Failure of Solar Inverter Transformers and Power Transformers in Solar Power System -

Causes and Remedies

The total installed power generation in India s reported by IEEMA is around 375 GW as on 31.10.2020. Out of which the total installed renewable energy capacity stood at 89 GW of which solar contributed 36 GW an 38 GW. The Government of India has an very ambitious plan of generating solar energy of 114 GW by 2022. So lot of solar inverter transformers and medium and large power transformers are added in the power system. It is reported that quite a significant numbers of these transformers have problems in the systems due to various reasons described in the following clauses.

Causes for failure of transformers

1.1 Faulty design – Improper understanding of system operating conditions
1.2 Use of poor quality of materials
1.3 Improper manufacturing and testing processes
1.4 Improper commissioning and inadequate maintenance
1.5 Inadequate / Improper protection
1.6 Frequent short circuits (Earth Faults) and over voltages coming on the transformers due to system disturbances and operating conditions
1.7 Magnetic inrush due to frequent switching on and switching off

Improper understanding of system operating conditions

Since these transformers are getting loaded for about 6 – 9 hours in a day (may be 8 AM to 5 PM), there is a tendency to under estimate the operating conditions and choose design parameters in such a way that the design becomes more competitive to meet the competitive price demand. This results in over heating of windings, development of hot spots in windings and generation of gases resulting in tipping of transformers under OTI / WTI operation, BR etc. (Photo 1)

Photo 1 - Insufficient Cooling of Windings Resulting in Thermal Failure

Also due to inadequate cooling area to dissipate the losses generated in the systems during the operating conditions even though the transformers have been successfully tested in factory for Temperature rise. (Photo 2)

Photo 2 - Insufficient Cooling of Total Losses Generated

Cracking and leakages from LV epoxy bushings due to differential thermal coefficient of expansion of resin system and Copper material (Photo 3)

Photo 3 - Breaking And Leakage From LV Epoxy Bushings

Improper selection of HV bushings resulting in failure due to inadequate creepage for the voltage class (Photo 4)

Photo 4 - Failure of HV Elastimould Bushing due to Inadequate Creepage Distance

Improper installation

Thermal heating of transformers due to insufficient natural cooling (Photo 5 and 6)

Photo 5 - impare of natural cooling due to blockage from inverters mounted close to the transformer

Photo 6 - Burning Of Lv Side Bus Bar Sleeve Due To Insuffcient Cooling (Bus Duct Blocking The Heat Dissipiation)

Use of inferior grade of materials and frequent short circuit in the system

These kind of transformers are subjected to frequent short circuits in the systems (Earth faults). If the materials used are of inferior grade or sufficient mechanical supports are not provided due to improper understanding of operating conditions the Transformers are prone to fail under dynamic short circuit forces. (Photo 7, 8, 9, 10)

Photo 7 - Inadequate (Improper) Mechnaical Support

Photo 8 - Poor Quality of PW Rings

Photo 9 – Failure of LV Windings in all three Phases under Dynamic Inability to withstand Short Circuit Forces

Photo 10 - Inadequqte Mechnical Supports for Short Circuit Forces

Due to frequent switching on and switching off of the Transformers, the magnetic inrush current which is of the order of the 10 to 15 times the rated current depending upon the instant of switching on can cause the effect of dynamic failures in the windings.

Failures due to over voltages

Even though the transformers have been successfully tested in the factory for all the dielectric tests as per relevant standards, it has been noticed that there are many cases of dielectric failures of these kind of transformers in the system. (Photo 11, 12, 13,14). The dielectric failures have resulted in thermal failure damaging the complete HV and LV windings.

Over voltages in the solar system can be due to lightening impulse, switching surges, resonant over voltages due to the transformer inductances resonating with cable capacitances. It is reported in many technical journals that these resonant voltages can be of very high magnitude causing severe dielectric failures. One such technical reference is listed under the references.

IS 2026 and IEC 60076 (Part 3, 2018) have indicated over voltages due to vacuum switching on and off, and the precautions to be taken in the design. Designers to note the same.

Photo 11 - Dielectric Failure Resulting in Short Circuit Failure In HV Windings

Photo 12 - Dielectric Failure Resulting in Short Circuit Failure of Windings

Photo 13 - Dielectric Failure of HV Windings due to over Voltages

Photo 14 - Dielectric Failure of Insulation System due to over Voltages

Remedies

Failure of solar inverter transformers will result in huge generation losses in the system hence it is required to build, maintain and protect these kind of transformers with utmost care.

7.1 Adopt robust design considering the system operating conditions like frequent earth faults, resonant over voltages, fluctuating load conditions, frequent switching on and off , over voltages due to vacuum switching on/off, not just design for competitive price. Provide sufficient cooling considering the overload in the systems and the harmonics from the inverter side. Calculate the winding hot spot temperature more accurately. Adopt latest analyses tools like FEM method, MATLAB etc. to analyze short circuit forces, voltage distribution and mechanical structure design.

7.2 Use best grade of insulation materials to meet the system operating conditions.

7.3 Adopt good manufacturing practices like proper lead routing, anchoring of coils for containing both axial and radial forces. Refer photographs 15 and 16

Photo 15 – Good Practice Of Lead Routing And Coils Anchoring

Photo 16 – Good Practice of LV Bus Bars Anchoring.

7.4 The users to take care of proper installation considering the cooling requirements based on the heat generated in the transformers due to no load loss and load losses

7.5 The protection provided should be robust enough to take care of the Transformers under severe faults coming on the Transformers. IEEMA have brought out series of articles (Part 1 to 5) on tripping analysis of Power Transformers depicting the actual reasons based on the case studies, protection lacuna, and the inadequate maintenance. (Please refer IEEMA Journals of September 2020 to January 2021). The solar power system engineers are requested to read these articles as they are very useful.

7.6 It has been noticed that in many a cases the failures are also due to improper / inadequate maintenance of these type of transformers. The user are here by requested to follow the operation and maintenance manual provided by transformer manufacturers as well as the procedure described in CBIP manual on transformers.

7.7 Maintain proper log books in the substation to analyze the problems if any, so that proper CAPA can be taken.

7.8 Manufacturers to look at the possibility of using fiber glass LV bushings instead of Epoxy bushings to avoid leaks due to cracking of epoxy bushings as described above. Refer photo. 17

Photo 16 – Fibre Glass Bushings for LV (High Current).

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Innovative use of Auxiliary Bus in EHV Switch-Yard

A case history narrating extension of 220 kV supply to needy 220 kV S/S at Sarni in MPPTCL

Synopsis

A Bus System in any Sub-station / Switch-yard in a power system are analogous to a bulk supply reservoir. Bulk Power supply is received on a bus from the generator units through GTs and /or from other nearby supply sources and is transmitted through different feeders to other adjoining sub stations. Bus arrangements in the Switch yards/ sub stations facilitate easy operations. There are two types of Bus arrangements in 220kV and above S/Ss as follows;

i. 1&1/2 Breaker scheme.

ii. 2 main buses and an auxiliary bus(Transfer bus) system.

In both the schemes, the main focus is on taking out Circuit breakers for maintenance/replacement without interruption of supply to the feeders/ transformers. In the state of MP right from the MPEB days the norms of 2 main buses and an auxiliary Bus system is followed for 220kV switch-yards / sub-stations.

Principal Author had innovated an idea of extending supply to a 220kV S/s which was deprived of 220kV supply due to failure of its circuit breaker , through the 220kV auxiliary bus and implemented this arrangement successfully.

Auxiliary (Transfer) bus Configuration

The Auxiliary bus facilitates interruption free breaker maintenance /breaker replacement,

i. It is strung with the same sized conductors as the main bus.

ii. It has connection to the main bus 1&2 through main bus 1&2 main bus isolators (as the case may be) and an aux bus isolator.

iii. Each bay is equipped with auxiliary bus isolator.

The figure no.1depicts the concept of an Auxiliary bus and how it is utilised in by-passing the bay Circuit breaker for maintenance/ replacement without interruption.

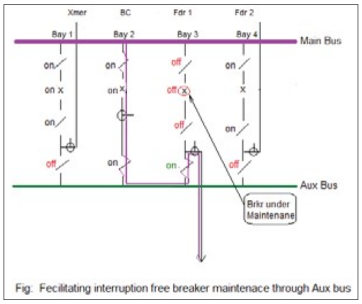

Fig.1: Use of Aux.bus in 1-main bus + an auxiliary bus configuration

Extending 220kV supply to needy 220kV S/S Sarni through innovative idea using Aux bus;

Case history

An incidence had occurred when all the important Express/ mail and goods train stopped plying with electric locomotives between the Itarsi Rly Jn. to Nagpur Rly Jn. (Grand-Trunk route between New Delhi to Hyderabad-Chennai) and vice versa consequent to non-availability of traction supply from 132/25kV Rly Traction Sub stations. This incidence occurred as the 220 kV mother Substation at Sarni (MP) was deprived of 220 kV Supply from Satpura Th .Power Stn..

3.2 Supply arrangement:

The 220kV Sub-station Sarni (mother S/S for the Rly Traction S/Ss) is 3 Kms away from SSTPS(Satpura Super Thermal Power Station)at Sarni in Betul Distt. It had an installed capacity of 2x100 MVA, 220/132kV Transformers. It gets 220kV supply from SSTPS's 220kV Bus through single 220 kV Transmission line. The other 220 kV feeders emanating from SSTPS Switch yard are 220kV Itarsi feeders- 1,2,3 & 4 & 220 kV Ambazari feeder(inter- state fdr).(Please refer fig. No2)

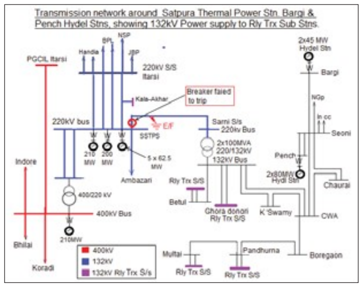

Fig. 2: SLD Transmission System around Satpura Super Thermal Power Stn, Sarni ,Fault on Sarni S/S Fdr & Trx S/Ss