Y9.ET4.3 Advancement in Insulation Coordination of SST Connected Directly to the 15 kV Distribution Line

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Overview

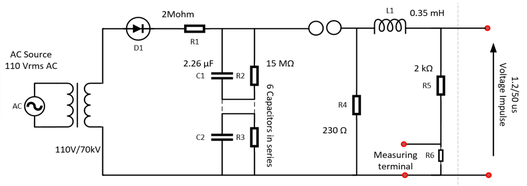
Background

- The Solid State Transformer (SST) is one of the key elements in the proposed Future Renewable Electric Energy Delivery and Management (FREEDM) Systems.
- Since SST is connected directly to the 15kV distribution line, voltage surge caused by lightning stroke on transmission line would damage the SST.
- IEC 60071 specifies test methods of electronic components like an SST.
- According of this standard the SST or other electronic components must be tested by short duration impulse.
- The SST or other equipment must withstand the 1.2/50 μs impulse with a peak value defined by IEC 60071.
- The name of this impulse is "**Basic Lightning Impulse Insulation Level** (BIL)".
- The BIL depends on the rated AC voltage. The BIL at 15 kV distribution level is 60 kV.
- The standard allows that the tested equipment is protected by **Metal-Oxide Surge Arresters (MOSAs).**
- The surge arrester is a nonlinear resistance, which has high resistance at the rated AC voltage but the resistance is reduced by the increasing voltage.
- This diverts the lighting current to the ground and protects the equipment.
- **Insulation coordination** is the method to test and protect the electronic equipment against lightning stroke.

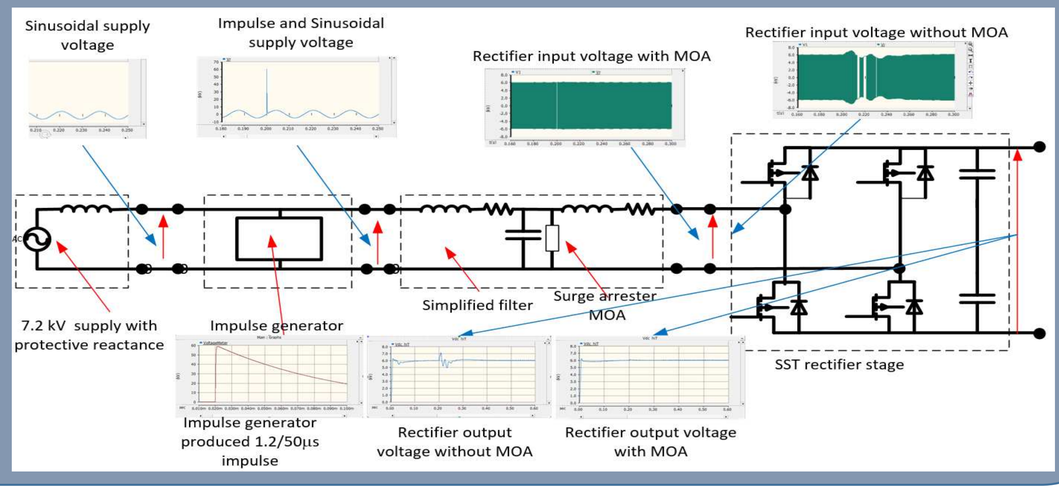
Method

1. The most important component of the insulation coordination testing is the impulse generator.
2. Presently ASU is building a 60 kV **impulse generator**. The connection diagram is shown below:

- A regulating step-up transformer that converts the 110 V_{rms} AC voltage to 44 kV_{rms} AC.
- This charges the capacitor banks to 60 kV_{pk} DC.
- The DC voltage triggers the sphere gap to discharge capacitors through inductance and two resistors, generating the 1.2/50 us waveform.



3. Test arrangement for the testing of SST is shown below



Results

Test method

- The electronic equipment must withstand 1.2/50 μs impulses under operating conditions.
- The test circuit is supplied 7.2 kV AC voltage by a small transformer.
- The transformer is protected by a series inductance.
- The parallel connected surge generator produces the impulse voltage superimposed on the AC voltage.
- This voltage supplies the SST through a filter and protection inductances.
- The filter circuit reduces the 60 kV impulse voltage to a small oscillation at the SST rectifier terminal.
- The oscillation is eliminated by the MOSA connected in parallel to the filter capacitor.
- ASU simulated this system operation by PSCAD. The figure below shows the expected waveforms.

Conclusion

Impacts

- The front filter protects SST from lightning strokes. Because the impulse voltage is absorbed by the filter, which requires the redesign of the filter to withstand the 60 kV impulse.
- The future redesign of the filter requires the division of the filter into 6 sections protected by MOSAs.

Conclusion

- **Without insulation coordination and impulse testing the SST can not be used in a distribution system**

Future Work

- Complete the building of the 60 kV impulse generator.
- Redesign and upgrade the filter to withstand the impulse voltage.
- Test the system and the filter component with 60 kV impulse.

References

1. X. Rong, D. Zhang, G. Karady, G. Heydt, "Insulation Coordination of FREEDM Solid State Transformer", CIGRE US National Conference: Grid of the Future Symposium. Philadelphia, PA, October 30, 2016.
2. Standard IEEE 1313.1
3. IEC 60076-3
4. IEC 61000-4-5