CIGRE-IEC 2016 Colloquium on EHV and UHV
Montréal, QC, Canada, May 9-11, 2016

Testing of 400 kV GIS

Robert le Roux, Dermot Dorgan, Brian Perry
ESB International - Ireland

ESB International

Paper 028

Introduction

- The 400 kV transmission is designed for critical periods of low loading.
- Due to critical under dampening, the lightning impulse (BIL) and switching impulse (SIL) levels were selected for the equivalent to that of a 550 kV transmission system.
- The 400 kV system is relied on for frequency support and spinning reserve.
- The GIS substations, during light loads, may be more critically at risk of dielectric failure due to high TRV incurred during switching events.
- Dielectric failures of GIS leads to forced outages of a greater amount of HV plant due to the protection schemes employed and compactness of the switchgear itself.

Introduction cont'd

- Experiences with new GIS installations resulted in development of more stringent criteria for type, factory routine and in particular site tests after installation in the specifications.
- Specific tests and procedures, in addition to IEC standard tests IEC62271-203, carried out in multiple installations to date.
  - These specific test requirements have been performed on a range of GIS installations, different manufacturers, different voltage levels.
- Some notable issues that the tests are designed to provide reassurance against include
  - Internally leaking insulators,
  - Intermittent PD sources,
  - Particle generation from switching operations and latent manufacturing defects that may pass normal routine factory testing.

Specifications (background)

- Ireland has a weak 400 kV transmission system:
  - The specified TRV and BIL levels for the 400 kV system are those normally used on a 550 kV transmission system.
- The consequence of dielectric failure presents a greater risk for GIS switchgear at this voltage level
  - Thus more stringent requirements for the design, specification, testing and site quality assurance.
- Specifications has to be detailed – you only get what you specify.
- Primary Plant Log trends all equipment failures, common quality issues and defects.
- Include key manufacturing quality checkpoints or tests to ensure that previously known defects on previous equipment are detected in any new order.
- No of mechanical operations for switching devices, corrosion protection tests and other specific checks are specified according to the relevant defect history.

VT Selection

- Initial testing of the prototype GIS voltage transformer - two flashovers occurred.
  - Both due to dust or particles on the inner surface of the insulator.
- Root cause analysis - free issued barrier insulator the main cause of any test failures during production of all VT types.
- Insulator design used can influence the risk and rate of routine test failures.

VT cont'd

- VT used on the GIS based on the design for a 420 kV rated voltage unit.
  - Housing used identical to 420 kV insulation level type.
- Active part only redesigned i.e. the primary winding insulation design and the shape of the high voltage electrode (grading ring) to achieve the 550 kV insulation levels required.
  - Width of the insulation foil increased to enlarge the insulation distance between the conductor, core and inner surface of the compartment.
  - Increasing the width of the insulation foil layers - effective insulation distance has increased, similar to effect of adding sheds to AIS insulators.
- Shape of the HV electrode/grading ring adjusted for the increased stress and coated with layers of dielectric paint to achieve an even and smooth surface to ensure a uniform electric field.

VT cont'd

- HV withstand test was carried out at 710 kV, the IEC insulation level for 550 kV rated voltage.
  - Negligible PD was observed at the 1.2 times rated voltage (phase to ground)
  - Maximum allowable PD level of 2 pC was applied to the new equipment. The IEC limit currently 10 pC thus increased quality margin over the IEC requirement was obtained.

GIS Type Testing

- Manufacturing facility inspected during initial design review.
- A 400 kV bay was demonstrated and tested at the higher BIL level.
  - Internal flashovers resulted at several barrier insulators.
  - Due to incorrectly placed/sized corona shields installed for the increased dielectric withstand requirement.
- Several points also subjected to dielectric field overstress due to particles formed during incorrect cleaning or mechanical operations.
- Dielectric insulation design revised - changes to the profile of insulators and increased SF_6 pressure.

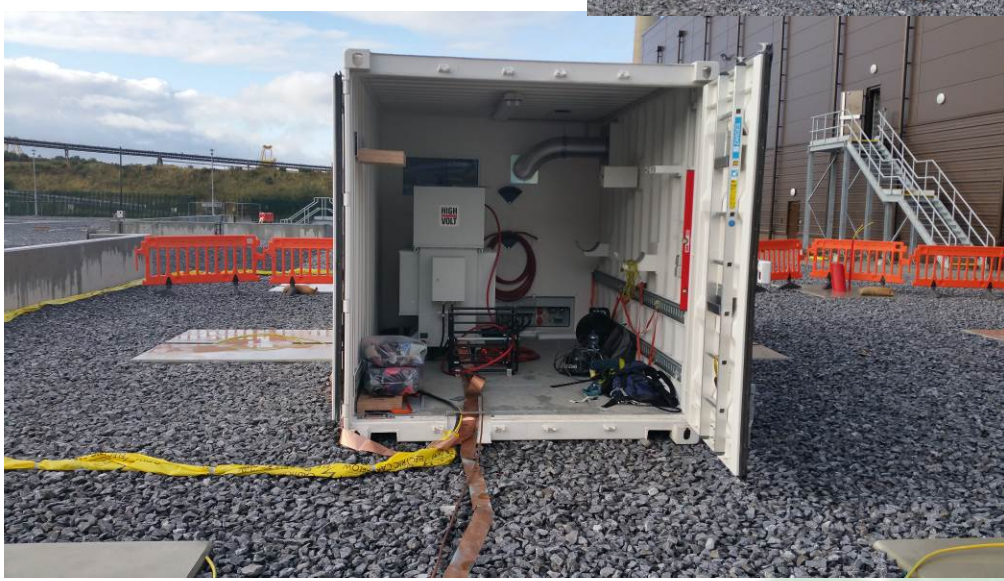
Factory Acceptance Testing

- Three complete GIS bays were factory tested.
  - The bays chosen - feeder, transformer and busbar coupler bays.
- Routine tests as per IEC 62271-1, IEC 62271-100, IEC 62271-203 and the customer specification.
- Following routine tests performed as agreed with the manufacturer prior to the Factory Acceptance Test (FAT);
  - Mechanical tests of the circuit breaker and all disconnector and earth drives
  - Contact resistance measurement of the circuit breaker and disconnectors
  - Gas tightness tests
  - High voltage withstand tests with partial discharge measurement
  - Customer-specific functional test of the control and operation systems

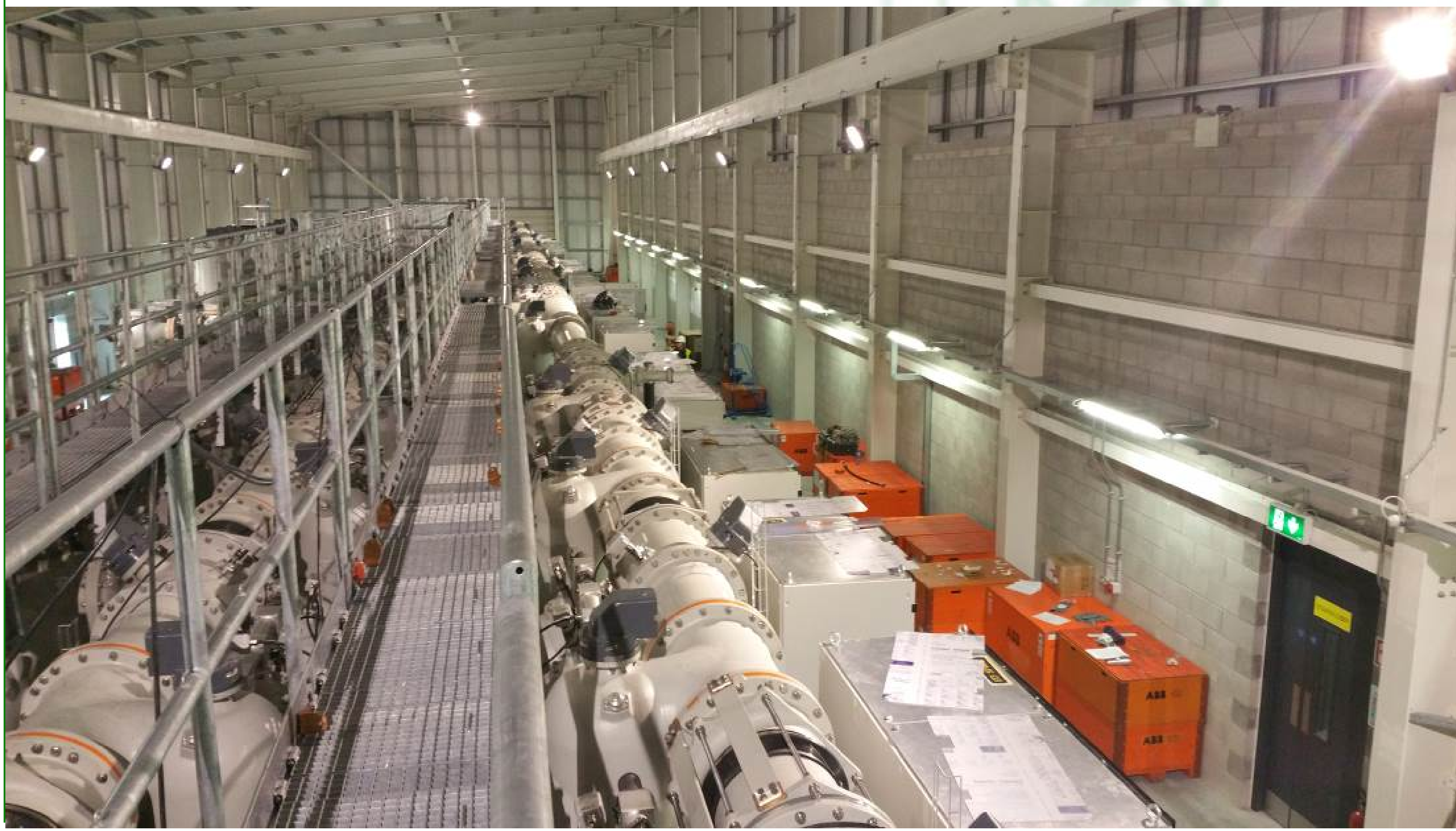
FAT cont’d

- As per customer specification the HV withstand tests were performed at insulation levels corresponding to 550 kV rated voltage, i.e. 710 kV.
- Six failures during FAT.
  - One due to incorrect assembly – a 400 kV endcap installed instead of 550 kV type.
  - The other five flashovers and PD events were due to particles and/or voids in the insulators.

Site Test setup



Moneypoint completed installation



Site Testing

- Flashovers and PD issues with GIS in other installations, specification required an extra 200 mechanical operations on all units - standard mechanical conditioning procedure - before dielectric test.
  - To ensure all possible particles are formed and removed before the final on-site HV test. If successful, procedure provides some confirmation of no switch or contact misalignments.
  - After the 200 operations, manufacturer opens and clean a number of sample compartments to check for excessive particle generation.
- All on site tests done as per IEC requirements
  - but longer conditioned time according to the below table and lower threshold acceptance criteria for PD detections

Table indicating values for 420 kV and customer requested values at 550 kV

Test parameters

Conditioning	230 kV >= 10 minutes
Conditioning	381 kV >= 10 minutes
Conditioning	500 kV >= 2 minutes
Test voltage	560 kV 1 minute
PD test voltage	381 kV n minutes
Frequency range	69 Hz – 179 Hz

	Phase-to-earth and between phases	Across open switching device and/or isolating	Phase-to-earth and across open switching device	Between phases	Across isolating distance	Phase-to-earth and between phases	Across open switching device and/or isolating distance
420	520	610	950	1 425	900(+345)	1 300	1 300(+240)
			1 050	1 575		1 425	1 425(+240)
550	620	800	1 050	1 680	900(+450)	1 425	1 425(+315)
			1 175	1 760		1 550	1 550(+315)

Site testing

- Site testing - fourteen occurrences of flashover or PD.
  - Almost all occurrences were due to metallic particles inside the gas compartments or due to voids within the insulators.
- After replacement and cleaning of the affected sections / chambers, tests repeated and then passed the required IEC clause of the HV tests.

Conclusion

- Due to reduction in size of equipment following
  - Implication: designs have lower thresholds of dielectric insulation margin.
  - No errors in manufacturing process and procedures - the slightest anomaly or intolerance can cause dielectric failure.
- Increasing trend of dielectric breakdown in new compact GIS types at FAT and on site HV withstand tests after installation.
- Sizable number of failures occurred at close to nominal system voltage, no confidence in product by asset owner
- IEC - include a minimum design margin on the test levels for all GIS
- Higher number of mechanical tests prior to factory and site testing - minimise the increased threat posed by particles.
- More switching operations after installation to disturb or shake out particles and increase the effectiveness of the on-site dielectric tests.

Conclusion cont'd

- On-site HV withstand tests - longer duration at 1.1 or 1.2 Un following the PD test voltage, better simulate increases above nominal system voltage.
- Switching during increased soak period to simulate network switching events advised to disturb any possible particles and trapped charges.
- Factory and site test pass parameters should be rigid and clear
  - To ensure no errors in specification interpretation.
- Dielectric failure acceptability criteria for on site tests should be considered by the purchaser.
  - Failures due to incorrect assembly, while undesired are not necessarily indicative of material defects.
  - Unexplained dielectric breakdowns in critical areas such as circuit breakers and other compartments with switching devices should however trigger a re-examination of the dielectric design margins.

- **Thank you for your attention and**

- **Any Questions? – but please no difficult ones ☺**