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National Grid
Commissioning
Handbook
Procedure 24

Installation & Commissioning of Numerical Busbar Protection

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1 PURPOSE

The purpose of this procedure is to outline the recommended practice for commissioning numerical Busbar Protection on the National Grid system. This covers protection installed on new sites and also asset replacement of existing high impedance schemes.

This document should be used in conjunction with the setting recommendations contained within PS(T)010, Application and Setting of Protection and TGN(E)184, Application and Setting of Protection.

2 GENERAL OVERVIEW

Numerical Busbar Protection using a biased differential algorithm is now the accepted equipment installed on National Grid sites for protection of busbars at 400kV, 275kV and 132kV. The protections have a number of features including the following:-

- A single Bay Unit per Feeder fed by a single current transformer
- One or two Bay Units per Coupler/Section (depending on the algorithm) fed by one or two CTs.
- A single Central Unit either ring or star connected collating the bay unit information and making trip decisions.
- Internal check and discriminating zones.
- A measurement supervision algorithm per Bay Unit, which measures the three phase inputs and compares these with the neutral on that Bay Unit. A non-compliant comparison will block operation of the protection zone the bay unit is connected to.
- Direct digital inputs for busbar disconnector auxiliary switches (ie not in the AC wiring and no CT switching).
- Differential Current Transformer Supervision.
- Direct interpose close inputs to bay units such as couplers and sections where the zone CT connection is dictated by circuit breaker auxiliary switches.
- Integral circuit breaker fail protection.
- Numerical busbar protections have been engineered with a duplicate central unit to cover for a central unit failure as defined in TP162.

The protection types available include ABB REB500, Siemens 7SS522, and VA Tech DRS-BB and Areva P740.

The use of a single numerical protection for the protection of busbars requires a fallback strategy in the event of failure. This is covered by TP 162, Preparation & Implementation of Contingency Plans for the Failure of Numerical busbar Protections.

The commissioning of such protection relies heavily on a robust set of factory acceptance tests and can also allow for novel methods to match CTs using load current.

3 STAGE 1 COMMISSIONING PRINCIPLES

The stage 1 commissioning documentation must comprise Type Registration information, a comprehensive Factory Acceptance Test (FAT), Site System Test, and Site Commissioning Test (SCT).

3.1 Type Registration

A brief statement of the type registration position for the equipment to be installed shall be provided in the commissioning records. This shall include the appropriate EGI code and state the equipment order code, the current registered firmware version and functional configuration.

3.2 Factory Acceptance Test

A full FAT must be carried out on all new protection installations using either the actual IED hardware or representative hardware (i.e. that of identical model number type).

For subsequent re-configurations (e.g. for additional bays) then a **subset of the full hardware must be used - all bay types ; bus sections / bus couplers and a selection of feeders plus all new hardware.** The database topology must be re-validated i.e. proven that all bay positions are valid but done by moving/re-addressing hardware during the FAT.

As much testing as possible should be carried out in the factory on a test platform including all bay units to be configured for the substation layout required. The tests shall include all fault scenarios (ie R-Y-B-N, R-N, Y-N, B-N, R-Y, etc) on all bay units connected for internal and external faults; and a set of comprehensive tests to prove the correct operation of circuit breaker fail protection and associated backtripping on all bays.

Should defects be found which should have been proven at FAT, then National Grid reserve the right to request further ad-hoc tests.

FAT tests must be carried out by experienced test personnel with detailed knowledge of the equipment in use.

The FAT results form part of the overall commissioning programme and shall consist of the following:-

- Block diagram showing the test connections.
- A test programme detailing all the tests carried out with comprehensive results all fully signed off. This must include peer to peer communications where applicable.
- Details of relay software and settings installed at FAT. Calculated relay settings should be installed pre-FAT with the final settings available post-FAT.
- CH21 documentation.

Prior to commencing the FAT the proposed test programme and tests to be carried out shall be made available to the National Grid Commissioning Officer for review.

The FAT must be witnessed and accepted by the National Grid Commissioning Officer.

3.3 Site System Test

As part of the stage 1 commissioning works a full site system test must be carried out prior to the final overall commissioning tests with all bay units connected to the central unit. It is acceptable for individual circuit bay units to have external wiring connected prior to the tests - for asset replacement this may be necessary due to the physical location of the bay units and to minimize circuit outages. External connections must be disconnected from the installed grid system prior to the system tests.

For new installations the system test shall consist of tests to determine the correct connection of the overall system with all configurations installed and supplies connected. In addition there shall be repeated a subset of the tests carried out at FAT. This shall consist of repeated FAT tests for each circuit type.

For extended installations, the system test shall determine the correct connection of the new bay unit to the system. No repeat of FAT tests shall be carried out.

Any subsequent changes to the FAT tested system must be fully tested on site or, in the case of software changes in numerical relays, have CH21 documentation agreed with the Commissioning Officer.

Any items interfered with/installed following the FAT must be re-proven with a clearly defined overlap on site - for example inter-panel or inter-subrack wiring which is disconnected when equipment is transported to site or was not connected if representative hardware was used. Where such connections interface with a relay, the overlap must be to either an input or an output on that relay.

The system test results form part of the overall commissioning programme and shall ideally consist of the following:-

- Block diagram showing the test connections
- Panel drawings and schemes highlighted for positive and negative checks
- A test programme detailing all the tests carried out with comprehensive results all fully signed off.
- Details of relay and/or SCS software and settings installed at SAT.
- A test of the changeover procedure where a duplicate central unit is installed.

Any deviations from the above shall be agreed at the first commissioning panel meeting.

It is acceptable that some SCT sheets can be part completed during system test if agreed by the commissioning panel.

The system test must be witnessed and accepted by the National Grid Commissioning Engineer.

3.4 Site Commissioning Tests

SCTs are carried out after connection to the external interfaces and shall consist of the usual array of DC and AC scheme checks, insulation resistance and equipment specific tests not covered by the FAT or system test.

For Busbar Protection it must be ensured that the following checks are also carried out if not covered by the above:-

- A secondary injection to each bay unit at rated fault current to verify correct operation of the measurement supervision algorithm - for example 31.5 amps for at least 300ms but not exceeding 1 second to mimic 63kA fault level on a 2000/1 CT. Note that care must be taken during such tests to ensure the thermal capability of the relays are not exceeded.
- A test or inspection on each bay unit to verify that correct disconnector auxiliary switches have been used such that the busbar protection sees a disconnector as closed (although it may be DBI) prior to the pre-arcing point of disconnector travel.
- A test to verify correct operation of direct interpose close inputs to bay units such as couplers and sections where the zone connection is otherwise dictated by circuit breaker auxiliary switches. Note that for the REB500 relay with feeder end protection, this applies to feeders as well.
- A check of the operation of the test/normal and/or maintenance switch or link fitted to each bay to ensure the correct functionality is enabled/disabled.
- For all new or not previously used CTs, per bay primary injections must be carried out to conform with SCT 20.2.

4. STAGE 2 COMMISSIONING PRINCIPLES

Stage 2 commissioning tests are carried out when there is interference with the in-service system. There is a requirement to match different circuit CTs with one another unless this is deemed to be previously proven - see 4.4 below.

Where primary injections are required to match CTs this is considered as stage 2 in this document due to the use of and interference with existing busbars and busbar protection systems; but might be considered as stage 1 for new substation installations not yet connected to the primary system.

Numerical busbar protection has the ability to view (via the relay MMI and/or manufacturers software) ampere values in each bay and combined differential values for each zone. It is therefore possible to match CTs using load current. If this is not possible then the traditional method of using primary injections must be adhered to.

4.1 CT Matching Using Load Current

Testing using load current is preferred to primary injection as it negates the need for the sometimes onerous connection and disconnection of test leads which can have health and safety implications. It is also a quicker method. On new CT installations where primary injections are required anyway CT matching must also be carried out using primary injection.

Where load current is used then there must be at least 100mA secondary current available in each CT - for a 2000/1 CT this is equivalent to 200 primary amperes.

A set of CTs on a circuit should be chosen as a reference to match all the other circuits against. This is likely to be either a Bus Coupler or a Bus Section. For asset replacement, spare CTs tend to be available on at least one of these circuits for permanent connection during the installation outage. If these are not available then the matching must be against a previously proven circuit. Other CTs can be used for reference as long as these have first been matched with the original reference.

A programme of tests is required to cover each circuit. An example is given in **Appendix 4**. Using load current in effect provides a stability "shot". An operation "shot" can be omitted.

Tests can be carried out either during circuit outages following installation of the required bay units or later during the final transfer.

4.2 CT Matching Using Primary injection

Where load current cannot provide sufficient confidence, normally due to insufficient current, then a series of primary injections must be carried out. It may be possible to prove some circuits with load current and others by primary injection.

There must be at least 100mA secondary current available in each CT - for a 2000/1 CT this is equivalent to 200 primary amperes

Assuming all circuit CTs are already tested for ratio and polarity of the three phase group, primary injections for matching with other circuits shall consist of a single phase shot on each phase to prove stability.

An operation shot shall be provided by primary injection. This does not need to cause operation of the busbar protection but should show correct bias and differential currents on the busbar overview provided by the busbar protection software. .

An example is given in **Appendix 3**.

Tests can be carried out either during circuit outages following installation of the required bay units or later during the final transfer.

Care must be taken to ensure in-service CTs are shorted - ie those connected to in-service protection.

Primary injections should use the busbars where outages permit. There may be certain instances where the use of test leads is more convenient - in this case disconnector auxiliary switch contacts may need to be shorted.

4.3 Other Commissioning Tests

Prior to commencing stage 2 commissioning, settings loading verification tests as per CH20 must be carried out.

Before final commissioning of the new busbar protection, at least one busbar changeover per

section must be carried out to confirm stability during switching.

4.4 Asset Replacement Issues

For asset replacement of busbar protection there are a number of issues which may also require consideration as follows:-

4.4.1 Use of Existing Check CTs

On circuits with check zone CTs, these are normally used to feed the new numerical busbar protection.

During a series of circuit outages, busbar protection bay units should be installed and part commissioned. For the check zone CTs, temporary links are fitted during the outages to allow AC connection to either the new protection or the existing. The connection at the end of the circuit outage is moved back to the existing check zone.

On completion of the outages, the check zone on the existing busbar protection is depleted (see 4.4.3) and the AC wiring is permanently connected to the numerical busbar protection prior to stage 2 commissioning.

If commissioning personnel indicate that they are 100% certain that the interference with the AC wiring on these circuits has resulted in the CT circuits being of identical orientation to the existing check zone prior to interference, then there is no requirement to match these circuits against each other. Reasons for this are as follows:-

- Personal supervision by National Grid of the interference with the star point with commissioning method statements.
- Secondary injection from beyond the point of disturbance for polarity of the 3 phase CTs as a group to the respective old and new busbar protection.

If the above is not stated then further tests are required as per sections 4.1 and 4.2.

Circuits can be matched during the circuit outages provided the final changeover is such that any subsequent interference is managed.

4.4.2 Bus Coupler and Section CTs

For bus coupler and section circuits with no existing check CTs, spare CTs can be used for connection to the numerical busbar protection. Primary injections must be carried out to prove ratio and polarity of the three phase group. The CTs are then permanently connected following the circuit outage. These CTs cannot be considered to be matched against any other circuits.

Where there are no spare CTs, then the existing discriminating zone CTs must be used, again with links. The transfer is similar to that described in 4.4.1 above but the discriminating CTs cannot be assumed to be matched against any of the other circuits.

4.4.3 Check Zone Depletion

For asset replacement of traditional busbar protection with check and discriminating zones operating on a two out of two principle, the methodology is to connect the check CTs to the new numerical busbar protection as detailed in section 4.4.1.

Prior to the final transfer strategy, when the check CTs are permanently connected to the new busbar protection bay units, the existing busbar protection must have the check zone disabled and operate on a one out of one basis via the discriminating zone. For this to occur the following must be considered:-

- All DC tripping contacts from AC check zone relays must be shorted.