# FIRE & EXPLOSION MANAGEMENT SYSTEM FOR ENERGY STORAGES IN HOT AND HUMID CLIMATES: AN ARDT-BASED, RESILIENCY-ORIENTED APPROACH

## PROJECT SUMMARY

The hot and humid climate of Singapore poses a challenge to the safety, performance and lifespan of the ESS. Prevention of fire and explosion in the ESS requires proper control strategies and predictions of any undesired future event. Existing strategies to manage fire and explosion risks are largely designed based on protection schemes. In a protection framework, corrective actions will be executed by safety devices, such as Current Interrupt Devices, to deal with a failure or nonconformity that occurred. This correction design, often simple and cost-effective, may fail to stop accidents due to untimely remedy actions, unreliable monitoring, and improper safety thresholds.

This project proposes a novel preventive solution, called Fire & Explosion Management System (FXMS), to address the possibility of an accident in complement with the correction counterpart. FXMS uses a virtual battery-based augmented reality and digital twin (ARDT) technology to combine real-time data measurement through the Internet of things (IoT) and leverage advanced machine learning and data mining algorithms.

- Develop Digital Twin of energy storage system
- Define and quantify the safety requirements & key influential factors under hot and humid conditions
- Design and implement a safety management system for the most common ESS applications under tropical climate conditions
- Enhance grid resiliency and optimize the performance of ESS by designing energy-system-to-grid module

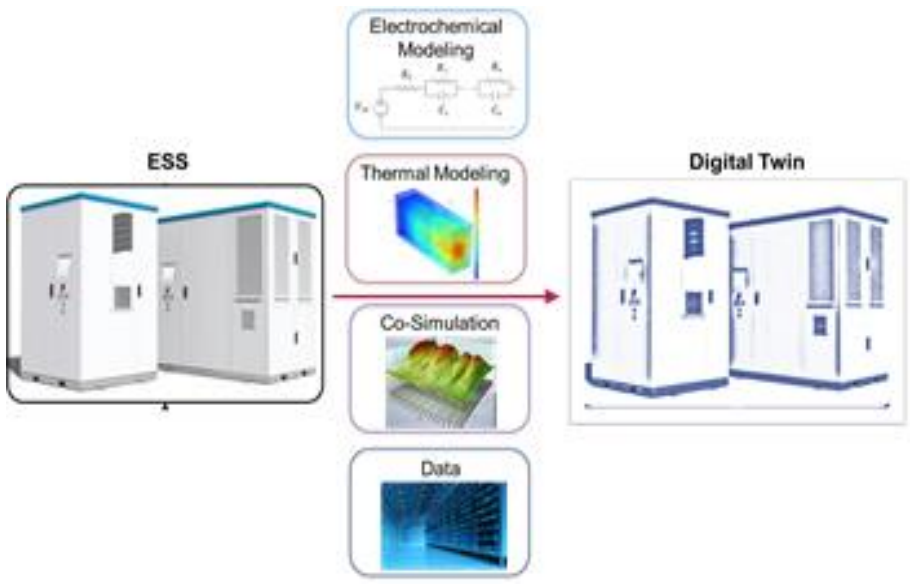


*Figure 1: Virtual Energy Storage System with Digital twining and 3D-enabled modeling*

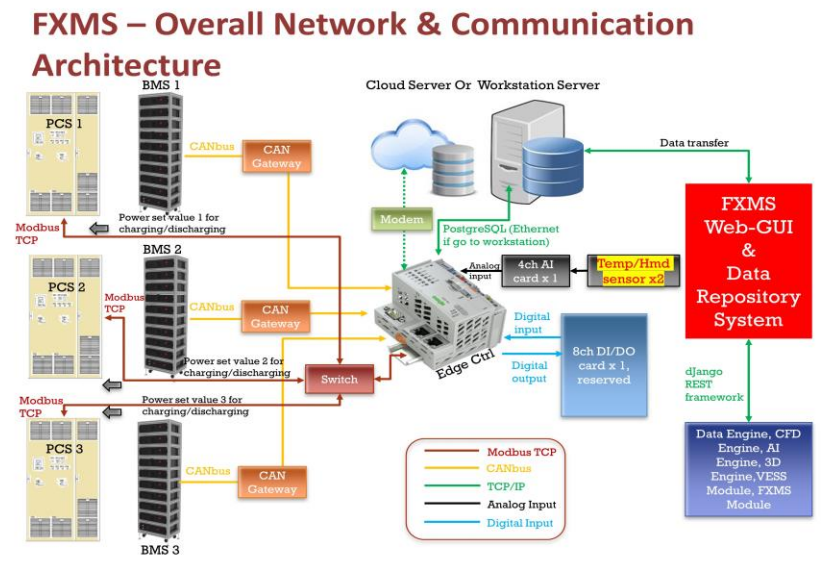


*Figure 2: Overview diagram for FXMS IoT-based VESS safety management system*

## PROJECT OUTCOMES

**Brief Description of Solution**

- A Virtual Energy Storage System (VESS)
  - An augmented reality and digital twin (ARDT) technology for developing operation, control, and planning strategies.
  - Analytical and simulation models for battery state of charge, temperature, remaining useful life, and an optimal grid-connected ESS operation scheme respecting ESS health conditions was developed.
- A Fire and Explosion Management System (FXMS)
  - FXMS can perform real-time safety assessments and design resilient response strategies for hot and humid climates.
  - A dynamic ESS operational region-construction framework and two-layer optimal control of battery temperature have been established with acknowledging battery degradation and safety concerns.
  - Actual battery data has been acquired and analyzed to constantly trace battery states change under different environmental temperatures, humidity, and operating conditions during chamber testing.
- Overall integration of VESS and FXMS
  - A customizable software platform with the user interface at the front-end and VESS & FXMS module at the backend and real-time data exchange with IoT devices
  - A basic Web GUI framework has been developed.

**Technical Targets / Key Performance Indicators**

- Development of a system-level thermal model having global error less than 10% compared to the actual system.
- Increase the prediction accuracy of VESS by 5% compared to conventional prediction techniques.
- Design auto-recalibrating algorithms for sensors with improved accuracy.
- Increase the Mean Time To Failure due to Fire & Explosion (MTTF-fx) of ESS by 30% compared to the existing solutions.
- Optimize the coordination of ESS with the power grid for frequency and voltage regulation.
- Apply the preventive and corrective control from FXMS to prolong the remaining useful life of the ESS by 15%.

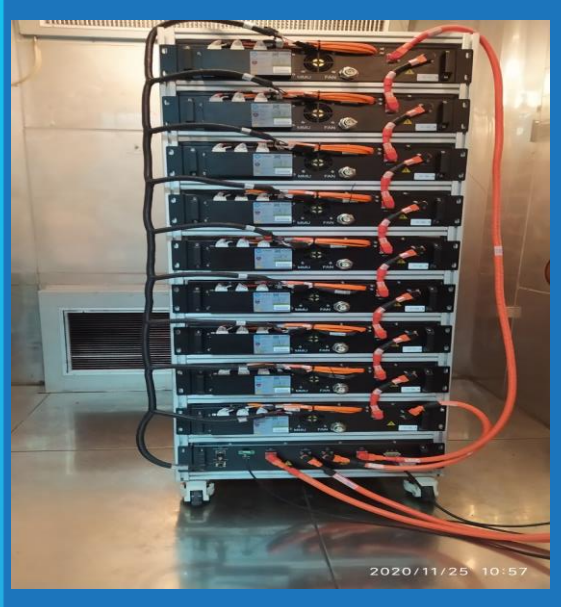


*Figure 3: Chamber testing of ESS*

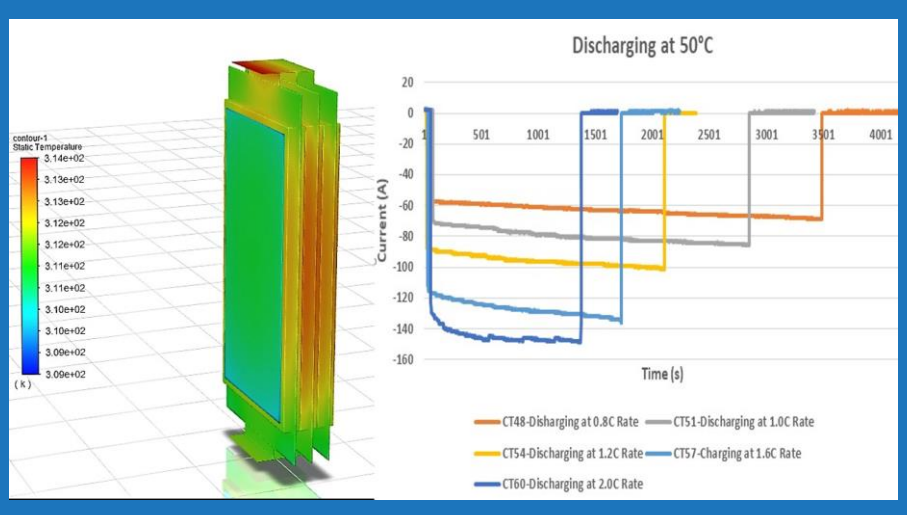


*Figure 4: The contour of three-cell parallel battery model under the conditions of 298K ambient temperature and discharging test curves at 50°C at various C rates*

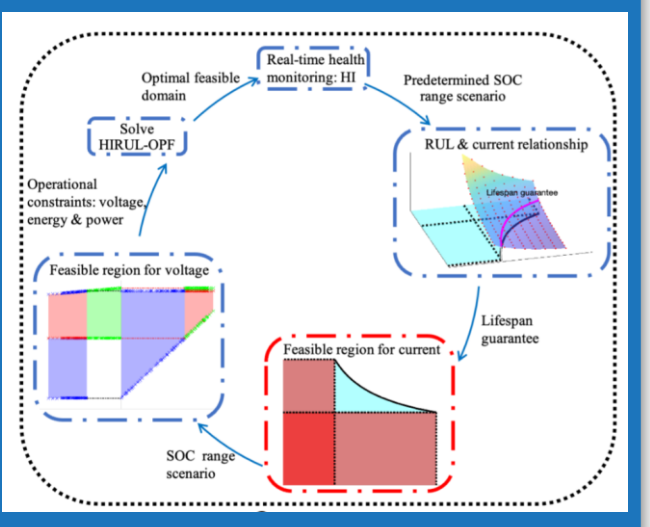


*Figure 5: Dynamic operational region construction considering battery degradation as well as customized services and safety constraints*


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