NSF Center for GRid-connected Advanced Power Electronic Systems (GRAPES)

**GR-17-07 Short-term, Operational Reliability Evaluation of HVDC Transmission Systems Considering the Influence of Power Electronics**

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Semi-Annual Meeting

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Project Overview

- Anticipated Project Dates: 1/1/2017-12/31/2017
- PI Name: Dr. Lingfeng Wang, Associate Professor, University of Wisconsin-Milwaukee
- Overall Project Budget: $49,969
Motivation of the Proposed Work

High Voltage Direct Current (HVDC) transmission systems (also called electrical super highways) are being increasingly deployed in the long-distance power transmission (e.g., interconnection of off-shore wind farms).

- Low transmission losses
- Fast control of power flow, ensuring higher system stability
- Capable of carrying more power than HVAC
- No contribution to short circuit power in existing AC networks

However, reliability is a major concern in HVDC transmission.

Comprehensive and objective reliability evaluation for HVDC transmission systems has become a pressing topic – The existing work was focused on long-term, planning reliability.

However, HVDC operations highly rely on power electronics. The real-time operating condition affects the availability of power electronic devices.
In many cases, HVDC transmission is used in connecting remote wind farms to the main grid.

The volatile and intermittent power output of wind farms causes changes in the temperature of the power electronic devices and affects their reliability.

Since power electronics is an important part in HVDC transmission and its failure rate is highly correlated with temperature, in this study short-term, operational reliability of the HVDC system is evaluated considering real-time failure rates of power electronic devices.

Real-time or operational reliability evaluation of HVDC transmission systems has not been studied thus far.
This project aims at evaluating the operational reliability of HVDC transmission systems considering the impact of power electronics.

A wide spectrum of scenarios will be examined to quantify the real-time operational reliability of the HVDC transmission system as well as the impact of the power electronics.

A commercial-grade, comprehensive software tool will be developed for enabling informed decision-making in HVDC-related power system planning and operations for a broad range of users.
The influence of power electronics availability on the overall reliability of HVDC transmission system: Physics-of-failure model.

In operational reliability studies, the physics-of-failure model is especially suitable, because it reflects power electronics reliability under different operational conditions.
System modeling - Operational reliability of HVDC transmission systems

- System reliability is evaluated based on the failure rates of all components and their connections.
- A comprehensive set of HVDC transmission schemes will be examined.
HVDC systems have more versatile and faster controls, which may be utilized at the wind farm interconnection point to enable independent voltage, frequency and power control.

A wind farm interconnected with an HVDC link has the potential to offer grid control functions similar to conventional generators.

The proposed research relating to real-time reliability evaluation of HVDC transmission and distribution features a high industrial relevance and business need considering the promising benefits brought about by the use of HVDC technologies.

The proposed research will be beneficial to the IAB members by enabling the wider deployment of HVDC in power grids in a secure and reliable manner.

The developed software tool can be used by the IAB members, which will also be commercialized to bring additional revenues to the GRAPES and IAB members.
Research Tasks

- In this project, operational reliability of HVDC transmission systems considering real-time failure rates of power electronic devices will be evaluated.

- Real-time failure rates of power electronic devices are modeled in a probabilistic manner based on the actual operating conditions of the power grid.

- Major Research Tasks:
  - Research Task 1: Building short-term reliability models for power electronic devices in HVDC transmission systems;
  - Research Task 2: Evaluating the operational reliability for a variety of HVDC schemes;
  - Research Task 3: Performing a wide spectrum of case studies;
  - Research Task 4: Reliability worth (cost-benefit) analysis;
  - Research Task 5: Software tool development and test.
Expected Deliverables

- At least two graduate students and one undergraduate student will be involved in this project.
- Detailed documentation on all the system models, solution methodologies, and research outcomes.
- A fully functional, user-friendly decision-making software tool with all the desired functions and features (for both operational and planning reliability assessments). The tool will be commercialized (software licensing).
- A detailed user manual for this developed tool.
- Detailed introductions of multiple example applications.
- Publications in top journals and conferences.
The wider use of HVDC technologies is beneficial to maintaining a more stable power grid in the face of various disturbances and uncertainties as well as enabling a higher penetration of renewable energy resources (Green Power Superhighways).

The developed software tool will enable informed decision-making concerning HVDC-related asset management for various users (e.g., recommending optimal HVDC schemes to power system planners).

We will also perform comprehensive case studies for practical HVDC systems provided by the GRAPES IAB – Detailed technical report could be prepared for each interested IAB member.

The research outcomes will be integrated into educational curricula and outreach activities.