D industry result due to “unsafe equipment or installation; unsafe environment; and unsafe work practices”. After identification of the potential hazards (dormant and active) proper risk mitigation techniques supposed to be implemented in order to control the frequency, severity and exposure level of injuries.

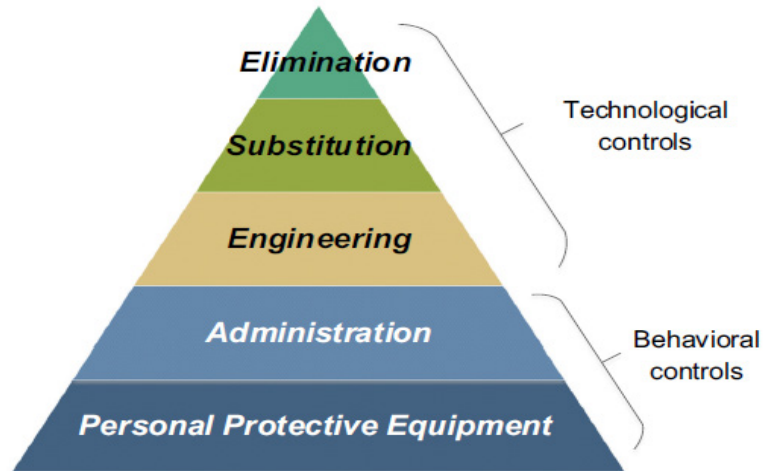
**Figure C: Illustrates common causes of electrical breakdowns in business facilities <sup>(10)</sup>**



\* Source Hartford Steam Boiler Insurance and Schneider Electric

Electrical hazards are well known by the people and believed to be controllable (Floyd and Liggett, 2010; Kleiner et al., 2008). Hence, a need comes up for assessing effectiveness of existing control measures & inclusion of any other parameter to make the mechanism robust and full proof.

During risk mitigation practice, to estimate a protection’s effectiveness performance evaluation often uses a Hierarchy Of Controls (HOC) standard (Manuele, 2006; Wakefield et al., 2014).

**Figure D: Hierarchy of Controls (HOC) <sup>(9)</sup>**

HOC classifies control measures having five primary levels in descending sort of effectiveness. These five levels are in a top-down order- Elimination, Substitution, Engineering, Administration, and Personal protective equipment (PPE).

Top three stages of control (shown in Fig. D) are categorized as technological controls in that they take action on changing the physical work environment; while the bottom two steps symbolize behavioral controls in that they look for an alteration the way people work.

As per U.S. Centers for Disease Control and Prevention (2014) the hierarchy is being explained as follows.

- *Elimination and Substitution*: These two are the most efficient at reducing hazards. These measures are less expensive and less difficult at the design stage for implementation but, most difficult to implement in an existing process.
- *Engineering controls*: For well designed system, this is highly effective in protecting workers. Most of the times the initial cost of engineering controls are high but in the long-term operating costs are frequently low. Also there can even provide a cost saving in some instances.
- *Administrative controls and Personal protective equipment (PPE)*: These are frequently used in conjunction with existing processes, but have proven to be lesser effective than other HOC measures. Initial expenditures while implementing such processes may be comparatively low while in the long run costs to sustain such initiatives can be high. To implement such

measures significant effort by the affected workers are highly needed but, do not well control hazards.

The purpose of this study is to evaluate the available options of proper service management plan (maintenance plan) as a risk mitigation practice. Proper maintenance plan for the electrical physical infrastructure should be considered as an important action plan under *Engineering control* of hierarchy of controls (HOC) standard to estimate a protection's effectiveness.

Studies have revealed that electrical equipment (not under any schedule maintenance program) failure rates for the components are 3 times higher as compared to equipments which are part of a service plan.<sup>1</sup> Disrepair and faulty component not only do unanticipated downtime, financial loss- but both employees and visitors are also exposed to potential safety hazards. Absence of proper service management agreement; as a result, no response time commitments from vendors/OEMs in case of emergencies - set the electrical system operation at risk in most of the industries.

#### **4.1. On-demand Maintenance vs. Service Management Plan**

Business houses have a number of options to make when it comes to development of a maintenance program. One traditional option is called '*on-demand maintenance*'. In this option, maintenance is only performed against business owner's or related stakeholder's request. Here, issues related to equipment lifecycle are rarely taken into consideration. There is no long term service agreement between the business organization and the service provider. When this is being compared with a customer having service plan in place – as a general tendency the '*on-demand maintenance*' customer is not treated as a priority by the service provider. In such traditional maintenance plan cost is low, but high risk of financial loss & safety aspect can negatively impact on the business.

Another choice is to signing up a '*service management plan*'. In addition to standard maintenance, service management plan offers a '*predictive maintenance*' element that is based upon a health check up of electrical equipment to be covered by the plan. Under this scenario, costly technical issues can be prevented in advance. '*Predictive maintenance*' involves various approaches – starting from problem avoidance and take appropriate prevention depending upon the criticality of the business. Which means for any hospital total shut down cannot be possible for any maintenance activity. So all maintenance plans to be formulated based on the criticality of the business. There is an important different between '*preventive maintenance*' and '*predictive maintenance*'. '*Preventive maintenances*' is carried out when the machine is shut down (non operating), whereas in general sense '*predictive maintenance*' activity can be completed when the machine is running



(in operation). 'Corrective maintenance' comes into picture during crisis situation against any unexpected sudden break down.

'Service management plan' also indicates the minimum stock level for spare parts to be maintained for various equipments. So, there should not be any scarcity of spares during any sudden breakdown. Experienced field service representatives conduct the maintenance by using special tools and they are also supported by powerful data management tools, making the work more efficient and precise.

Nature and criticality of business varies from one business to another. For example, any hospital cannot afford to have unexpected breakdowns. Similarly, a supermarket or a hotel also cannot afford to lose customers and also a risk of product spoilage, due to sudden electrical system failure. In such a case planned maintenance is critical as electric faults can be predicted before they occur. However, these facilities may have alternate sources of power like generators into their systems; but lack of maintenance of those generators compromise overall safety and reliability.

#### **4.2. Anticipate Equipment Failure with Predictive Maintenance**

Powerful diagnostic tool in combination with manufacturer's know-how; predictive maintenance gives insight into the state of the equipment in operation and expert advice on how to optimize it, enable maintenance team to manage the existing electrical equipments proactively.

'Predictive maintenance' can be done – either with or without shutdown, which significantly reduces the possibility of unexpected downtime and service interruption. These may help to anticipate equipment failure and associated costs. It also keeps user to comply the necessary service regulations and international standards for safety.

Benefits with '*predictive maintenance*':

- Manufacturer's data can be accessed to analyze effectively
- Greater ability to manage maintenance time and costs
- Improvement of installation safety and availability by anticipating as well as future failures
- Diagnosis can be performed during equipment operation & hence, no service interruption/shut down
- Clear analysis of diagnostic results in formal report and expert recommendations- to take corrective action



#### **4.3. Optimize Performance and Maximize Uptime with Preventive Maintenance:**

Manufacturer generally offers standard service plan to the user. '*Preventive maintenance*' is being done with shutdown only. However, tailored made service can be formulated based on the nature and criticality of business of end user. Moreover, to ensure the maintenance is conducted in the optimal way, it needs to be performed by properly trained and skilled professionals.

Benefits with '*preventive maintenance*':

- Flexible and tailored made scheduling and maximum continuity of existing service
- Compliance with service regulations and international standards based on the criticality of the business
- Extension of equipment service life
- Improvement of installation safety and availability as per requirement

#### **4.4. Minimize Costly Downtime with Timely and Efficient Corrective Maintenance**

When unexpected downtime occurs, every second counts! In order to maintain the criticality of business and speed up of restart time; each and every installation need assured timely support by an experienced, well-trained field service team with guarantee of spare part availability.

Benefits with '*corrective maintenance*':

- Access to properly trained and skilled personnel for 24 × 7
- Immediate reactivity commitment in case of a breakdown due to proper service agreement with service provider.
- Reduction in indirect costs of downtime
- Availability of spare-parts on time

### **5. CONCLUSION**

Globally, occupational injuries due to electrocution are common safety issue in all industries. Most of the industries have implemented relating control measures of electrical hazards for decades; however these hazards still caused many deaths of workers during construction stage and also maintenance staffs year after year. This safety issue demands more robust and full proof quality and effectiveness of control measure. In an risk mitigation practice and to estimate a protection's

effectiveness performance evaluation, industry follows safety measure as per the guideline of Hierarchy Of Controls (HOC) standard. In order to mitigate electrical hazards and also to get more stability of electrical power system equipment used in the industry; a proper maintenance plan for the electrical physical infrastructure should be implemented under *Engineering control* of HOC. This will help to minimize the chances of electrocution, financial losses, interruption in manufacturing process and wastage of raw materials during production. On the other hand, service plan reduces overall operating expense as well as enhances the life cycle of electrical equipment & machinery.

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