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ANALYSIS OF ONSITE FAILURE OF PERMA-WOOD RING OF THREE-PHASE AUTO TRANSFORMER AT 400KV TRANSMISSION SUB-STATION

Engineering

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ABSTRACT

This paper presents an analysis of solid insulation perma-wood ring failure of 315MVA, 400/220/33kv transformer at site and its on-site replacement procedure in details. In power transformers, insulation of high voltage (HV), low voltage (LV) and tap windings are designed in which all the insulation co-ordination i.e. phase to phase and phase to earth, partial discharge and stray & eddy current losses are considered and calculated. The basic insulations i.e. perma wood ring insulation, lead insulation, Inter turn insulation , insulation between respective winding , insulation with respect to tank , yoke & core etc are designed and placed as per voltage level of transformer. For uniform pressing of winding coils, Perma wood ring are used in each phase of core coil assembly (active part) of transformer for uniform pressing of winding coil and also for providing insulation between coil & core clamp.

KEYWORDS

Permawood ring failure, transformer tripping, DGA, onsite repair

INTRODUCTION

In power system, Transformer is most necessary and costly equipment in the Generation, Transmission & Distribution network. Transformer is highly efficient equipment in electrical system having more than 99% efficiency, which are used in transformation of power by stepping up or down as desired voltage level. In India, considering the three voltage level 765/400/220KV substation for power transmission, there is 765/400/33KV, 500MVA single phase unit of transformer which is formed the three phase bank of rating 1500MVA, 765/400KV wherein its 765kv side get connected with 765KV Bus-1 & 2 in 765kv switchyard through four- break type Circuit breaker and 400KV side get connected with 400KV Bus-1 & 2 in 400KV switch yard through two–break type circuit breaker. There is two terminals of 33KV winding comes out in each transformer which get connected in delta form for providing closed loop for stabilizing or compensating delta winding which is generally unloaded type or connected with station transformer of rating 1MVA,33/0.433KV for providing auxiliary supply.

Further power transformation at voltage level of 220KV , in 400kv switchyard, there is three phase transformer of rating 500MVA or 315MVA , 400/220/33kv used wherein 400KV side connected to 400KV bus-1 &2 through two-break type circuit breaker and 220kv side connected to the 220KV bus-1 &2 through single -break type circuit breaker.

In India, electrical Power is being transmitted at extra high voltage level of 220kv/400kv/765kv which reduces the I-square losses by reducing the current while transmitting the electrical power. The huge loss in revenue and system reliability is imposed due to long outage or breakdown /failure of transformer of any rating or voltage class. Also, failure of transformer shifts the extra loading on other connected transformer of same rating which is caused to overheating that results weaken the insulation and reduces the life of the other transformer as well.

REVIEW OF LITERATURES:

Jaspreet et al 2016 analyzed that insulation failure and line surges are the major cause of the failure of transformer (jaspreet et al 2016). In their research work , failure analysis was carried out on transformers of various capacity. Also on-site inspection, internal inspection, diagnostic testing and tear down analysis were performed to find out the cause of failure of transformer [1].M.Akbari et al 2013 analyzed that the failure modes, causes and effects in the power transformers through FMEA(Failure mode & Effect Analysis) by which demonstrated the ranking of unreliability of components in graphical charts and matrices which is very useful tool for designers to identify weak points in the transformer design & for O&M designers to give the most of considerations in the transformer maintenance [2] *IEEE Std C57.104-2019* provided a guide for evaluating dissolved gases analysis results from mineral oil-immersed transformers using statistical based analytical tools and fault interpretation methods[3]Shrikant S.Rajurkar et al 2010 analyzed that important reasons for the power transformer failure along with methodology to classify the failures depending on various factors. Based on various failure factors , many times transformers interfacing distribution network experience more number of faults for longer duration further which resulted into failure of EHV transformers. Also discussed about preventive methods in brief to minimise the rate of transformer failure[4]A.K. Lokhanin et al 2005 discussed that the failure mechanisms in oil-barrier transformer insulation and oil-paper condenser type insulation of transformers and HV bushing with reference to typical defects and failure modes of oil-barrier insulation of transformers. He observed that the two failure modes :ionisation-mode and aging-mode failures in which breakdown voltage due to deposit of insoluble aging products resulted insulation breakdown due to degradation of materials[5]

Aim Of Work

Analysis of tripping of 315MVA, 400/220/33KV Auto Transformer at Transmission sub-station.

Trip Incident

There was Bucholtz relay protection get operated which caused to trip the 315MVA, 400/220/33KV auto transformer at transmission sub-station. After tripping, disturbance recorder, Event log , trip indication of protection relays of transformer and relays of other feeders of sub-station were taken and analyzed for the tripping sequence of events. On-site visual checks of transformer and other connected equipments i.e. Bushings, LA , BPI, CT and any oil leakages were checked .and reading of LA counter and WTI/OTI temperature were analyzed with previous.

On-site Inspection

In 400KV switchyard, there is one & half breaker scheme used and in 220KV switchyard, double main transfer scheme (DMT) used .While on-site inspection, all the equipments i.e. BPI, CT, CB, Jumpers & Aluminum tube of 400KV main & tie bay and concerned 220KV bay of tripped transformer were thoroughly visually checked. During the visit, discussions were held with the people who were there and witnessed the incident or observed the any abnormal sound during the fault or during normal operation.

Also CCTV camera provided on the transformer which was checked and got evidence or sequence for the occurrence of tripping of 315MVA,400/220/33KV Auto transformer. Incident time was checked with time of GPS clock which was duly synchronized with all the protection relays and CCTV system. After visual checking & inspection, no damage was observed in the tripped 315MVA, 400/220KV Transformer.

Diagonistic Test On Transformer

Further confirmation of healthiness of transformer, following Low Voltage tests were conducted at site –

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1.MAGNETIC BALANCE TEST -* Applied voltage – 1 –phase ,230V AC voltage applied						
From HV (400KV) side (Star connected)						
1U-N	1V-N	1W-N	Test results remark			
*230V	195V	39V	Generally found within acceptable limit			
112V	*230V	117V				
38V	198V	*230V				
From IV (220KV) side (Star connected)						
2U-N	2V-N	2W-N	Generally found within acceptable limit.			
*230V	174V	62V				
114V	*230V	115V				
61V	171V	*230V				
From LV (33KV) tertiary side (Delta connected)						
3U-3V	3V-3W	3W-3U	Generally found within acceptable limit			
*230V	161V	73V				
114V	*230V	116V				
76V	159V	*230V				
2.MAGNETIZING CURRENT TEST @* Applied voltage – 3 –phase ,415V AC voltage						
1U	1V	1W	HV-400KV SIDE	Generally found within acceptable limit		
2.1mA	1.9mA	2.15mA				
2U	2V	2W	IV-220KV SIDE			
4.3mA	3.9mA	4.24mA				
3U	3V	3W	LV-33KV SIDE			
20.3mA	19.8mA	20.5mA				
3. INSULATION RESISTANCE TEST @ applied voltage 5KVDC for 10 min						
HV-IV-N / LV winding		HV-IV-N / E		LV/HV-IV-N		Generally found within acceptable limit
60 second	600 seconds	60s	600s	60s	600s	
2.7 G-Ohm	4.95 G -Ohm	1.7 G	2.9 G	2.2 G	4.5 G	
4.CORE INSULATION RESISTANCE TEST@500VDC						
Core to tank	Core to Clamp	Clamp to tank	Test Duration	Generally found within acceptable limit		
2.3 G-Ohm	2.7 G-Ohm	1.8 G-Ohm	60 seconds			
5. CAPACITTANCE & TAN DELTA TEST@10KV for Winding & Bushings						
WINDING	HV-IV-N/E (GST Mode)	LV/HV-IV-N (UST Mode)	HV-IV-N/LV (UST mode)	OTI temp 40degC		
Capacitance/ Tandelta	21.235 nF	8.252nF	8.352nF	Yearly tan delta value Increment should be less than 0.001 wrt previous value		
BUSHINGS	400KV-HV-1U	400KV -HV-1V	400KV-HV-1W			
Capacitance/ Tandelta (in UST mode)	563.4Pf/0.0038	567.3PF/0.0029	568.3PF/0.0035			
	220KV -IV-2U	220KV -IV-2V	220KV-IV-2W			

	375.4PF/ 0.0028	377.8PF/0.0036	378.9PF/0.0038			
	33KV-LV-3U	33KV-LV-3V	33KV-LV-3W			
	278.9PF/0.0039	282.4PF/0.0036	279.2PF/0.0031			

All the LV test results were generally found in order and also within the acceptance limit as per POWERGRID Transformer manual/CBIP manual /IEC standard.

Oil Sample Testing

Further analysis, oil sample for Dissolved Gas Analysis was taken & tested through portable DGA analysis kit available at site. The DGA result indicated the dissolved gases i.e. C2H2, C2H4, H2 in the oil which indicated the burning / spark inside the transformer tank. On the basis of DGA result, the subjected transformer was to be inspected internally for investigating the fault location and damage or deterioration of the insulation. For the internal inspection, Valves of cooling bank & conservator were kept shut-off and oil draining from main tank was started. After main tank oil drain, side inspection cover was opened and dry air having dew point-50degC was pushed from top for maintaining positive pressure which kept to reduce the entering the moisture. During internal inspection, it was required to wear the neat & clean oil entry wearing kit for control the dust particles and it was also to be ensured the exposure time of the Transformer must be minimum.

Observations & Findings:

While internal inspection of active part of transformer, there was black spot marks observed in Perma wood ring of W –Phase top side and core clamps which caused to create condition.

Perma-wood ring

During manufacturing of Perma wood insulating ring , process was bypassed or reduced due to which moisture and dust particles were trapped inside the solid ring. In the summer, top oil of transformer was heated up and touched the 78 deg C or more with 80% loading of transformer due to which trapped moisture comes out and caused treeing and tracking inside the insulation . Also insulation cellulose got degraded which resulted to decrease the die-electric strength of insulation.

It was analyzed that while manufacturing of above perma wood ring, moisture and dust particles got trapped inside the various layers of insulation that was got weaken due to overheating and caused to ruptured the insulation with respect to core clamp during overvoltage transient condition. There was occurance of flashover between perma wood ring & clamp stud which produced the dissolved gases inside the transformer that was resulted to operate the Bucholtz relay protection and transformer got tripped. While failure of any insulation i.e. turns to turn insulation, inter-winding insulation, lead insulation etc., transformer get failed electrically. During the fault condition, all the vector sum of the forces, i.e. radial and axial forces across & inside the winding got disturbed and become abnormal. Further, the axial forces within winding having attractive nature thus placement of PICC and insulation i.e. block, spacer got compressed which get the stressed and may be get bended.While , the axial forces between winding to other winding of same phase having repulsive nature which may press the winding against end lamination of core. Above axial forces i.e. attractive & repulsive contribute the more stress on the insulation provided between winding, core & tank.

Action For On-site Repair :

While replacement of perma-wood ring on -site , following step by step actions need to be executed -

1. Closed environment by using tent or tarpaulin to be arranged
2. Oil from main transformer tank up to bottom level to be drained
3. Bushings and OLTC diverter to be taken out by using hydra crane.

After dismantling , diverters to be kept in oil drums with wrapping of polythene and bushing to be laid down at angle 30 deg with respect to ground.
4. Earthing connection of CFT (Core-frame-tank) to be removed.
5. Removal of bell cover of main Tank and covering winding by tarpaulin to be done.
6. Crane capacity of 100-Ton with 22 Ton Hood to be used.
7. IR test for C-F-T (Core-frame-tank) to be measured for isolation.
8. All bolts of top frame (yoke) to be taken out.
9. Yoke lamination of core to be taken out and to be stacked adequately in sequence on pallets.
10. Failed Parma wood Ring to be lifted and taken out from active part.
11. Cleaning of all charred surface, carbon, other residue on the the coil to be done.
12. New Parma wood ring to be installed.
13. Yoke Lamination filling done in proper sequence as dismantled.
14. Tightening checks of HV/LV side frame, OLTC Bracket, leads to be done.
15. Bell Tank cover to be cleaned through oil flushing thereafter to be placed.
16. Final Tightening of tank rim bolts and complete fixing of blanking plates to be done.
17. OLTC Diverter to be cleaned and to be reinstalled in oltc chamber
18. All balance accessories Turret CT, Bushings to be installed.
19. Finally tightening to be done and leak test to be carried out through dry air or N2 having dew point -50degC.
20. Oil Filtration and Hot oil circulation to be done.
21. Vacuume cycle and dry out cycle to be repeated until desired PPM value to be achieved.
22. All pre-commissioning testing to be carried out and to be checked with respect to factory test results or previous test results.
23. After checking healthiness of all protection, air release from B'relay and cooler bank , transformer may be taken into service.

CONCLUSION:

In this paper, the tripping of 315MVA, 400/220/33KV auto transformer are discussed and failure analysis of 315MVA,400/220/33KV power transformer of one of transmission sub-station of POWERGRID. Onsite external & internal inspection, relay DR/EL analysis & diagnostic testing are performed as per POWERGRID /CBIP manual. In this paper, it covers the perma-wood ring insulation failure is main cause of the tripping of transformer and also covers the onsite replacement of failed perma-wood ring of 315MVA, 400/220/33KV auto transformer.

REFERENCES:

[1] Jaspreet singh , Sanjeev singh "Transformer Failure Analysis:Reasons and Methods"in International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 ACMEE - 2016 Conference Proceedings.
[2] Mohsen Akbari, P. Khazaee, I. Sabetghadam and P. Karimifard "Failure Modes and Effects Analysis (FMEA) for Power Transformers," in *Proc.* 28th International Conference on Power System, Tehran, Iran, 4-6, November 2013.
[3] IEEE Guide for Interpretation of Gases generated in Oil filled Transformers, IEEE standard C57.104-1991.
[4] S.S. Rajurkar, Amit R. Kulkarni , " Analysis of Power Transformer failure in Transmission utilities "in Proc. 16th National Power Systems Conference, 15th-17th December,2010.
[5] A.K. Lokhanin, G.Y. Shneider V.V. Sokolov V.M. Chonogostsky, "Internal insulation failure mechanisms of HV equipment under service conditions",15-201 CIGRE Session 2005
[6] Manual on transformers -CBIP manuals-publication no -295.
[7] J & P Transformer Book: A Practical Technology of the Power Transformer