Distributed Edge Computing for Secure and Interoperable Energy Cyber-Physical Systems

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This proposal addresses the gap in **Secure Digital Infrastructure for Energy** which is mentioned in the CITES Research needs assessment as **Category number 6.**

Digitalization is the integration of digital technologies and communication infrastructure into various parts of the energy system. The large volume of generated data and the real-time analysis and response requirements of ECPS present significant system operation challenges. To address these challenges, different management methodologies are implemented using Internet-of-things (IoT) or cloud computing. The cloud-based controller can neither manage ECPS devices directly nor satisfy real-time requirements. Communication bottleneck exists between ECPS and the cloud because of the need for different sensing and actuating devices that generate and process extensive sensed data. Another critical issue is security for long-distance transferring to cloud communication. Edge computing is a promising technology to address these challenges. However, in a multi-stakeholder scheme, the raising issue is how the edge computing system achieves global objectives while keeping privacy, security, real-time response, and interoperability?

The project proposes a distributed edge computing architecture with a sparse communication network of the edge layer to enhance the security and interoperability of ECPSs. While cloud computing relies on centralized centers, the distributed edge moves computation closer to the grid. Computational power is decentralized on a network of endpoints and smaller, local data centers. Since information doesn't need to travel as far, it lessens the risk of a centralized failure impacting the whole network and improves security, bandwidth, and latency. An FPGA-based distributed edge computing framework is proposed for networked microgrids. This is to ensure the system's security, interoperability, and optimal operation.

The project will be realized by developing software-based simulations and practical hardware deployments. For implementing the cyber-physical system and the interaction of the edge computing layer, the communication network plays an important role in data collection, data exchange, and data security. To study the impact of communication on the operation of the ECPS and the devices of the edge nodes, the edge computing platform developed consists of a network emulation to reproduce the network characteristics and different scenarios of latency, connection failure, congestion, etc. The project is conducted in three main thrusts as follows.

Thrust 1: Develop distributed edge computing platform infrastructure for energy cyber-physical systems. The platform consists of the energy cyber-physical system, the edge computing layer including edge nodes that can gather a large volume of information from the cyber and physical systems. The latter performs intensive computations. The system also includes the Data Distribution Service (DDS), a data-centric middleware: for the communication network with quality-of-service properties used for interoperability and security of the edge computing layer.

Thrust 2: Develop distributed edge computing for a multi-microgrid ECPS. The microgrid comprises distributed energy resources, loads, renewable energy. A single MG system may not provide reliable operation under certain extreme circumstances, such as main grid outages and natural disasters. The interconnected MGs can improve the reliability and resilience of the overall system. The edge node is responsible for (i) maintaining the stability of the corresponding microgrid and (ii) ensuring the optimal operation of the networked microgrids by moving energy between microgrids in a secure and privacy-preserving manner.

Thrust 3: Deploy distributed edge computing for the ECPS platform with distributed control strategies developed on the smart grid testbed at FIU. The hardware testbed includes a unique facility to emulate a real-time AC power grid that provides real-world power generation, transmission, and distribution scenarios. The system is implemented on three microgrids interfaced to the AC grid by bidirectional AC/DC inverters. The edge nodes are developed to be implemented in FPGA-SoC embedded devices.

The project will be conducted in 12 months, and the estimated budget is $50,000 (including one graduate student). The outcomes of the project are three scientific reports two-three publications. We will implement an FPGA-based distributed edge computing capability for the cyber-physical multi-microgrids. This will be Alpha tested on the FIU smart grid testbed and possibly Beta tested at an industry location.