APPLICATION OF THE FMEA FOR ANALYZING DEPENDABILITY OF POWER TRANSFORMER AT HASSI R'MEL GAS FIELD

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Abstract: Transformers are essential elements in electrical network. These equipments are classically constructed out of copper, steel, paper and insulating oil. Transformers have been used worldwide for many years and their availability and reliability is a major concern for all electricity users. This paper describes the use of the failure modes analysis and their effects (FMEA) for analyzing the dependability of power Transformer in boosting station at Hassi R'Mel gas field in Algeria..

Keywords: Transformer, Dependability, Power, FMEA, failure, Availability

Introduction

The south Algeria has natural ressources, among which the hydrocarbon reserves, hence the presence of a wide range of products related to oil and gas fields. For the separation of these products and their derivatives, Algeria has acquired and installed the large treatment complexes, such as the Hassi R'mel complex. The overall plan for gas installations located on the Hassi R'mel field is designed to allow a rational exploitation of the deposit and recover the maximum of liquid. In the installations implemented, three boosting stations were installed . In the central zone, we find SBC. This is a gas discharge unit; it increases the pressure and maintains the deposit flow of the modules supply. The SBC complex is powered by two arrivals and a generator in emergencies. All energy distribution is made using substations in the complex. The Boosting unit is considered the strategic point of the HASSI R'MEL region. Therefore, it must be always available and reliable. The transformer 30 / 5,5KV,10MVA is the essential element in it electrical network of this Boosting station and it's reliability is more important. Analyzing the dependability parameters of industrial systems such transformer can be done with different methods. The famous method has been used; the failure modes analysis and their effects (FMEA).The FMEA is an inductive technique, it adds to identify the failure modes of an item, the causes of each mode and the effects on the function of the item. The results of FMEA are generally represented into a table.

Materials and Methods

Failure modes and effects analysis (FMEA) is a procedure by which each potential failure mode in a system is analyzed to determine the results or effects there of on the system and to classify each potential failure mode according to its severity. It has been used firstly on 1960 in aeronautic for analyzing air plans security, A.Villemeur (1988).

First and in order to make the rest of the paper clear, we take these definitions:
failure: Termination of the ability of an item to perform its required functions.
failure cause: The circumstances during design, manufacture, or use which have led to failure; syn: root cause.
failure mode: The manner in which failure occurs; generally categorized as electrical, mechanical, thermal, and contamination.
Before applying the FMEA to our system, we will describe the different constraints that may occur during operation.

Constraints and associated defects:

-constraint: Each transformer is sized to take a number of nominal constraints (mechanical, dielectric, thermal) due to disturbances (lightning strike, short circuit, etc .) , which partially reflect the operating conditions. Some of these constraints may cause defects, or impact the life of a transformer.

- Failure: Accidental change affecting normal operation. In this work a defect will be seen as an internal physical problem visually identifiable by an expert, during access to the active part, which can stop or having stopped the normal operation of the device.

-Symptom: Sign indicative of a material situation. In our case,a given internal defect will generate one or more symptoms. Symptoms may be highlighted following analysis of available information.

In this work, a defect is the result of a constraint that could not be contained. Any defect will manifest itself by symptoms that one will try to qualify by different information and means of measurement.
The transformer being a complex object located in a tank, its internal access is not obvious and the visual confirmation of these internal defects is not so either, especially the removal of transformer windings operation is never innocuous, and relatively expensive.
In the worst case, it is sometimes possible to go to the explosion of the transformer.

The différents constraints of a transformateur, J.Sanchez (2011) are :Dielectrics stress and overvoltage , Electrodynamic and overcurrent constraints; Electrical constraints;Thermal constraints (overloads, hot spots and aging);Contraintes électromagnétiques et courants de Foucault ; Contraintes mécaniques (vibrations, fuites et transport ions, fuites et transport). All these constraints can therefore be the cause of various defects within a transformer.

Results and Discussion

Table 1,2 and 3 represent the synthesis of FMEA applied to our transformer using the results published by B.William 2000**.**It is noted that a large part of the failures of the elements of these tables have a direct impact on the insulators which themselves affect the availability transformer availability.

In transformers and more particularly in power transformers, insulating solids provide several functions. They are used to mechanically maintain the windings and to materialize the coolant circulation channels . By their dielectric nature, the papers isolate electrically the coils between them. In addition, their porosity allows them to be impregnated by the insulating liquid and coolant circulating in the transformer.
The dielectric stress characterizes the voltage withstand of the various transformer elements. This dielectric strength within the transformer is related to the paper insulator (to insulate the conductors) , dielectric oil(immerses the whole of transformer active and bushing.
For Normal constraints(stress), the transformer must normally withstand its nominal AC voltage .

For abnormal stress, the two most important normalized dielectric stresses are lightning strikes (1452KV in 200µs) and shocks (1050 kV in 200 µs), which are very brief high voltage phenomena.

The dielectric stress can cause several faults; priming and partial discharges.
If the characteristics of the insulators degrade too much, due to excessive internal humidity for example, or are forced beyond their limits then it can develop;
Priming devices under voltage:

- Between them: as between windings or between turns.
- With the mass: as the initiation of a crossing or a winding to the tank or to the magnetic circuit.

Partial discharges: Inside an insulation, classically solid in transformers. These are micro local dumps that tend to spread over time.

All these defects create carbon, which is conductive, thus impacting the dielectric strength locally. This phenomenon being irreversible, it is impossible to find a normal operation following a dielectric priming.

Table 1: Application of the FMEA to transformer elements 1 and 2:

N°	Element	Function	Failure mode	Cause	Effect
1	Tank	Protection of active part of transformer	- heating	- Foucault Current	losses of electrical power
			degradation of the tank coating	-Corrosion -Rust	-Oil leak -Explosion and heating of tank
			vibration	- Bad tightening of the support	- Components displacement
			Heating of the tank sheet	rising of atmospheric temperature	Insulators Breakdown Increase of gas bubbles
			Cooling of the tank sheet	decreasing of atmospheric temperature	Bad oil circulation
2	Bushings	Control of the magnetic field shape and magnetic field intensity	-crushing of bushings joints	-Mecanical shock -Joints aging	-Leak of joints -Direct contact of oil with outside.
			-Crack of porcelain bushing	-False maneuver - Mecanical shock	-Electric arc between line and tank
			Loss of joints elasticity	-Overheating -Aging	- oil Leak - Risk of joints fissures
			Partial discharges	-Electric field value exceeds that of dielectric resistance of inslating material	-Increase of gas bubbles -Breakdown of oil

Table 2: contains the analysis of failure modes and effects analysis applied to transformer elements 3,4 ,5

N°	Element	Function	Failure mode	Cause	Effect
3	Windings	Support of electric circuit	-Paper aging -Coils deformation	-Overload - Shorts circuits -mecanical shocks Incrising of temperature	Short circuit between windings coils - Winding overheating -Pressure rise - Variation of the transformation ratio
			Winding displacement		- increase of Shorts circuits -variation of the distance between primary and secondary
			Hots points		-Paper degradation -Power loss
			Increasing of winding temperature	-Overload -Shorts circuits	-Slow insulation destruction - Decreasing of rigidity -Risk of materiel damage
			Increasing of the leak flow.	-Overload	-Saturation of magnetic circuit
4	Connections Windings	Amplification of magnetic field - connection between windings and tap changer	-Short circuits	-Transitory phenomenon	-Overcurrent (generate the overheating and electrodynamic effect at winding)
			-increase of Iron losses and Joule losses	-Unbalanced regime	-winding heating - insulation breakdown
			-Winding overheating	-Losses Joule	-Oil overheating -Energy dissipation in the breakdown form

		-Association of windings connections	-short Circuit between winding and connections	-Insulation aging (liquid,solid)	-Liquids breakdown -appearance of gas bubbles
			-direct contact with tank		-Single phase short circuit ,phase/ground
			-Overheating	Bad tightening	Variation of connection resistance -Overheatimg of oils
5	Insulation	Cooling of internal components	-Viscosity decrease	-Variation of internal temperature	-Difficult of oil circulation between coils,-Malfunction of the cooling function
			- Change of oil color	-Impurities	-Poor detection of oil state.
			-Inflammation of hydrocarbon constituents	Overheating -Arc of pre-breakdown	-Changement of oil color, -Changement of oil characteristics
			-Gravitational settling	-Presence of solid particles	-Reduction of rigidity voltage of dielectric -Breakdown oil
			-Overheating of oil	Presence of leakage current	Dielectric losses

Table 3: contains the analysis of failure modes and effects analysis applied to insulation (element 5)

N	Element	Function	Failure mode	Cause	Effect
5	Insulation	Isolation	-Electric arc	-Presence of humidity in paper	-Carbonization -Internal destruction of transformer - Variation of output voltage at secondary -Reduction of breakdown voltage
			-Variation of oil dielectric capacitance	-Presence of humidity in oil	
			-Deterioration of paper	-Increasing acidity	-Increasing of impurities -Oil breakdown
			presence of ions	Chemical reaction between the copper of windings and oil	Increasing of value of oil dielectric capacitance
			contamination of oil by humidity	chemical reactions between molecules	Increasing of partial discharges -Increasing of breakdown number

Conclusion

Using the FMEA for analyzing the dependability parameters is very important, it permit to find the critical points of the considered system. This method is a contribution to the study of the dependability of the power transformer, it's allowed us to perform the functional analysis of our system namely the transformer. The identification of the modes, causes and effects of the failures of each element is important information for transformer diagnostics.

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