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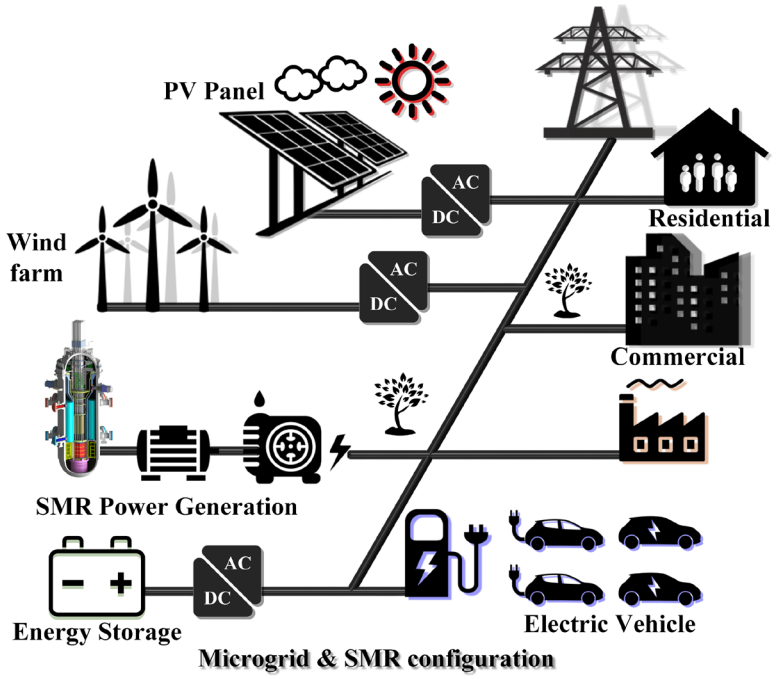
Comprehensive Multi-Domain Modeling and Real-Time Digital Emulation of Small Modular Reactors

To advance the opportunity for Small Modular Reactors (SMRs) to supply zero-emission power and heat for Albertans in the future, and in support of Canada's SMR Action Plan, Prof. Venkata Dinavahi's team seeks to develop a detailed real-time digital twin for different types of SMRs. The digital twin will be designed to precisely replicate the intricate workings of SMRs. It will encompass an array of simulation domains ranging from neutronics and thermal-hydraulics to mechanical dynamics and electromagnetic transients. This holistic modeling approach will span across time- and frequency-domains, and will enable the study of power system dynamics and transients with various types of sustainable generation sources.



FUNDING DETAILS

RECIPIENT:
University of Alberta

PARTNERS:
Canadian Nuclear Laboratories
MITACS
Terrestrial Energy Inc.

TOTAL BUDGET:
$1,070,000

AI FUNDING:
$250,000

PROJECT DATES:
JUL 2024 – JUN 2028

PROJECT TRL:
Start: 3
End: 7

APPLICATION

A standout feature of the SMR digital twin will be artificial intelligence (AI) assisted modeling methods and its compatibility with external advanced digital programmable boards and other controller hardware, enabling parallel processing, real-time execution, and hardware-in-the-loop emulation. User-centric design and a graphical interface will enhance the practicality and functionality of the digital twin. The platform can serve as a training, analytical, and innovation tool for students, researchers, designers, and operators of SMR systems, and empower users to test the effects of adjusting SMR subsystem parameters.

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PROJECT GOALS

Development of the digital twin during the Project will focus on the following activities and deliverables:

- Multi-Domain Mathematical Modeling and Model Decomposition: Includes investigating ways to mathematically model the physics of SMRs that includes multiple domains and components, and developing novel decomposition strategies. Develop and integrate machine learning techniques for acceleration and implement AI-driven fault detection systems to improve reliability and performance.
- Parallel Numerical Solver Design and Real-time Digital Twin Implementation: Develop novel parallel numerical integration methods, nonlinear solution schemes, and digital hardware designs.
- Graphical User Interface (GUI) Development and Optimization: Develop an advanced GUI front-end interface to the detailed SMR simulation.
- Testing, Verification, and Validation: Utilize the completed platform to conduct joint digital twin simulations and

BENEFITS TO ALBERTA

- The SMR digital twin will serve as a testing and development platform for engineers to plan and deploy SMRs in Alberta, paving the way for further reductions of greenhouse gas emissions on the Alberta electricity grid.
- The digital twin will serve as a training tool for developing a highly skilled nuclear energy workforce in Alberta.
- The virtual replica offers a safe, lower-cost, risk-free platform for performance testing and evaluation of real systems.
- The platform will enable rigorous testing and evaluation of system strategies and responses of different SMR technologies under various electricity grid scenarios, including extreme and abnormal events.
- These capabilities will help ensure future electricity affordability and reliability. Furthermore, they will contribute to employment opportunities in advanced SMR simulation technologies and for optimizing performance in Alberta's energy sector.

3 Publications

6 Students Trained

2 New Products/Services

CURRENT STATUS

AUG 2024

The project is underway, with two IEEE journal papers and one IEEE review article already published, and an additional two papers under submission. Currently, the focus is on negotiating specific details and timelines with industrial partners and engaging with post-secondary students who will participate in the project.