Safety Assessment in Major Electrical Equipment

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***Abstract*—**

The major electrical equipments are essential component of several systems. Many plant operation base on the working of these electrical equipment. There are several failure and hazard conducted by failure in the equipment which can cause harm to the people, property and environment surrounding it. Failure modes and effects analysis (FMEA) is a procedure in product development and operations management for analysis of potential failure modes within the equipments for classification by the severity and likelihood of the failures. A FMEA done in any equipment helps to identify potential failure modes based on past experience with similar equipment or working process, enabling to take safety precautions or design those failures out of the equipment to minimize hazard and improve safety.

Keywords*— *safety assessment, transformer, generator, turbine, FMEA.

I. INTRODUCTION

Now a day's any industry have several major electrical equipments this major electrical equipments are the essential part of any industry. The operation of the industry needs the proper work of equipment to done there intended operation. Some common measure electrical equipments are transformer, generator and turbine which is the main concern of this Paper. Any electrical equipment made of several small components. For the proper work of equipment each component should properly perform its intended operations. For proper working every component of the equipment has its specific criteria like limits of mechanical stress, working temperature, working pressure, and other physical, chemical or environmental criteria. When these criteria goes beyond the limits the component fails to done its intended operation cause the failure of the equipment. There are also some external causes which lead to a equipment failure and may cause several hazard. In this paper failure modes analyse and assess by the failure mode effect analysis (FMEA).

II. METHODOLOGY

Failure modes and effects analysis (FMEA) is a systematic and proactive methodology for evaluating a system and analysis of potential failure modes within a system for classification by the severity and likelihood of the failures. *Failure modes* are any errors or defects in a process, design, or item, especially those that affect the equipment, and can be potential or actual. *Effects Analysis* refers to studying the consequences of those failures.

"A systematic process for identifying potential design and process failures before they occur, with the intent to eliminate them or minimize the risk associated with them"

The FMEA analysis generally follows these steps [10]:

Step1: Identify function: the function of the item being analyzed to meet the design intent. Include information (metrics measurable) regarding the environment in which this system operates. If the item has more than one function with different potential modes of failure, list all the functions separately.

Step2: Identify Potential Failure Modes: List each potential failure mode associated with the particular item and item function. The assumption is made that the failure could occur but may not necessarily occur. Potential failure modes that could occur only under certain operating and usage conditions should be considered.

Step3: Identify Potential Effects of Failure Describe the effects of the failure in terms of what the customer (internal or external) might notice or experience. State clearly if the failure mode could impact safety or non-compliance to regulations.

Step4: Determine Severity (S): Severity is the rank associated with the most serious effect for a given failure mode. Severity is a relative ranking within the scope of the individual FMEA. A reduction in the severity ranking can be effected only through a design change. Suggested severity is given in Table 1.

Step5: Determine Occurrence (0): Occurrence is the likelihood that specific cause/ mechanism will occur during the design life. It has a relative meaning rather than an absolute value. Preventing or controlling the causes/mechanisms of the failure mode through a design change or design process change is the only way a reduction in occurrence ranking can be effected. Occurrence can be estimated using Table 1.

Step6: Determine Detection (D): Detection is the rank associated with the best detection control listed in the design control. Detection is a relative ranking within the scope of the individual FMEA. In order to achieve a lower ranking generally the planned design control has to improve. Detection can be estimated using Table 1.

Step7: Calculate Risk Priority Number (RPN): The Risk Priority Number is the mathematical product of the numerical Severity (S), Occurrence (0), and Detection (D) ratings.

$$RPN = (S) \times (0) \times (D).$$

Step8: Take Actions to Reduce Risk: the primary objective after calculating the RPN is give recommendation to reduce RPN of the failure mode by intent of reducing severity, then occurrence, and then detection.

Table 1: Ranking Table:

ranking	Severity effect	Occurance	Detection
10	Hazard without warning	Almost certain	Absolute uncertanity
9	Hazardous with warning	Very high	Very remote
8	Very high	high	remote
7	high	Moderately high	Very low
6	moderate	moderate	low
5	low	low	moderate
4	Very low	Very low	Moderately high
3	minor	remote	high
2	Very minor	Very remote	Very high
1	none	Absolute uncertanity	Almost certain

III. SYSTEM DISCRIPTION

A. Transformer:

A transformer is a device that transfers electrical energy from one circuit to another through inductively coupled conductors—the transformer's coils. A varying current in the first or primary winding creates a varying magnetic flux in the transformer's core, and thus a varying magnetic field through the secondary winding. This varying magnetic field induces a varying electromotive force (EMF) or "voltage" in the secondary winding. This effect is called mutual induction.

The Transformer has following components:

a) CORE: The core's function is to carry magnetic flux.
b) WINDINGS: The windings belong to the active part of a transformer, and their function is to carry current. The windings are arranged as cylindrical shells around the core limb, where each strand is wrapped with insulation paper.
c) TANK: The tank is primarily the container of the oil and a physical protection for the active part of the transformer. It also serves as support structure for accessories and control equipment.
d) SOLID INSULATION: The solid insulation in a transformer is cellulose based products such as press board and paper. Its function is to provide dielectric and mechanical isolation to the windings. Cellulose consists of long chains of glucose rings.
e) COOLER AND OIL INSULATION: The functions of the cooler and oil insulation are two; cool the active part of the transformer, and be electrical insulation between the different parts.
f) BUSHINGS: The function of the bushings is to isolate electrical between tank and windings and to connect the windings to the power system outside the transformer.
g) TAP CHANGER: The function of a on-load tap-changer (OLTC) is to regulate the voltage level by adding or subtracting turns from the transformer winding.

B. Generator:

An electric generator is a machine that converts mechanical energy into electrical energy. An electric generator is based on the principle that whenever flux is cut by a conductor, an e.m.f. is induced which will cause a current to flow if the conductor circuit is closed.

The generator has following components:

a) ARMATURE - An armature starts out as a bare hardened steel shaft. To this shaft is added a series or group of non-insulated copper wires wound close together. They in turn will form what is called a loop. The loops of wire are then embedded in a series of slots in an iron core. This iron core is then attached to the armature shaft. This shaft spins and helps to generate the electrical current.
b) COMMUTATOR - The commutator is a series of segments or bars that are also attached to the armature shaft at the rear of the armature. It is the wire ends from the loops of the armature windings in the iron core that are attached to the commutator. When this is done, a complete circuit is formed.
c) FIELD COILS - Field coils are the windings or the group of wires that are wrapped around the pole magnet. It is the job of the field coils to take the current drawn to the pole magnet, and make it stronger.
d) BRUSHES - After the generator develops the current, it is the brushes that carry the current to the “field” circuit and the “load” circuit, so the electricity can be used by the battery and the accessories. This process is called “commutation.” The brushes will ride on the commutator segments of the armature.
e) BEARINGS AND BUSHINGS - At either end of a generator you will find a bushing or a bearing. They have the job of making the armature shaft run true in the housing between the field coils and pole shoes. Bushings will be made of copper or brass and are soaked in oil before they are installed. The brass or copper bushing material is porous and able to absorb the oil like a sponge. This provides the lubrication between the shaft and the bushing. They can also be re-oiled from the oiling tube on the outside of the generator.

C. Turbine:

Turbine is the electrical equipment which converts compressed air or steam energy into mechanical energy (rotation motion) to operate rotating machine or attenuator in plant.

There are several types of turbines used in industry like:

- Steam (condensing, non-condensing, single stage and multi-stage)
- Gas (using liquid or gaseous fuels and air).

The turbine has following major components:

a) MOVING BLADES: These absorb the energy of the flowing fluid and transfer it to the rotor.
b) FIXED BLADES: The vanes which direct the motive fluid through the machine.
c) ROTOR: The moving part that extracts work form the motive fluid and transfers it to the shaft.
d) RADIAL/THRUST BEARING: These support and restrain the rotor in place while offering minimum resistance to free rotation.
e) CARBON RINGS: A component of seals
f) SEALS: The components which keep motive fluid from leaking outward past the rotor at its point of exit from the case.
g) GOVERNOR VALVE/HOUSING: This device is the primary power and rotation speed controller for the turbine. The valve is simply the regulator for admitting the motive fluid.
h) OVER SPEED TRIP: If the turbine is allowed to spin with little load while motive fluid is freely supplied, the result is invariably excessive rotor speed and (often dangerously explosive) self-destruction. The function of the over speed trip is a last resort stop valve for inlet fluid to prevent this destruction.
i) CASING: The containment shell for the passages handling the moving parts and the motive fluid.
j) COMPRESSOR, COMBUSTION CHAMBER, AND INTERCOOLER: Terms applying to gas turbines. All gas turbines have a compressor, which pressurizes air for entry into the combustion Chamber. The compressed air is mixed with fuel in the combustion chamber where the temperature and velocity are boosted. The hot turbulent gas then flows into the turbine where energy is extracted. A portion of this energy drives the compressor while the excess is available as shaft work output.

VI. FMEA ON MAJOR ELECTRICAL EQUIPMENT

FMEA worksheet for major electrical equipments:

Table 2: FMEA worksheet for Transformer:

s. no.	Failure mode	Failure cause	Failure effect	Likelihood of occurrence	Likelihood of detection	severity	RPN	Action to reduce occurrence of failure
1.	Oil spillage	Rusting, overflow	Fire, overheating	7	3	9	189	Maintenance, oil paint
2.	Fire/ explosion	Overheating, oil spillage, spark	Fire, equipment damage	5	7	10	350	Fire extinguisher, proper cooling
3.	Overload Electrical Circuit	Excess load	Damage on insulation and winding	8	4	7	224	Load maintenance, monitoring
4.	Improper Installation	Weak installation base, misalignment	Equipment collapse, physical damage	6	8	5	240	Training, proper support
6.	Prolonged Short Circuit	Insulation damage	Spark, fire	7	8	7	392	Fire extinguisher, proper insulation
7.	Insulation Failure	overloading	Equipment damage	4	6	7	168	Proper insulation
8.	Line Surge	Improper earthing	Winding damage	4	7	6	168	Proper earthing

Table 3: FMEA worksheet for Generator:

s. no.	Failure mode	Failure cause	Failure effect	Likelihood of occurrence	Likelihood of detection	severity	RPN	Action to reduce occurrence of failure
1.	Insufficient Torque	Component damage	Operation failure	4	6	8	192	Maintenance, changing the faulty component
2.	Locked Rotor	Insufficient lubrication	Rotating part damage	5	7	7	320	lubrication on roter
3.	Thermal Aging	Improper cooling	Shorter life	3	5	4	60	Proper cooling system
4.	Over And Under Lubrication	Defected indicator, leakage	Friction in internal parts	7	4	5	140	Regular inspection for leakage and oil property
5.	Vibration	Misalignment, loose parts	Component damage	8	2	3	48	Proper alignment, regular maintenance
6.	Fatigue	overload	Shorter life, body damage	5	7	7	245	Overload trip system

Table 4: FMEA worksheet for Turbine:

s. no.	Failure Mode	Failure cause	Failure effect	Likelihood of occurrence	Likelihood of detection	severity	RPN	Action to reduce occurrence of failure
1.	Blade Failure	overpressure	Shorter life, permanent damage	2	7	9	126	maintenance
2.	Mechanical Fatigue	Over load, friction,	Shorter life, permanent damage	6	8	5	240	Load maintenance
3.	Vibration	Misalignment, loose parts	Component damage	8	2	3	48	Proper padding, regular maintenance
4.	fire in lubricating or cooling oil	Overheating, oil vapour	Fire, property damage	6	5	9	270	Fire extinguisher
5.	Rust	Water vapour in steam	Shorter life	4	6	3	72	Lubrication , dry steam system
6.	overheating	Insufficient cooling, failure of cooling system	Component damage, system failure	7	1	6	42	Regular checking of oil for its cooling property

Calculation for RPN Oil spillage:

RPN = (Severity) x (Occurrence) x (Detection)
RPN= 9 x 7 x 3
RPN= 189

Our first priority will be the potential failure which has highest severity ranking. when the potential failures have same severity ranking. But one has occurrence higher than other. So that should be prioritized next. There is no threshold value for RPNs. In other words, there is no value above which it is mandatory to take a recommended action or below which we automatically excused from an action.

V. CONCLUSION

FMEA analysis is a flexible process that can be adapted to meet the particular needs of the industry and/or the system. We applied FMEA on the equipment to evaluate the possible failure modes in its operational life and to minimize or eliminate the effect of failure by recommended correcting action. These corrective actions also include suggestions to proactively reduce the adverse events after failures have occurred. FMEA is particularly useful in evaluating failure mode in new designed equipments prior to installation and in assessing the impact of a proposed change to an existing situation. The documentation of the analysis is done in the final stage which provides the flexibility to customize the future analysis and reports. These documents can also be useful for redesign the equipment to meet the industry's needs for a particular application.

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