Isolated Phase Busbar Connection between Generator and Generator Transformer Bank – A Review

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Background

Phase mismatch during synchronization was seen while commissioned 500MW units in initial days of NTPC. The phase mismatch is noticed during the synchronization activity. The phase sequence was noticed different between Turbo Generator and Switchyard, Turbo Generator and Generator Transformer and involved a large modification in isolated phase busduct connection between Turbo Generator and the Generator Transformer. The phase mismatch has been avoided in large fleet of switchgear. Where, phase mismatch was common at switchgear incomers and switchgear tie panel in earlier days. The same has been completely eliminated despite of large fleet of HT switchgears. Phase mismatch issues still exists in other utilities.

The paper elaborates the common issues, which results in phase mismatch between Turbo Generator and Generator transformer bank, high voltage station and unit transformer at one end and high voltage switchgear at other end.

Reasons of Phase Mismatch

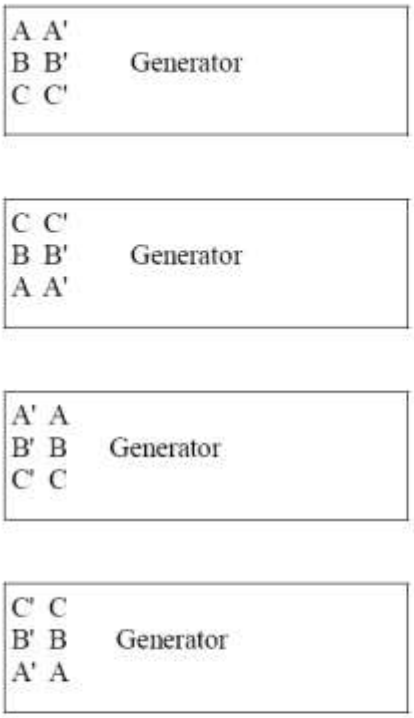
The Generator Step up Transformers (GST) for large rating units are formed by a bank of three single phase units. A common vector group chosen by utilities is YNd11 (Sometimes kept different to match the existing generators and/or MV systems). The LV side of a GST is generally Delta connected and the HV side is Star connected The Generator to GST connections and also the Delta formation is carried out by Isolated Phase busduct (IPBD). It has been experienced several times in past, that the phase sequence are different on high voltage line side and the Generator. The actual phase sequence mismatch of the units has been experienced by utilities during Generator Protection System testing prior to synchronization. This mismatch is despite the fact that the delta formations are carefully designed during engineering stage. The solution carried out in past involved cumbersome modifications in Isolated Phase busduct.
This paper discusses users' experience during replacement of a 3-phase GST Transformer (Case A) and discusses a novel method of providing flexibility in Delta connected bank of 1-phase GST Transformers (Case B).

The various reasons for mismatch in phase sequence are:

a) The Transformer manufacturers have different physical orientation of HV Bushing.

b) The IEEE standard is clear vis-a-vis definition of vector group, whereas IEC standard is not.

c) The generator manufacturers have different winding bushing terminal arrangement and phase sequence (Fig.1).



The peak voltages appear in time in the order A-B-C-A-B-C-A-... for the given direction of the rotation of field (i.e rotor).

The physical direction of rotation of rotor is associated to the Terminal Markings and the same should appear on the Generator Outline drawings as well as Turbine Outline (or the composite Turbine-Generator) drawings. It is pertinent to mention that the DOR as seen from Generator non-driving end (NDE) is either Clockwise (CW) or Counter Clockwise (CCW). This varies as per manufacturer's standard practices. Different arrangements have been observed even for the same manufacturer too.

FIG.1 Different Configuration of Generator Terminals

Case A: Three (3) Phase Generator Transformer:

The IEEE Std C57.12.70 specifies the vector group of a three phase transformer phase sequence of HV Bushings as R-Y-B from right to left and those of LV Bushings as r-y-b from right to left when looking from the HV side of the transformer. See Fig.1 of user installation.

However IEC 60076-1 does not define the standard physical phase arrangement on HV side of transformer and accordingly the manufacturer has option to choose R-Y-B either from left to right or vice-versa. It is worthwhile to mention here that transformer manufacturers in India follow R-Y-B sequence from left to right when one looks from HV side of the 3-phase Power Transformer.
The issue resulted in availability of large number of transformer with same vector group having different phase sequence and thus a transformer conforming to same vector group (as per nameplate data) is not good for replacement at another power station.

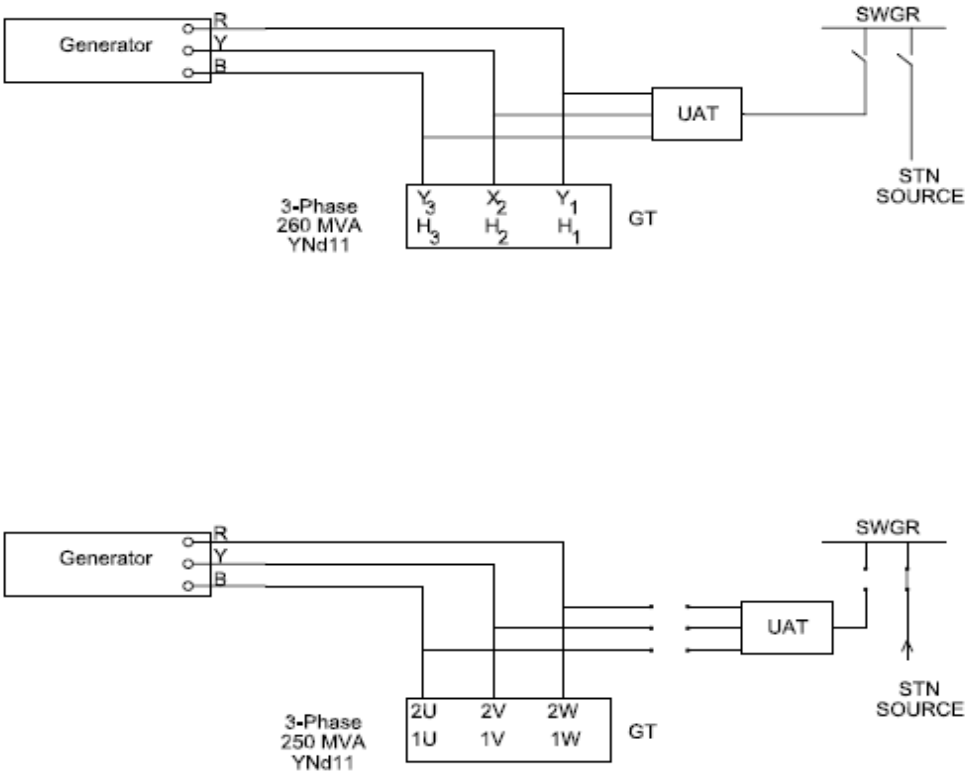


Fig.2 Utility case of 3-phase GST replacement

This resulted in mismatch of vector group when user tried to change one make generator transformer with another make. The above illustration discusses the typical case, where user has replaced one transformer

confirming IEEE vector group by another transformer confirming to IEC vector-group.
A temporary solution was reached by disconnecting the UAT (see Fig.1) and restoring the generating unit (with reduced reliability). At a suitable time subsequently, the UT connections were changed internally and the whole system was normalised (involved extra efforts and costs).
The solution lies in matching requirements in IEC and IEEE and also in the National Standards. The IEEE scheme can be adopted.

Case B: Bank of There (3) number Single Phase Generator Transformer:

NTPC in past has experience different type of phase sequence mismatch at three projects. The same has been described as follows:

i) In one of the NTPC project, the generator looking from NDE has phase R-Y-B from left to right. The connection through Iso phase busbar has been done so as to have single phase transformers bank with R-Y-B from left to right, if seen from switchyard. The Indian manufacturers have 2.1® of LV on left side and 2.2® on right side, if viewed from switchyard. Whereas the Japanese manufacturers follow IEEE standard, where the 2.1® and 2.2® are placed on right and left side respectively, if viewed from switchyard.

ii) In second case, the generator from GEC, UK follows the phase sequence right to left R-Y-B (opposite to case-i). However the marking on single phase transformers was 2.1® on left side and 2.2® on right side, if viewed from switchyard. As the busbar connection were done similar to case-1, mismatch in phase sequence again happened.

Similar mismatch has been experienced in different projects, till the system was set right to carryout the detail analysis prior to busbar connections.

NTPC has also experience of ordering a three phase generator transformer following phase marking as per IEEE i.e. R-Y-B from right to left if viewed from switchyard, but got the transformer with phase marking R-Y-B from left to right, if viewed from switchyard, as per manufacturer convention. This has resulted change of vector group from Dyn11 to Dyn1, a phase difference of 60 degree from the desired. In such case, prior to unit synchronization the connection of unit transformer on HV side are required to be modified. This aspect has been discussed in case-B.

Proposed Addition in Busbar drop connection for Delta Formation:

The standard terminals of a single phase transformer are shown in Fig.3. A typical formation to achieve vector group of Ynd11 is also shown.

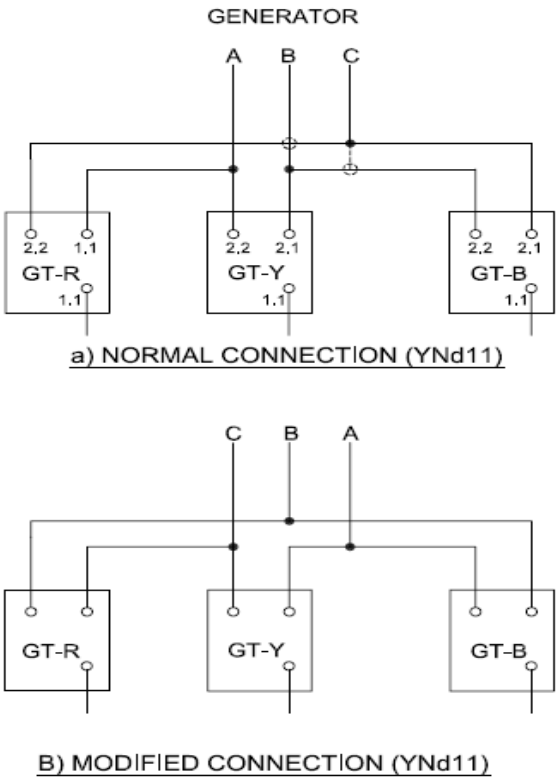


Fig.3 Utility case of Bank formation using 1-phase GSTs

Keeping in view the fact that various utilities don't have the expertise to ensure phase sequence matching at time of synchronization at every

instance, scheme for future application has been developed where with shifting of one pair of flexible link from one location to other, the phase sequence can be matched/corrected. The scheme works for various combination of Generator phase configuration and bank of single (1) phase transformers provided with standard arrangement of bushing terminals as per manufacturers standard. See Fig.3 of proposed installation.

The action taken for carrying out such changes have been discussed in the paper. It may be noted that the replacement can be done without carrying out any modification in the busduct.

Cost: The scheme envisages an additional of four (4) numbers of T-joints i.e. two (2) in Main run and two (2) in Delta run with necessary cover plate to have the option of flexibility in the standard design.

Advantages: The nominal expenditure allows the utility to:

a) Save time in unit synchronization, if any phase mismatch is observed.
b) Save cost of cumbersome connection modification of Iso-phase busduct and the associated delay in unit commissioning.

Conclusion:

Two cases of GST transformer connections have been discussed. This should provide insight to utilities for taking care of phase sequence during engineering. The paper highlights the need of caution while replacing Transformers based on Nameplate data. A novel method of provision of changing vector in three phase bank formation has been discussed and can be usefully implemented. It is suggested to review and harmonize the available Standard with respect to terminal marking on Generator and Generator Transformers.