Digital Twins for New Energy Processes in MATLAB® & Simulink®

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Contents

- Background
- Digital Twins in MATLAB and Simulink
  - Types of Digital Twin Models
  - Common Digital Twin Applications
  - Digital Twin Deployment Options
  - AI-based Modeling and System Design Workflow
- Simulink® Digital Twins for New Energies
  - Multi-physics Digital Twins for Green Hydrogen Production
  - Modular Open-Systems Approach (MOSA) for Digital Twins
  - Optimizing Turbine Predictive Maintenance Scheduling
- MathWorks® Digital Twin Toolset
Background

The integration of new energy processes in the value chain requires a thorough understanding of time, cost, demand, and resources necessary to streamline these processes in the most effective and timely fashion.

New energy processes comprise complex, multi-physics, dynamic systems that require comprehensive and continuous analysis and control steps to maximize data value using existing assets and allocated infrastructure.

Digital twins and advanced process control (APC) are useful digital technologies for engineers, scientists, and decision makers to design, test, predict, and plan how to make the most out of a new energy process.

MathWorks developed digital toolboxes in MATLAB and Simulink for organizations to build (i) digital twins that simulate dynamic systems and processes, and (ii) APC systems to maximize process performance, stability, and efficiency.
Customizable Digital Products for Energy Upstream & Downstream

**Subsurface**
- SeReM + MRST
  - MATLAB® Reservoir Modeling & Simulation

**Oilfield**
- Oilfield & Plant Digital Twins
  - MATLAB® & Simulink®

**Plant**
- Simscape

**Process Modeling & Simulation**
- MATLAB® Production Server
- MATLAB® Cloud Service
- MATLAB® Quantum Computing
- Parallel Computing Toolbox
- GPU Computing Toolbox
- Simulink® Simscape
- Image/Signal Processing Toolboxes
- Computer Vision Toolbox
- Machine Learning Toolbox
- Deep Learning Toolbox
MathWorks in Energy Resources
Digital Twins in MATLAB® & Simulink®

Digital Twin: A digital simulation of dynamic systems to predict outcomes and inform decisions
Types of Digital Twin Models

- **Process Model**
- **Parameter Estimation**
- **Reduced-Order Models**
- **AI-based Models**

**Build Digital Twin**

**Leverage Digital Twin**

**Deploy Twin & Algorithms**

- **Physical Components**
- **Hybrid Models**
- **Machine Learning**

- **Physics-driven modeling**
- **Data-driven modeling**

- **Parameter Estimation**
- **Reduced-Order Models**
Common Digital Twin Applications

- **Monte Carlo Simulations**
- **Operations Optimization**
- **Predictive Maintenance**
- **Fault Diagnostics**
Digital Twin Deployment Options

- Build Digital Twin
- Leverage Digital Twin
- Deploy Twin & Algorithms

Cloud-based Solutions

- Desktop Users
- Edge Devices

Digital Twin Deployment Options

7.973% 20 Motors Reporting 4 Motors Requiring Maintenance

Remaining Useful Life and Anomalies

Motor ID 5
Maintenance Interval 587
Anomaly Count 3

Dashboard: All Motors
Anomaly Count by Motor

Dashboard: One Motor
Anomaly Count vs. Motor Health

Python
Excel Add-in
Standalone Application

MathWorks
Digital Twins – AI-based modeling and system design workflow

1. Data Preparation
   - Data cleansing and preparation
   - Human insight
   - Simulation-generated data

2. AI Modeling
   - Model design and tuning
   - Hardware accelerated training
   - Interoperability

3. Simulation and Test
   - Integration with complex systems
   - System simulation
   - System verification and validation

4. Deployment
   - Embedded devices
   - Enterprise systems
   - Edge, cloud, desktop
Simulink® Digital Twins for New Energies

Objectives

▪ Model chemical reaction kinetics, thermodynamics, and mass balance across a multi-physics system of equipment components
▪ Integrate machine learning to develop predictive model for process testing, prototyping, DevOps monitoring, and process optimization
▪ Incorporate advanced control systems (ACS: PLC, DCS) and digital sensors to simulate data flow across OT/IT infrastructure (e.g., SCADA)

Case Studies

▪ Randall (Sasol) and Mantji (Opti-Num). Predictive maintenance of a steam turbine. MathWorks Video.
Simulink® Digital Twins for New Energies (Green Hydrogen)

Multi-physics Digital Twin for Pressurized Water Electrolyzer (Iribarren et al, 2023)

Electrical model + Thermal model + Green Hydrogen model

Multi-physics verification (experiments vs. simulations):

Electrical model

Thermal model

H2 production model

Electrical model

Thermal model

H2 production model
Simulink® Digital Twins for New Energies (Green Hydrogen)

Multi-physics Digital Twin for Pressurized Water Electrolyzer (Iribarren et al, 2023)

Digital twin validation – Wind Power Operation

Digital twin validation – PV-based Operation

Digital Twin for Green Hydrogen

Final Model
Simulink® Digital Twins for New Energies (Green Hydrogen)

Multi-physics Digital Twin for Pressurized Water Electrolyzer (Sakas et al., 2022)

Alkaline water electrolyzer process diagram

Alkaline water electrolyzer – Simulink model

Simulink model – Cooling water feed valve control

Conceptual dynamic simulation model
Simulink® Digital Twins for New Energies (Green Hydrogen)
Multi-physics Digital Twin for Pressurized Water Electrolyzer (Sakas et al., 2022)

Multi-physics verification (measured vs. simulated):
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Modular Open-Systems Approach (MOSA) for Digital Twins

Objectives
- Monitor, predict, and automate IT/OT systems
- Integrate data science and engineering analytics

Advantages
- Full traceability and interoperability of DevSecOps
- Efficient, secure, and high-quality outputs
- Verify, adapt, and transform before you invest

Digital Twin for Drilling Rig Automation

Digital Twin for Pump Predictive Maintenance
Optimizing Turbine Predictive Maintenance Scheduling

**Goal:** Analyse performance of past maintenance and predict future efficiencies in only 100 engineering hours.

**Challenges:** Using historical data to detect unlogged maintenance and detect patterns that indicate efficiency of maintenance.

**Solution:** Predictive model to indicate an efficient maintenance schedule. Develop a frontend that allows operations staff to track the effects of inefficient maintenance.

**Problem statements**
- 13.5MW condensing steam turbine @ 6,700 rpm
- 7 compressor-turbine trains | WCP: 1,600-2,550 kPa
- Plan and predict fouling within a year
- Optimize turbine performance h-s & T-s

Predictive Maintenance Workflow and Deployment

- Data Access & Preprocessing
- Data Analysis
- Model Development
- Deployment
MathWorks® Digital Twin Toolset

Key technology differentiators

- Customizable STEM and BDIA toolboxes developed and fully interconnected on MATLAB® platform
- Model-based and data-driven science & engineering workflows to maximize data & image usage
- MathWorks® support, training, and development of data science, engineering, and analytics solutions
- Adaptive digital solutions to assess and integrate new energy processes using high-end technologies
- Low-cost, high-quality software solution to maximize technical expertise, IT infrastructure, and budget
- 200+ energy companies globally currently use MATLAB® solutions across upstream and downstream