**TERMS OF REFERENCE FOR R&D PROJECT**

1. **Title of the project:** Reactive Power Management of Ultra High Voltage Transmission Lines.
2. **Background:**

Transmission lines due to the geometry of their physical configuration have a finite amount of capacitance:

1. within the conductor bundle comprising of the sub-conductors
2. between conductors of different phases within same circuit
3. between different circuits in proximity and
4. between conductor and ground.

For UHV transmission lines, since the physical dimensions are quite large, the capacitive impedance Zc will also be quite significant. Moreover, UHV lines are expected to be used for long distances and thus the effect of the shunt capacitance (or admittance) will be quite significant, especially when the lines are on light or no load.

Currently, to mitigate effects of climate change, power generation through renewable energy (RE) sources like solar photovoltaic cells and wind turbines is on the rise. The share of RE generators in the power system is increasing and the role of conventional steam turbine generators is reducing. The rotating salient pole or cylindrical pole generators had the capability to ride over situations of voltage and frequency variations arising out of transients in the power network. The RE generators being predominantly power electronics based sources, do not have this capability. Also, the location of RE generation plants is decided by the availability of the corresponding natural resources (like intensity and duration of solar radiation and wind speed) and also the land where such plants can be set up. Conventional power plants could be set up near the load centers. Thus, with RE resources confined to specific geographical locations, that may be different from load centers, the requirement of high capacity transmission systems to transport the high quantum of electrical power increases. High capacity AC networks can be realized with ultra high voltage transmission lines.

Since the sun and wind are not available all through the day on all days of the year, the UHV transmission system setup may remain lightly loaded or unloaded. This however, does not reduce the requirement of reactive power to be drawn by these UHV transmission lines. This reactive power loss in absence of the RE generation capacity has to be supplied by the steam turbine generators.

Another aspect to be considered is that during any line fault, the system may exhibit undesired outages. With the power electronics based RE generators, the short circuit ratio (SCR) of the system is very low which makes the system susceptible to outages during faults.

To avoid reactive power generation and consequent over voltages during periods of light or no loading on these lines, measures like reactive power absorption by means of static or rotary VAR compensation systems and /or load management have to be put in place. During no load conditions, the lines can also be switched off.

1. **Scope for R&D:**
2. Engage with key stakeholders, including government agencies, utilities, DER manufacturers, and industry experts to gather insights, feedback, and recommendations.
3. standardization of geometry of UHV transmission lines
4. standardization of line parameters (L&C) corresponding to each geometry
5. preparation of PSSe and PSCAD generic models for UHV transmission lines to be used for system studies
6. defining operation and response characteristics of VAR compensation systems behavior during variable loading of transmission lines
7. defining voltage profile along UHV transmission lines in case of faults at different SCR
8. calculation of transient over voltages and recovery voltages during abrupt opening of line breakers.
9. formulating dielectric test cases for switchgear to be used with UHV lines, especially for weak systems
10. recommended procedures for loading and unloading of UHV lines.
11. Documentation of the research findings, including an analysis of literature surveys, manufacturing processes (MSMEs, startups, etc.), and tests methodologies.
12. **Research Methodology:**

The project will involve the following research methodologies:

1. Conduct an extensive literature survey to review previous studies, research papers, and relevant publications related to Reactive Power Management of Ultra High Voltage Transmission Lines.
2. Detailed test methods for confirming compliance with safety, performance, and energy efficiency requirements
3. A comprehensive report documenting the research methodology, findings and recommendations.
4. **Expected Deliverables:**
* Submission of analytical report including standardized geometry of UHV transmission lines, line parameters (L & C) corresponding to each geometry, preparation of PSSe and PSCAD generic models for UHV transmission lines to be used for system studies, operation and response characteristics of VAR compensation systems behavior during variable loading of transmission lines, formulating dielectric test cases for switchgear to be used with UHV lines and recommended procedures for loading and unloading of UHV lines
1. **Criteria for Identification of Proposer to conduct Research work:**
* Proposer shall be a technical expert in the field of Ultra High Voltage Transmission system.
1. **Timeline and Method of Progress Review:**
* The review will be carried out in each month along with consultation of other experts if required. Information gathering and data collection shall be commenced and to be compiled within 3 months, the first draft at the end of 4 months and the final draft along-with report at the end of 6 months.
1. **Support BIS will Provide:**
* BIS will provide access to latest editions of standards required for the project.