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HIL Simulation Training Platform for AI PMS in Smart Vessel

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Hardware-In-the-Loop Simulation (HILS)

• Hardware-In-the-Loop Simulation

  - Hardware can be tested with real system
  - Real-Time Simulator emulates virtual system in real-time
  - Controller for power converter is tested with virtual system
Hardware-In-the-Loop Simulation (HILS)

• Applications
  – Electric vehicle controller test
  – Power converter test for Renewable Energy
  – Power management system test for Microgrid
Advanced Power Interface & Power Electronics Lab

• APIPEL
  – For Smart grid
    • Solid State Transformer
    • DC Micro-grid Test bed
    • Low Voltage Direct Current Distribution
  – For industry application
    • High Frequency/Density Power Converter
    • Wireless Power Transmission (WPT)
    • Induction Heating (IH)
  – With Power Hardware-in-the-Loop Simulation
    • Renewable energy
    • Modeling of Electric Ship
    • Power Hardware-in-the-Loop Simulation
  – 7 Students are studied in APIPEL
    • 3 Doctor target students
    • 4 Master target students
Proposal Introduction

• Proposal
  – Target hardware: Artificial Intelligent Power Management System (AI PMS)
  – Virtual test and training platform for AI PMS
  – We will provide HIL test & training platform using real-time simulation technique.
Proposal Introduction

- **HILS for Artificial Intelligence Power Management System (AI PMS)**
  - Power Management System (PMS)
    - PMS monitors and controls power system for safe and efficient operation
    - PMS prevents blackout of vessel’s power system
Proposal Introduction

- HILS for Artificial Intelligence Power Management System (AI PMS)
  - Conventional PMS operation
    - Operation regulation according to situation
    - The operation regulation is not ideal for efficiency

- AI PMS
  - Artificial Intelligence + PMS
  - collects huge power system data by itself while operating power system
  - Operates power system in the best situation based on the collected data
  - AI PMS gives better energy efficient operation
Proposal Introduction

- **HILS for AI PMS Test & Training**
  - **Virtual vessel’s power system**
    - Mathematical modeling of ship power system
    - Real-time simulator calculates target model in real-time manner
  - **Test and training platform**
    - AI PMS can collect the data by controlling virtual ship power system
    - Various power system situation can be simulated by adjusting target model
    - Safe, cost-effective and time-saving test and training platform

Concept of HILS for AI PMS test
Proposal Introduction

• R&D Consortium
  – We can develop HIL-based test & training system
  – We need AI and PMS experts (company, univ., RI, etc.)
  – Development of AI PMS with training and testing by using the proposed HILS test platform
Proposal Introduction

• R&D Competence of APIPEL, UNIST
  – Various HILS Test Platform Development
    • Power HILS for renewable energy (PV and battery)
    • Power HILS for various power converters
    • RT modelling of ship’s power systems and DC microgrid for HILS applications

Power HILS for PV

Power HILS for Seawater Battery

HILS for Ship’s PMS
Partners

- Research Fund Sources in Korea
  - National Research Foundation of Korea
  - Korea Electrotechnology Research Institute
  - Korea Electric Power Corporation
  - Ministry of Science, ICT, and Future Planning
  - Korea East-West Power Company
  - National Institute of Fisheries Science
  - Hyundai Motors
  - LG Electronics
  - Hyundai heavy industries
Contact

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Reference

APPENDIX

Research Project
Research Projects

• DC Microgrid
  – High performance bidirectional power conversion technology
  – AC-DC inverters and DC-DC converters
  – ESS power interface for DC distribution system
  – Autonomous DC microgrid using power line comm.
  – Virtual DC microgrid test-bed using power HILS system
Research Projects

- LVDC Power Converters for DC Microgrid
  - 1500 V dipole system for safety and reliability
  - High efficiency single- and multi-level converters
• **High Frequency LLC Resonant Converter**
  - High power density using high switching frequency
    - Decreasing passive components size (L and C)
  - Low SW loss with next-generation wide band-gap devices
  - Design digital controller for wide control bandwidth
Research Projects

- Modelling of Sea-Water Battery
  - Use Chemical-Electric modelling before perfect development of Sea-Water Battery
  - V-I curve characteristics test of Sea-Water Battery
  - Static and dynamic response of V-I prediction

\[ E = E^0 - \frac{RT}{nF} \ln Q \]
\[ i = nFAk^0 \left[ C_0(x = 0, t) e^{-\alpha x(E-E^0)} - C_0(x = 0, t) e^{(1-\alpha) x(E-E^0)} \right] \]
\[ V_{thm} = i \left[ \sum_j R_{c,j} + \sum_k \frac{L_{c,k}}{\sigma_{c,k} A_{c,k}} + \frac{dz}{\sigma_m (\Delta \lambda(z))} \right] \]

Concept of SeaWater Battery

Mathematical modelling

Seawater Power HIL

Real-Time Simulation

SW Battery Converter

Simulation modelling
• PHILS of Electric Ship for Emulating Electric Behavior of Power Interface
  – Ship’s entire electric system can be tested under similar operating circumstances.
  – Shipping power system analysis can be achieved according to various operating conditions.
  – Reduction of development/test time and cost
Research Projects

• Power Network of Electric Vehicle
  - Simulate power network and power flow of the vehicle
  - Power HIL simulation
    • Test-bed including vehicle and power hardware
    • EV hardware feasibility verification
Research Projects

• Design of Battery Management System (BMS)
  – A BMS is an electronic device that manages a rechargeable battery in order to protect the battery from damage
  – A BMS may project its batteries by preventing its safe operating area, such as:
    • Charge/Discharge control
    • Estimation of SOC and SOH
    • Cell balancing
    • Thermal management
Research Projects

- Grid System for Hyperloop
  - Total 80 MW power transmission is required to push ahead the capsule
  - AC-DC Rectifier from AC grid to DC grid (80 MW)
  - Battery Charger from DC grid to UPS battery (5 MW)
Research Projects

• Hybrid IH system for new value-addition
  – Free cook zone IH system with new functionality
  – High efficiency IH inverter and power control algorithm

![Scheme for IH application](image1)

![New Functionality of IH](image2)

Product Design of Free Cook Zone System

Power Conversion Efficiency and Power Factor