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Development of Pre-Insertion Resistor for an 800kV GIS Circuit Breaker

800kV GCB
Background & Objects

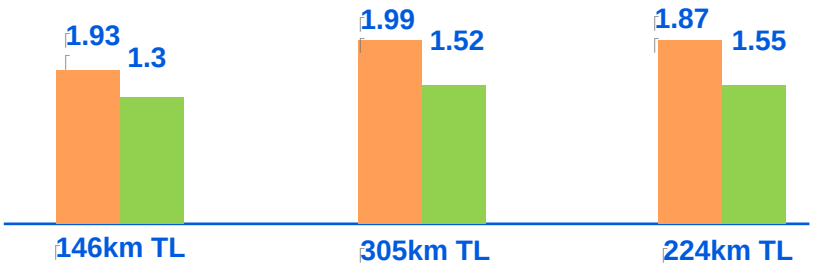
EHV/UHV system:

- Widely application for long distance transmission from large power plants to remote load centres;
- Demand more insulation distance in case of the clearance for switching impulse voltage.

Mostly, a combination of mitigation technologies to reduce the switching overvoltage more effectively: application of closing and opening resistors, MOSA and shunt reactor in the substation or the application of controlled switching;

To development GCB with Pre-Insertion Resistor;

No load OH Line overvoltage: reduction (p.u) of SOV by CB 400Ω Closing Resistor in 800kV system



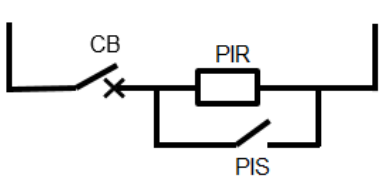
No load OH Line overvoltage: (90km)

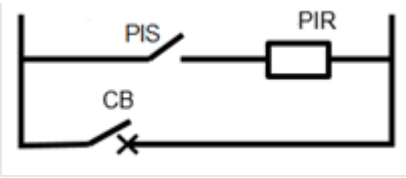
Mitigation	No mitigation	MOSA in both end and middle of line	MOSA in both end of line	MOSA in both end of line, and CB with 600Ω
Max overvoltage	2.54	1.79	1.83	1.23

800kV GCB
Design

PIR and PIS

- Features comparison of scheme
- Parallel connection of PIR and CB in EHV/UHV





No.	Item	Series Connection of PIR and CB	Parallel Connection of PIR and CB
1	Layout with CB	Larger single enclosure to accommodate PIR and interrupter; cost lower; but capacity limited	Smaller but may needs a separate enclosure; larger capacity for all application when enclosure separated.
2	Current flow	PIS carries rated current and short circuit current	PIS does not carry current after closing operation
3	Thermal capacity	Limited by enclosure dimensions (length). Only applicable for high resistance values.	Allows large variation of thermal capacity.
4	Dielectric insulation level of PIS contact gap	Comparable to disconnector gap, withstand BIL, Out of Phase level	Comparable to disconnector gap, withstand BIL, Out of Phase level
5	PIS function	switch full short circuit current	switch several thousand A depending on PIR resistance value
6	PIS mech. linkage	Mechanical linkage connected with CB's drive during closing & opening.	Mechanical linkage connected with CB's drive for closing; Disconnected after CB closed
7	Safety	Small particles from PIR could impact on dielectric stress	Individual tank avoids the interference between CB and PIR

800kV GCB
Design

PIR Thermal capacity - 1

- Required operation consequence (CN):
  - CO – 3min- CO -30min – CO -3min –CO under 1.3p.u.
  - CO-30min-CO at phase opposition (180° phase shift between source and line side) - Most demanding duty cycle
- Resistor's performance is defined by following characteristics:
  - Thermal capacity
  - Voltage withstand ability
  - Mechanical withstand ability
  - Dimension tolerance

  } Mechanical structure
- To accommodate Resistor disc in constrained space while satisfy requirement
  - Resistance, e.g. 300Ω
  - Dielectric stress;
  - Absorbed energy;

$$W = \int_{t_1}^{t_2} \frac{U(t)^2}{R(t)} \mathrm{d}t$$

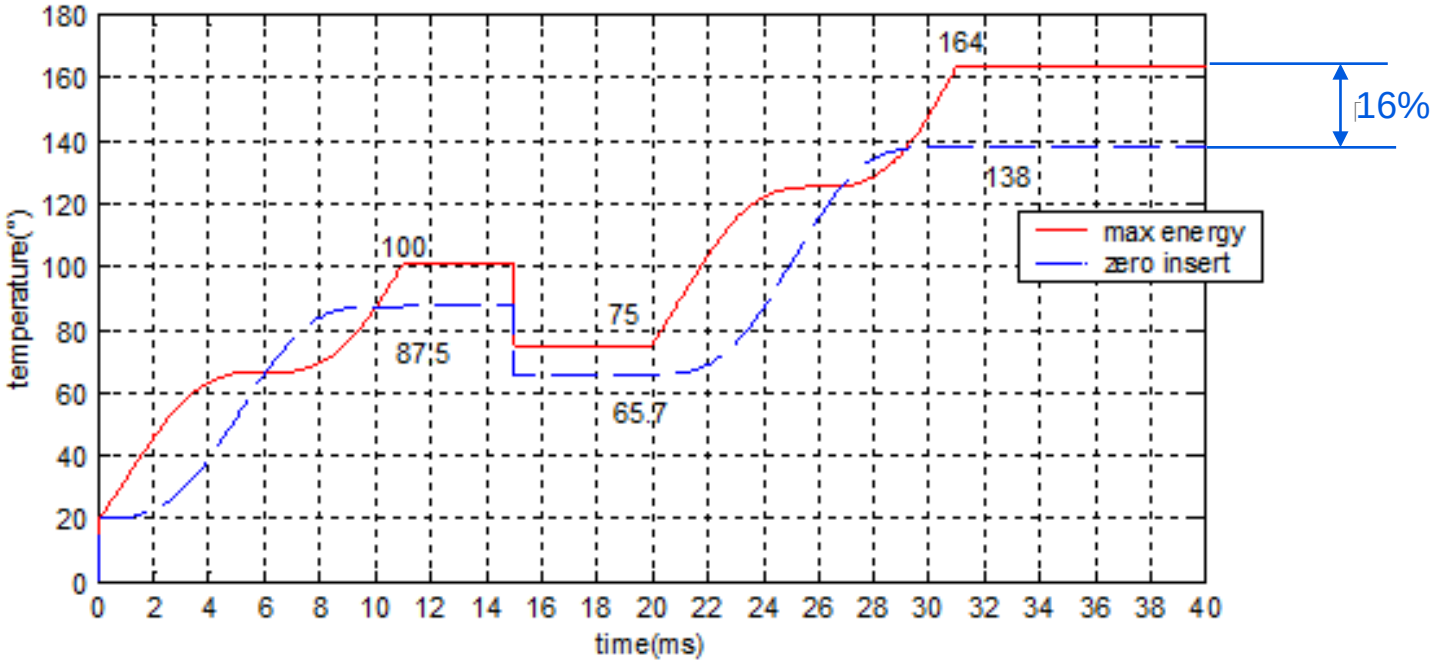
800kV GCB
Design

PIR Thermal capacity – 2

- Electric instant of energy injection

*one example of electric pre-insertion time 11ms at 400Ω

  - Max voltage peak vs zero point of applied voltage (for test purpose)

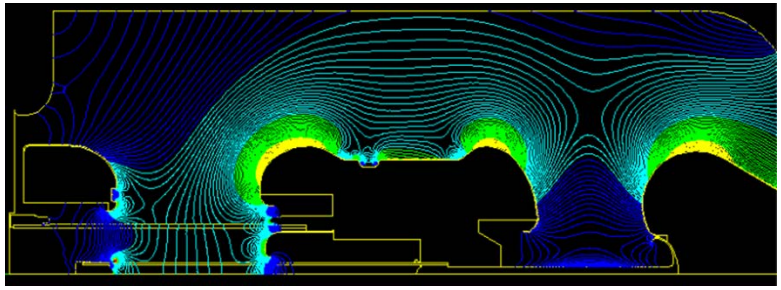


800kV GCB
Design

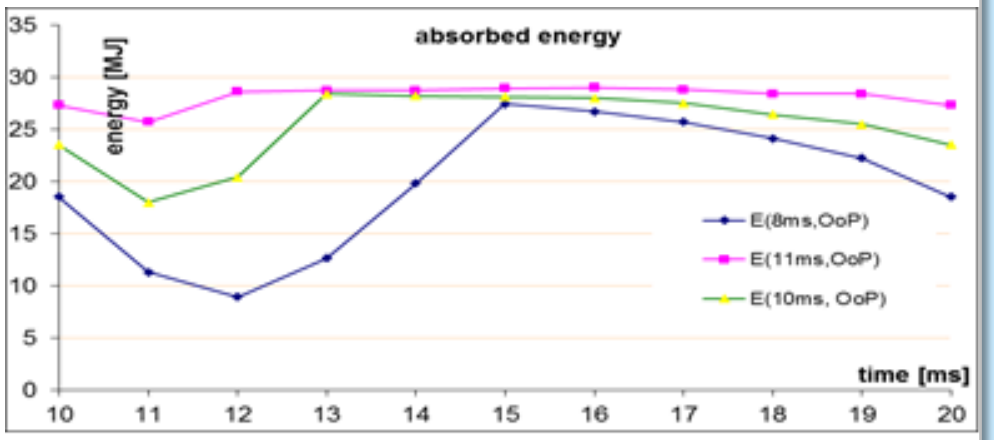
PIS Design

- Requirement
  - Insulation of PIS
  - Mechanical operation consequence to satisfy PIR pre-insertion requirement;
- Check pre-arcing time (electric insertion time) with RDDS of PIS, CB;

BIL POLOPT simulation show design satisfy electric stress requirement



Inject energy in different electric instant for mechanical pre-insertion times, 8ms, 10ms, 11ms for a 300Ω

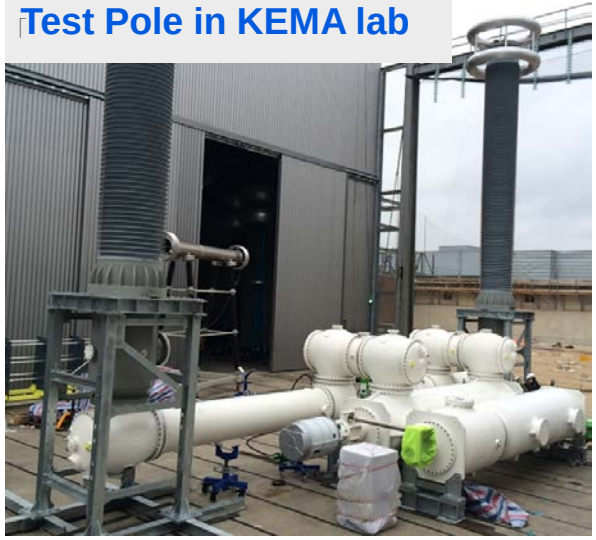


800kV GCB
Verification

PIS Making Test

- Test condition
  - Severe condition of out of phase situation, 1306kV$_{peak}$;
  - At max current - 3080A in min closing resistance;
- Good performance - dielectric and visual contact erosion after making

Test Pole in KEMA lab



Pre-arcing during making test

800kV GCB
Verification

PIR Thermal Capability Test -1

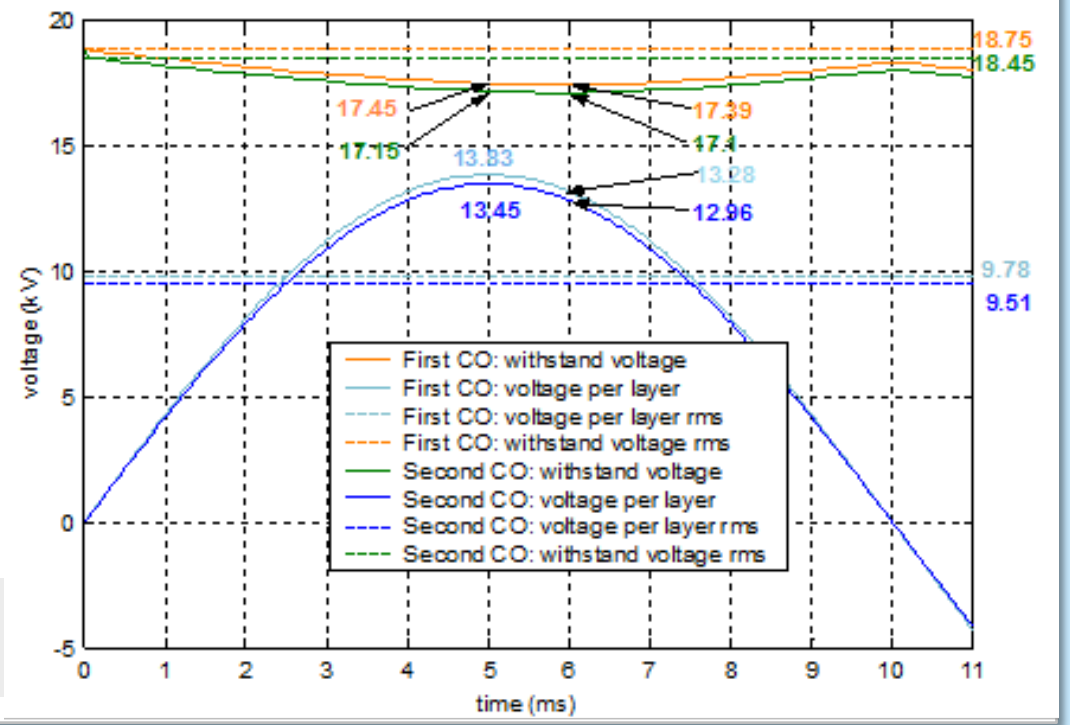
- Test condition
  - CO – 30min – CO under 2p.u.;
  - Pre-insertion time: 11ms and 400Ω - representative application;
- Actual test pole and test procedure
  - Proportional reduced resistance at typical test pole with 111.1 Ω under 256.6 kV and 2310 A;
  - Remain unchanged in PIR structure and thermal feature and dielectric stress by replacement material of the same heat capacity
  - Insert initiated at voltage zero point.

PIR Thermal Capability Test in PEHLA

800kV GCB
Verification

PIR Thermal Capability Test -2

- Analysis Result - Adjust and comparison by simulation and Test measurement
  - Environment factor: 11ºC test environment vs 70ºC serious application
  - Max. energy injection: 1.16;
  - Safety margin: >1.2
- Temperature rise
- Dielectric stress analysis
  - >1.2 safety margin;



Dielectric stress of each PIR disc layer

800kV GCB
Conclusion

- **Parallel PIR** - shows great performance achieved in compact footprint, high thermal and making capacity.
- **Dielectric stress, thermal performance** – key elements to PIR design, and non-linear behaviour of resistor material should be taken into consideration..
- **PIS features** - determines the insertion instant and pre-insertion time. electric pre-insertion time. Making test results shows that PIS has high making withstand ability.
- **Verification** – demonstrate design performance to meet specification; special test must be considered except conventional practice:
  - Thermal test of PIR;
  - PIS making test;

Typical 800kV CB with PIR development show all specification has been reached; and design, verification process are comprehensive and effective.

Thank you!

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