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ANGEL: An Intelligent Digital Twin Framework for Microgrid Security

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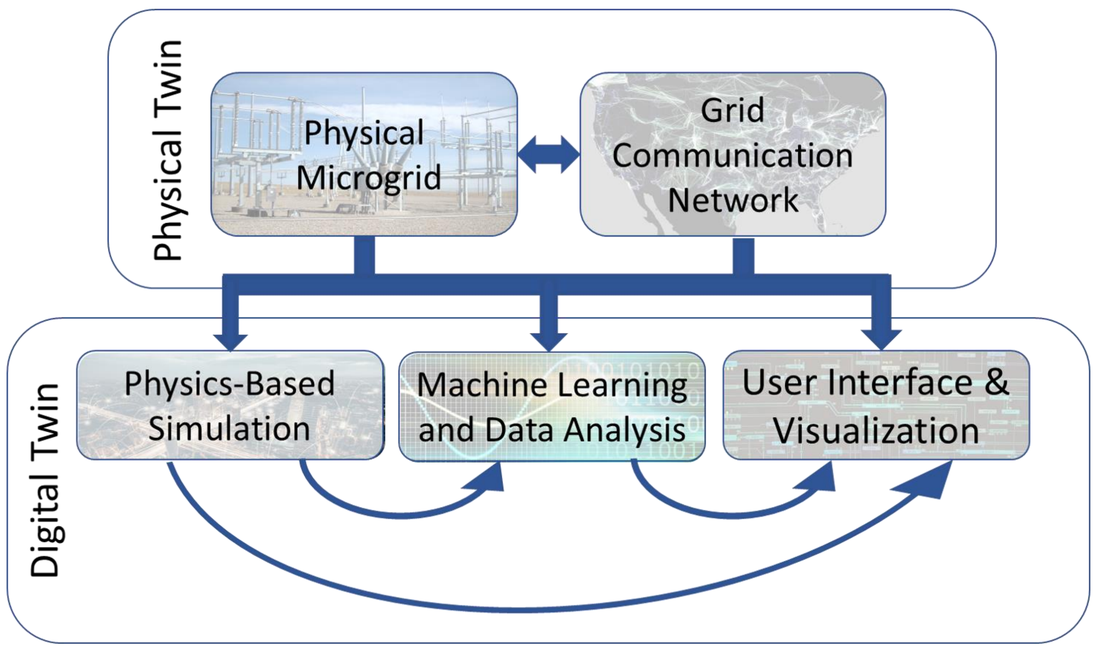
The ANGEL Framework

The ANGEL Digital Twin for Cyber-Physical System Security is a novel approach for improving the security of critical and non-critical infrastructure. Digital Twin technology, widely used in the aviation, manufacturing and automotive industries, has the potential to improve the security and resiliency of the microgrid. In this paper, we present a framework for adapting the Digital Twin to the application of microgrid security. The Digital Twin is a real-time, physics-based simulation that runs alongside the physical system providing for its constant monitoring and control. The **A**utomatic **N**etwork **G**uardian for **EL**ectrical systems, or ANGEL, will model both the cyber and physical layers of the microgrid and provide real-time data visualization. As a result, users will be aided in assessing the health of the physical plant and overall behavior over a range of operating conditions. The ANGEL Digital Twin will be able to use the real-time two-way coupling between the simulation and physical system to update and evolve the simulation to provide greater insight into the physical system. Ultimately ANGEL will provide the ability to diagnose and heal the physical system, mitigating both component failures and the effects of cyber attack.

Background

The modern Smart Grid has two interwoven components, the cyber communication network and the physical components of the power grid. The duality of the power grid creates a unique challenge to protect and defend the grid from natural outages such as weather-related causes as well as cyber or physical attacks issued by malicious actors. The cyber and physical layers of the modern power grid rely on constant and accurate communication to maintain a stable power grid.



Digital Twin

The Digital Twin as coined by Dr. Michael Grieves is an integrated multiphysics, multiscale, probabilistic simulation of an as-built vehicle or system that uses the best available physical models, sensor updates, fleet history, etc., to mirror the life of its corresponding physical twin. To accomplish this, the digital twin needs to expand beyond the traditional modeling and simulation techniques by incorporating sensor feedback in the simulation and feeding information from the simulation back into the physical model in real-time.

Level I: Pre-Digital Twin		Level II: Digital Twin	
Physics-based Simulation:	✓	Physics-based Simulation:	✓
Physical System:	✗	Physical System:	✓
Adaptive GUI:	✗	Adaptive GUI:	✗
Machine Learning:	✗	Machine Learning:	✗
Level III: Adaptive Digital Twin		**Level IV: Intelligent Digital Twin**	
Physics-based Simulation:	✓	Physics-based Simulation:	✓
Physical System:	✓	Physical System:	✓
Adaptive GUI:	✓	Adaptive GUI:	✓
Machine Learning:	✗	Machine Learning:	✓

Advantages of ANGEL System

The new Smart Grid that will be a fundamental building block for the future of Smart Cities could benefit from a more sophisticated system for control and security. The Automatic Network Guardian for Electrical (ANGEL) system can monitor the power system in real time and provide insight into the inner workings of the grid dynamics. This will allow a digital twin to direct the physical "twin" when abnormal grid behaviors are detected.

The modern power grid is a perfect application for the digital twin technology. Using the legacy SCADA system that is already in place, the digital twin can access real-time data about the physical system and provide guidance in real-time. While early adaptations of the digital twin would likely include a human in the loop structure, the fully realized digital twin could potentially analyze and control the power system with virtually no human interaction.

Using the legacy communication techniques already found in the SCADA and wide area monitoring (WAM) systems, the ANGEL digital twin is able to attach itself to the control center environment and provide useful feedback. The physical microgrid and grid communication network feed data into the physics-based simulation, machine learning and data analysis, as well as the user interface and visualization suite of the digital twin. While analyzing additional data from the grid could be advantageous, using the legacy communication protocols will allow the digital twin to be deployed and tested on a microgrid without significant modifications.

We gratefully acknowledge the support from the Office of Naval Research. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Office of Naval Research.

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