

Study Committee B3 Substations and Electrical Installations

Paper ID_11077

Test, Installation and Operational Experiences of World's First Substation Integrating Digital, Intelligent and Greenhouse-Gas Free T&D equipment

Dirk HELBIG¹, Marcel ENGEL², Matthias HEINECKE¹, Mark KUSCHEL¹, Peter MENKE¹, Fred OECHSLE², Richard SCHULZ², Puneet SINGH¹

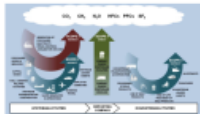
¹Siemens Energy, ²Netze BW, Germany

Motivation – The Need for a Next Sustainable Substation Generation

- Power grid operators globally are committed to the UN global sustainability goals, report according to the GHG protocol and take actions to become carbon neutral.



Reporting according to Greenhouse Gas (GHG) Protocol



Scope 1: Direct Emissions from own sources
Scope 2: Indirect emissions from purchased energy
Scope 3: All other indirect emissions in value chain

Action – Decarbonized and Digitalized Substations

- Decarbonization: as one important contribution, SF₆ in new switchgear (Direct emissions: Scope 1) must be substituted by a GHG-free gas
- Digitalization: Grids of the future need to handle fluctuating power: Digitalization is a key to handle this



Tests and performance of GHG-free products

- Superior test results of GHG-free GIS compared to gas-breaker technologies; -50°C operating temperature, 10,000 min. nom. current switching operations, 30 min. short-circuit current operations

✓ Type tests according IEC / IEEE passed

Voltage (U ₁ , U ₂)	145 kV / 275 kV / 500 kV
Current (I ₁ , I ₂)	96 to 7500 A / 40 kA (3s)
Rated frequency (f)	50 / 60 Hz
Temperature range	-50 °C ~ +40 °C w/o accessories & long endurance
Class classification	2, 3, 4, 5
Capacitive performance	IG, E2, M2
Min. nom. current switching operations s	10,000 (vacuum) / 25 (ignition) / 1,000 (GIS)
Min. short-circuit current operations (s)	30 versus SF ₆ (s) (s)
Interrupter / Insulation Technology	Vacuum / Clean Air (operator) or with SF ₆ (20 x 20 x 10) only report for design & construction
Final major inspection / Physical lifetime	> 25 years / > 50 years
Relevant	IEC / IEEE



Test and performance of digitalized components and products

- All Sensors and components of digitalization were tested
- Severe EMC, mechanical endurance, high voltage, high power and climate tests were passed

EMC Testing according to IEC 61000-6-5:2015 (Power Station and Substation Environment)

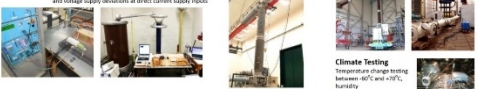
IEC 61000-6-2: Testing of the immunity to the discharge of static electricity
IEC 61000-6-3: Testing of the immunity to high frequency electromagnetic fields
IEC 61000-4-4: Testing of the immunity to fast transient electrical interference
IEC 61000-4-10: Testing of the immunity to conducted, symmetric and harmonic in frequency range from 150 kHz to 10 MHz
IEC 61000-4-18: Testing of the immunity to conducted periodic, aperiodic
IEC 61000-4-24: Testing of the immunity to voltage dips, short term interruptions and voltage supply disturbances at direct current supply source

Mechanical Endurance Test

20,000 switching operations (vacuum breaker (M2) testing)
Overload testing (3 times nominal)
Steady-state loading testing, Shock testing, Switching impulse testing (s. 11 p)

High Voltage, High Power Testing on Circuit Breaker and Gas Insulated Switchgear

Up to 420 kV / 63 kA
Disconnecter Switching Testing



Climate Testing

Temperature change testing between -50°C and +50°C, humidity

Substation of the Future in Germany

- Layout and Construction site of the new 110/20 kV substation in Burladingen, Germany
- Decarbonized: SF₆ substituted by GHG-free clean air insulation technology and vacuum interrupters
- Digitalized: LPIT and advanced sensor technology



Eco-efficient and digitalized: GHG-free GIS including LPITs and advanced sensors during installation



Study Committee B3

Substations and Electrical Installations

Paper ID_11077

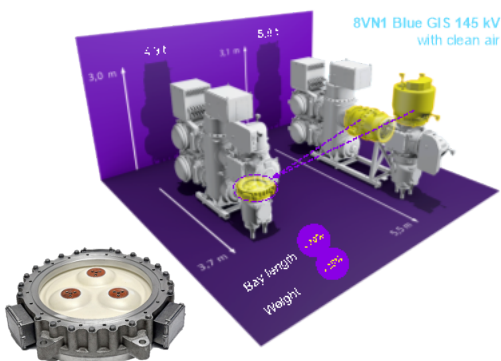
Test, Installation and Operational Experiences of World's First Substation Integrating Digital, Intelligent and Greenhouse-Gas Free T&D equipment

Dirk HELBIG¹, Marcel ENGEL², Matthias HEINECKE¹, Mark KUSCHEL¹, Peter MENKE¹, Fred OECHSLE², Richard SCHULZ¹, Puneet SINGH¹

¹Siemens Energy, ²Netze BW, Germany

Digitalization: Low-Power Instrument Transformers (LPIT)

Photo of the 145 kV GIS partition with integrated LPIT Sensors (left) and schematic overview about the 145 kV synthetic air GIS space and weight savings by the LPIT.



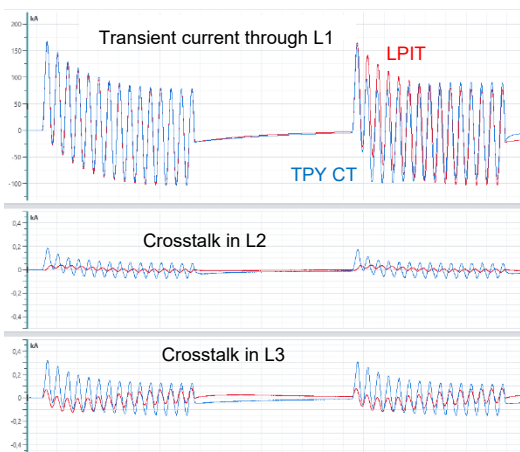
Test procedure of Low Power Instrument Transformers

Some of these tests plus some special test were done jointly in October 2021 at the Switchgear Factory Test Laboratories in Berlin.

IEC Product family standards	Standard	Products
41869-1 General requirements for instrument transformers	41869-2	Additional requirements for current transformers
	41869-3	Additional requirements for inductive voltage transformers
	41869-4	Additional requirements for combined transformers
	41869-5	Additional requirements for capacitive voltage transformers
	41869-6	Additional requirements for electronic current transformers
	41869-7	Additional requirements for electronic voltage transformers
	41869-8	Additional requirements for electronic current transformers
	41869-9	Digital interface for instrument transformers
	41869-10	Additional requirements for low power stand alone current sensors
	41869-11	Additional requirements for low power stand alone voltage sensors
	41869-12	Additional requirements for combined electronic instrument transformer or combined stand alone sensors
	41869-13	Stand alone merging unit

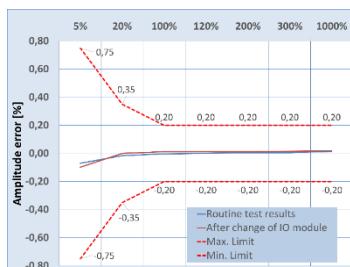
Test results – Example LPCT Transient performance

Transient Performance Test of a TPY CT and LPIT after calibration and routine test ($I_k''=63$ kA, $i_p=170$ kA)



Test results – Basic accuracy

Basic accuracy test results of the LPCT (Class 0,2) during routine tests and after a change of the IO Module



Conclusion

- The type tests carried out according to IEC 61869 were successfully passed.
- The tests according to the standard were supplemented by further tests in which the GIS LPIT was able to demonstrate its robustness and practical suitability. These included disconnector switching, a functional test of the distance protection and crosstalk in the event of a short circuit.
- Accuracy class was maintained after replacing connection box, cables, IO module and Merging units.

Study Committee B3 Substations and Electrical Installations

Paper ID_11077

Test, Installation and Operational Experiences of World's First Substation Integrating Digital, Intelligent and Greenhouse-Gas Free T&D equipment

Dirk HELBIG¹, Marcel ENGEL², Matthias HEINECKE¹, Mark KUSCHEL¹, Peter MENKE¹, Fred OECHSLE², Richard SCHULZ², Puneet SINGH¹

¹Siemens Energy, ²Netze BW, Germany

Decarbonization: GHG-free and T&D equipment

- Power grid operators globally take actions installing GHG-free power products
- >1900 units contracted; >700 units in operation
- 2,700,000 tons of CO₂e not produced and installed description/figure



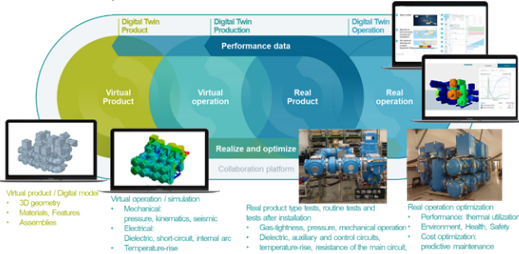
Decarbonization and Digitalization

- Digitally connected products merge reliable hardware and sensors with cloud connectivity, digital twins, and apps with artificial intelligence.
- The benefits are performance increase, health, safety and environment and cost and risk reduction for the benefit of grid operation, asset management, service and maintenance



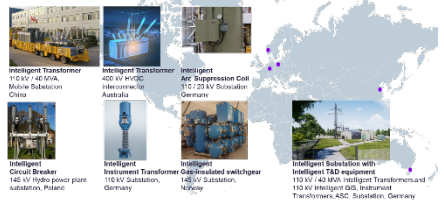
Digital Product Twins

- Digital twin operation to increase operational performance, GIS example



References

- Global installation examples of digitalized and intelligent substation equipment



Conclusion and Outlook- Decarbonized, Digitalized, Intelligent

- Eco-efficient and digitalized substations are the foundation of a CO₂ neutral power system and for global power grids of the future. Main values for society, grid owners and operators are:
 1. Zero CO₂ emission
 2. Compact design using LPITs
 3. Flexible and resilient, integrating fluctuating renewable power generation
 4. Easy operation, maintenance, and asset management

