

## ROOT CAUSE ANALYSIS OF TAP CHANGER FAILURE & ITS IMPACT ON POWER TRANSFORMER CONDITION

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### Abstract

Failure of power transformer component results in to failure of line & may results in to huge loss in terms revenue if it leads to complete failure of transformer. Tap changer is the important component of the transformer which maintains the voltage regulation, however it is one of the most vulnerable as this is the only component where mechanical movement occurs in the transformer. If failure of tap changer occurs then it becomes essential to know the condition of the whole transformer. If it affects the main winding & insulation then repairing will take time & become costly. This paper depicts one case study where failure of changer observed. It depicts in detail about the root cause analysis & analysis for further damage to transformer due to failure of tap changer.

### 1. Introduction

The condition and reliability of large power transformers is a major concern, because each transformer feeds many customers and its replacement/refurbishment would involve a considerable amount of time and expense. Auxiliary equipment, such as bushings, CT's, tap-changers, Insulators etc. has much shorter lifetime then the active part of the transformer. Moreover, it requires much more attention than the active part. As complete refurbishment of the transformer is much more time consuming & costly, one needs to take the decision about the healthiness of the transformer if one of the component fails. The study of fault on power transformer tap changer is a major concern in recent years. A statistical failure analysis has been conducted in [2] indicating that tap changer fault occupies the highest percentage in power transformer failures. Substation transformers

had a higher contribution of tap changer related failures (31%) [2]. Coking is one of the issues associated with tap changer deterioration. Coking is a chemical process when carbon is extracted from the surrounding oil inside the transformer tank and attached on the tap changer contact. The process started with thin oil film formation on the contact. Subsequently, it leads to the increase of tap contact resistance thus producing more heat. Another issue associated with tap changer deterioration is pitting corrosion. Pitting corrosion is formation of small cavities or holes on metal surface such as copper. Typically, pitting accrued in the advance stages of aging and on the changeover selector contacts. Due to deterioration of the tap changer condition, any high fault current passing through the tap changer may results in to the overheating of the tap changer contacts & sometimes failure of tap changer. There are various diagnostic techniques available which gives idea about the condition of various component of power transformer & by utilizing these technique one can identify the effects of one component failure on the overall health of the transformer. Sweep frequency response analysis of transformer gives idea about the mechanical integrity of transformer. Any issues with the transformer winding deformation due to high fault current can be identified in SFRA. Also any movement of winding & any shorted turns of winding gives changes in SFRA signature traces. Low voltage short circuit impedance measurements compliments the SFRA test. Insulation related issues can be found with the help HV tests like insulation resistance & capacitance/tan delta measurement. It is become very difficult to take the decision related to healthiness of other parts of transformer if one of the component fails, however by using visual inspection & utilizing the mentioned test technique identify the effect of failure.

### 2. Case Study:

#### 42.5 MVA 139/11 kV transformer tap changer failure.

One 42.5 MVA, 139/11 kV three phase power transformer manufactured in 2009 observed failure in tap changer. The sequence of event up to the failure of transformer R-phase tap changer suggest that heavy fault current fed to R-phase due to failure of lightning arrester of 132 kV side. During the failure of lightning arrester Generator Electrical lockout tripping & Generator T/F Buchholz Relay operated. The protection operated indicated that the high fault current passed through R-phase generated gases in the transformer indicating faulty condition in the transformer. Following failure of LA & R-phase tap changer, Insulation resistance test, Magnetizing current test, Magnetic balance test & turns ratio test were carried out. Except turns ratio measurement, all other test results showed no abnormality. Turns ratio test on the transformer reveals that the R-phase showed similar value of ratio i.e. it shows the value of ratio for tap no.3 on all the tap position. Please refer table no.1

Tap no.	Tap Position	Nom. Ratio	R-phase	Y-phase	B-phase
1	5.0%	7.661	7.315	7.681	7.68
2	2.5%	7.478	7.315	7.499	7.498
3	N	7.296	7.315	7.316	7.315
4	-2.5%	7.114	7.315	7.134	7.133
5	-5.0%	6.931	7.315	6.952	6.951

Table.1 Turns ratio measurement

The result of the turns ratio measurement of transformer indicated the tap changer has been stuck at the tap changer position no.3. Also the dissolved gas analysis of transformer shows the fault gases in the oil suggesting fault in the transformer.

Physically there was neither damage to transformer nor to paint of transformer due to overheating. The transformer was open at

the site after draining the oil & internal visual inspection carried out. During visual inspection at site R-phase tap changer found melted & stuck at position no. 3. Black carbon deposition on the tap changer suggest that the contacts have been welded after melting due to high current passed through the tap changer contacts.



Figure1: Melted contacts resulting in a joint (weld) at one position of R-phase tap changer

On detailed visual inspection it was found that the coking & pitting observed on the transformer tap changer contacts. Due to this when high fault current passed through the tap changer contacts produces heating effect & contacts have been melted. As the decision need to take whether any other parts of transformer are affected by the failure of tap changer or not, further inspection of transformer was carried out. On further inspection of transformer it was found that crack was formed on the end press ring of the Y-phase winding highlighted in circle as per figure 2.



Figure 2: Crack observed on End press ring of Y-phase winding due to heavy pressure

However the crack formed on the end press ring was not due to failure of tap changer of R-phase but

it seems that end press ring has been cracked due to excessive pressure of clamp holding the end press ring. Further to this, paper insulation was found in damage condition as shown in figure.3.

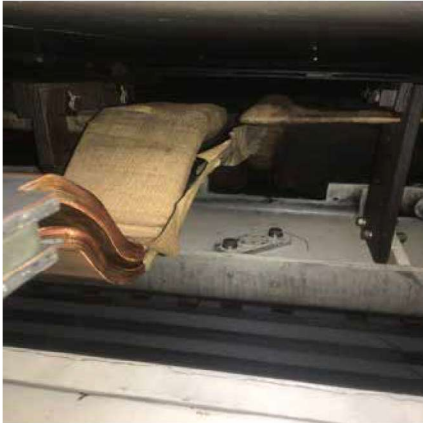


Figure 3 Damaged paper insulation on LV flexible connector

Based on the above observation it was decided to conduct the low voltage impedance measurement & SFRA of the transformer to further check the healthiness of the transformer. Impedance measurement of the transformer matches with the name plate data. The measured impedance was 9.74% which is matching with the ratio test of the transformer i.e. for R-phase of HV winding the resistance measured at all tap corresponds to the tap no.3 while variation with the resistance of other phases corresponds to tap changer position.

Tap	1R-1N (mΩ)	1Y-1N (mΩ)	1B-1N (mΩ)
1	923.8	969.3	970.1
2	924.1	946.1	946.8
3	924.2	922.9	923.7
4	924.5	899.8	900.4
5	924.6	876.9	877.3

Table 2 Winding resistance measurement of HV winding

The SFRA measurement were taken & revealed that there is no damage to main winding occurs due to failure of the tap changer of R-phase.

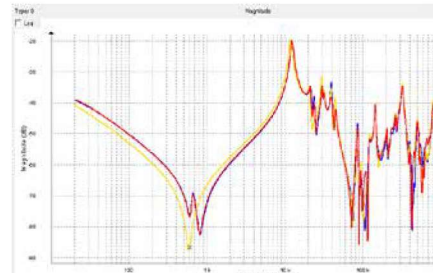


Figure 4: SFRA traces of HV winding in LV open circuit condition at tap no.3

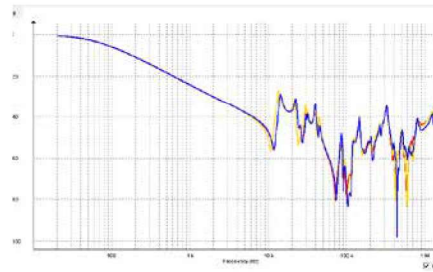


Figure 5: SFRA traces of HV winding in LV short circuit condition at tap no.3

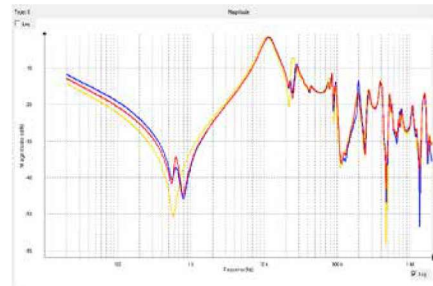


Figure 6: SFRA traces of LV winding

However it was noted that HV R-phase measurement at all taps are similar due to stuck tap changer & normal variation observed in Y-phase & B-phase as expected due change in tap changer position.

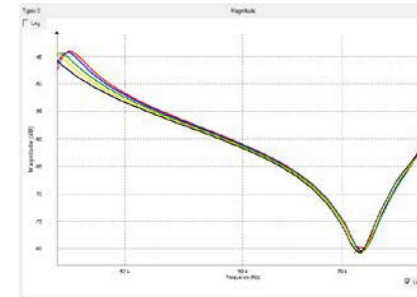


Figure 7: HV R-phase traces @70kHz at all tap position

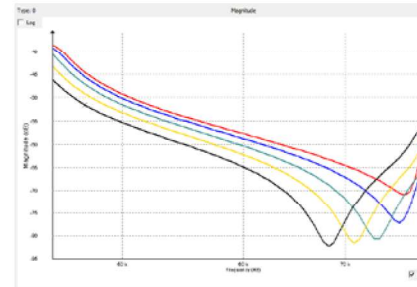


Figure 8: HV Y-phase traces @70 kHz at all tap position

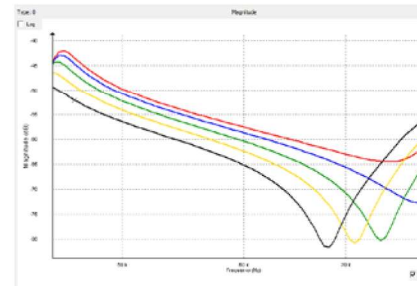


Figure 9: HV B-phase traces @70 kHz at all tap position

The above figure shows that R-phase has stuck tap changer at tap position no.3. Overall SFRA traces reveal no mechanical damage to main winding, core & bushing.

The results of Insulation resistance & polarization index measurement as per table no.3 shows the value of IR is in range of GΩ

Time	HV-LV	HV-Earth (LV Earth)	LV-Earth (HV Earth)
1 Min	5.48 GΩ	3.80 GΩ	2.75 GΩ
10 Min	15.4 GΩ	8.16 GΩ	8.13 GΩ
PI	2.810	2.147	2.956

Table 3 Insulation Resistance & polarization index.

The results of IR & PI shows no abnormality with the insulation of the transformer. It was evident that the tap changer for HV R-phase has been melted resulting in joint with tap position no.3 probably due to inrush of the heavy fault current. Sequence of event suggest that after failure of Lightning Arrester, installed on R-phase of 132 kV side, problem has been observed in HV R-phase tap changer. Visual inspection, result of winding resistance & SFRA also shows the stuck tap changer for HV-phase at tap position. SFRA traces & short circuit impedance however shows no major mechanical abnormality with the main windings. Insulation resistance & polarization index indicate overall healthy insulation system.

It was concluded that there is no further damage to transformer due to failure of tap changer. It was further recommended to do complete overhaul of the tap changer & replace the damaged end rings with damager paper insulation of LV winding. Further recommended to conduct the HV diagnostic test like capacitance/Tan delta before taking the transformer back in to service after rectification. It is also recommended to do periodic monitoring of the LA using third harmonic resistive current measurement, so any failure of the LA near to transformed can be avoided. Sequence of event suggest the flow heavy fault current through the R-phase for sufficient time to melt the R-phase tap changer contact, so it is recommended to review the protection relay coordination. Dynamic resistance measurement of tap changer can also reveals the defect related to tap changer due to coking & pitting. It was recommended to conduct the dynamic resistance of tap changer after rectification.

#### 4. Conclusions

This paper depicts the root cause analysis of tap changer failure & various aspects of its rectification. Tap changer failure can be avoided by regular monitoring of dynamic resistance. It is very evident from the visual inspection & various diagnostic tests conducted that overall transformer winding, insulation & core has no visible mechanical as well as electrical damage due to failure of tap changer.

By utilizing the available condition monitoring practices one can regularly monitor the transformer condition & know the deterioration before any failure occurs. Also it is very essential to monitor the healthiness of lightning arrester which are providing protection to transformer against lightning & switching overvoltage.

#### 5. Acknowledgement

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#### 6. References

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## TRANSFORMER FAILURE ANALYSIS FROM CONDITION OF WINDING

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### Abstract

Utilities deliver power to their customer through a network of generation, transmission lines, substation & distribution system. A distribution system carries power from substation transformer through feeder circuit to distribution transformer located near customer. For a Distribution utility the expense of distribution transformer holds a major portion. Also cause of concerns as network increases day by day along with the increasing power demand. Utilities are constantly looking forward to increase productivity in the distribution system. It means reducing the losses, improving customer service & protecting assets. A Distribution transformer is utilized to step down the voltage from 11 KV to 0.433/.250 KV. So, that the electrical power is usable for providing supply to customer such as domestic, industrial, etc. A consumer expects uninterrupted power supply because during failure of power all work i.e. domestic, official, industrial comes to standstill. Therefore, transformer failure leads to economic loss, interrupts power supply in industries, offices. Failure of distribution transformer can cause long outage due to various issue such as non-availability of transformer, transportation issues, accessibility to the location, etc. Due to that the failure of transformer should be reduced by proper monitoring and analysis. Every distribution company has lakhs of transformers in their population and providing advance monitoring system for all the distribution transformer is not possible. Especially for a public sector company i.e., at present population of Dakshin Gujarat Vij company limited (DGVCL) is 2.33 lakhs.

of internal inspection from the condition of burn coil, HV/LV jumpers, and transformer oil condition we can make analysis of reasons for its failure. This can be helpful for necessary rectification at the concern location which in turn reduces the failure of transformer.

### 1 Introduction

Most common probable causes for failure of distribution transformer are as under: -

- Insufficient Oil level.
- Seepage of water in oil.
- Prolonged Pink Silica gel in breather
- Prolonged Over loading.
- Single Phase loading.
- Unbalanced loading.
- Faulty Termination (Improper sized lugs etc)
- Power theft causing overload.
- Prolonged Short Circuit.
- Lack of installation checks.

Therefore, after conducting the analysis of failed transformer we can get exact reason for its failure.

### Insufficient Oil level



Fig 1: Low oil level

A low oil level in a distribution transformer leads to severe overheating and a reduction in

DGVCL has its own transformer repairing units. Thus, now any failed transformer is directly sent to the repairing unit from field. So, at the time