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Digital Twin Implementation With FMI for Automation System

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Agenda

Use the FMI-standard to connect simulation models with an automation system

- The **FMI** (Functional Mock-up Interface)-standard is used to share dynamic simulation models of physical systems
- The goal was to create a **POC** to show how the standard can be used together with an automation system
- The simulation models were used to interact with **PLC-applications** running on the automation system, for example, the models were controlled by the PLC-applications and the model outputs were used as feedback for the applications
- The FMI-standard was used in combination with **OPC UA**, which provided bidirectional, real-time communication between the PLC-applications and simulations

Functional Mock-up Interface

- **What is FMI?**
  - **FMI** (Functional Mock-up Interface) FMI-standard defines an interface for sharing dynamic simulation models and is currently supported by 220+ simulation tools
  - Developed for **interoperability** between different simulation tools
  - Ensures models are **tool-agnostic**, portable, and re-usable
- **Key Features of FMI**
  - **FMUs** (Functional Mock-up Units): Model files compliant with the FMI standard
    - Can represent **individual components** or **entire systems**
  - **APIs** to enable seamless integration with simulation environments
  - Support for different interface types (**Model Exchange** and **Co-Simulation**)

fmi Functional Mock-Up Interface

Source: https://fmi-standard.org/

Functional Mock-up Interface

- **Key Interface Types**
  - **Model Exchange (ME)**: Provides equations and derivatives, relies on external solvers
  - **Co-Simulation (CS)**: Includes its own solver, runs simulations with time synchronization
- **Why Use FMI?**
  - Facilitates **cross-tool compatibility** in system modeling and simulation
  - Reduces **integration effort** in multi-tool environments
  - Enhances **model reusability and portability** across platforms

Model Exchange

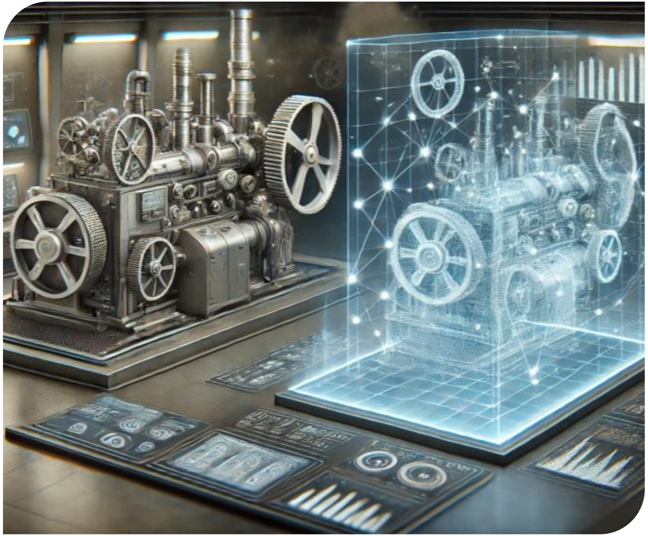
Co-Simulation

Source: https://modelon.com/blog/fmi-functional-mock-up-unit-types/

Digital Twins

- **What is a Digital Twin?**
  - A **virtual replica** of a physical system, process, or asset
  - Synchronizes with the **real-world system in real-time** using data from the physical system and simulations
  - Enables **monitoring, analysis, and optimization** of real systems

- **Key Components of a Digital Twin**
  - Digital model which models the physical system
  - Options for modelling:
    - **Machine Learning model**
    - **Physical model**
  - Bidirectional, **real-time communication** between physical and digital systems

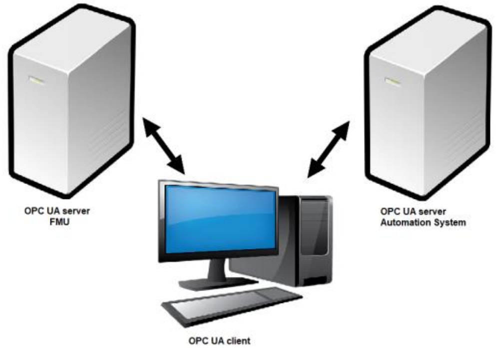


Proposed implementation

- **The goal**
  - Use FMUs as digital twins for PLC-applications running on an automation system
  - Have bidirectional, real-time communication between the automation system and the FMU-simulations
- **Method used**
  - Create FMUs to represent the physical system that could be controlled by the automation system
  - Use OPC UA to connect the FMU-simulations with the PLC-applications
  - The FMUs execute simulations according to real-time data received from the PLC-applications and simulation outputs are used to control the system

System Architecture

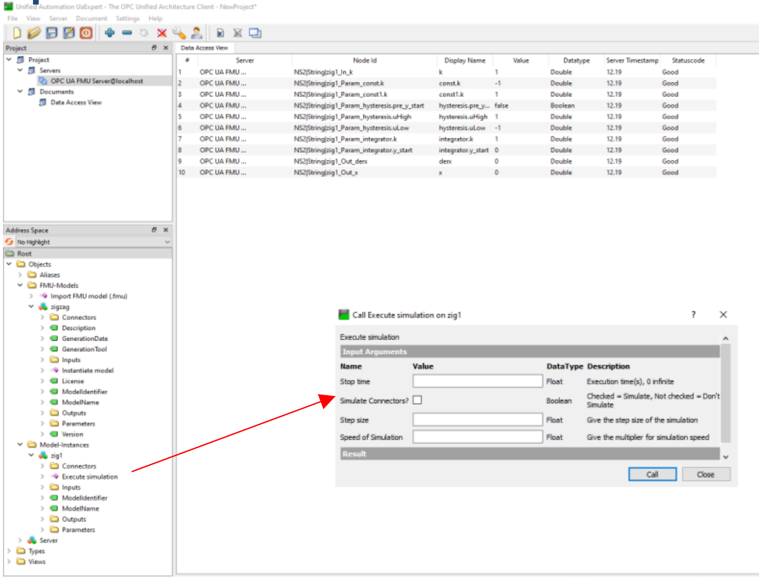
- **System consists of:**
  - 2 OPC UA servers
    - One for handling FMUs
    - One on the automation system
  - OPC UA client(s)
    - Used for connecting the servers
- **FMU-server:**
  - Reads the FMU-file, provides simulation data
- **AS-server:**
  - Included with the automation system
  - Provides data about the PLC-applications
- **OPC UA client(s)**
  - Transfers simulation and control data between the two servers



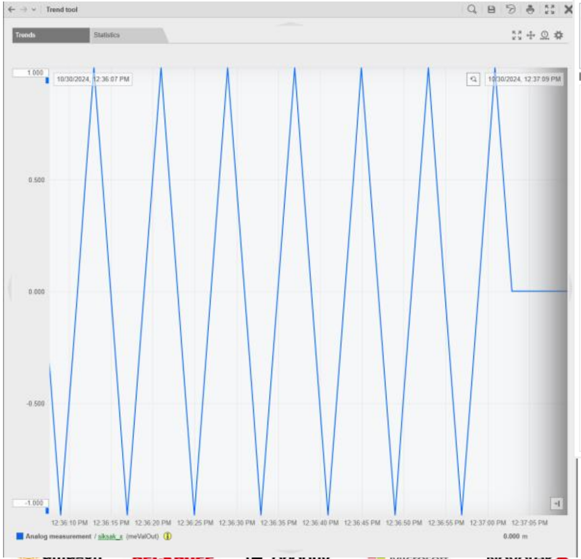
OPC UA methods

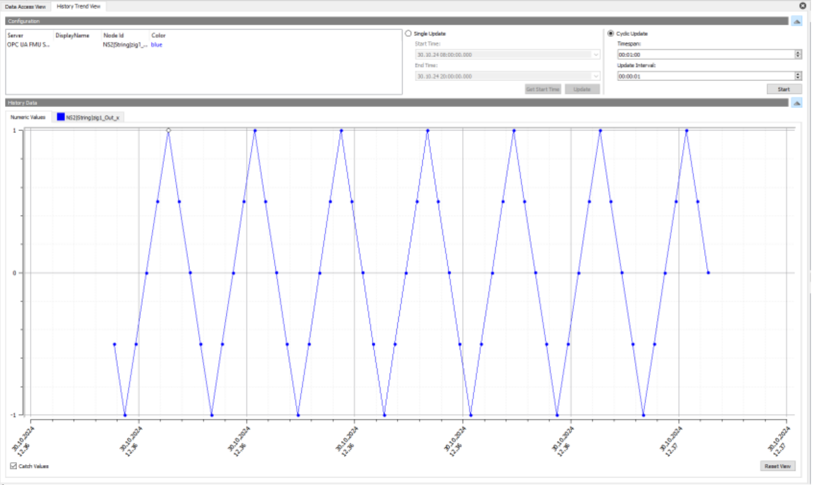
- FMU-server uses methods for handling the FMUs
- The methods can be invoked by the clients that connect to the server
- **Methods:**
  - Import FMU
    - Reads the FMU-file, generates an information model to the Address Space according to it
  - Instantiate model
    - Creates an instance of the previously generated information model
    - Allows the user to create multiple instances, which can be executed simultaneously
  - Execute Simulation
    - Executes the FMU-simulation according to parameters given by the user

Address space and instance method call to “Execute simulation”



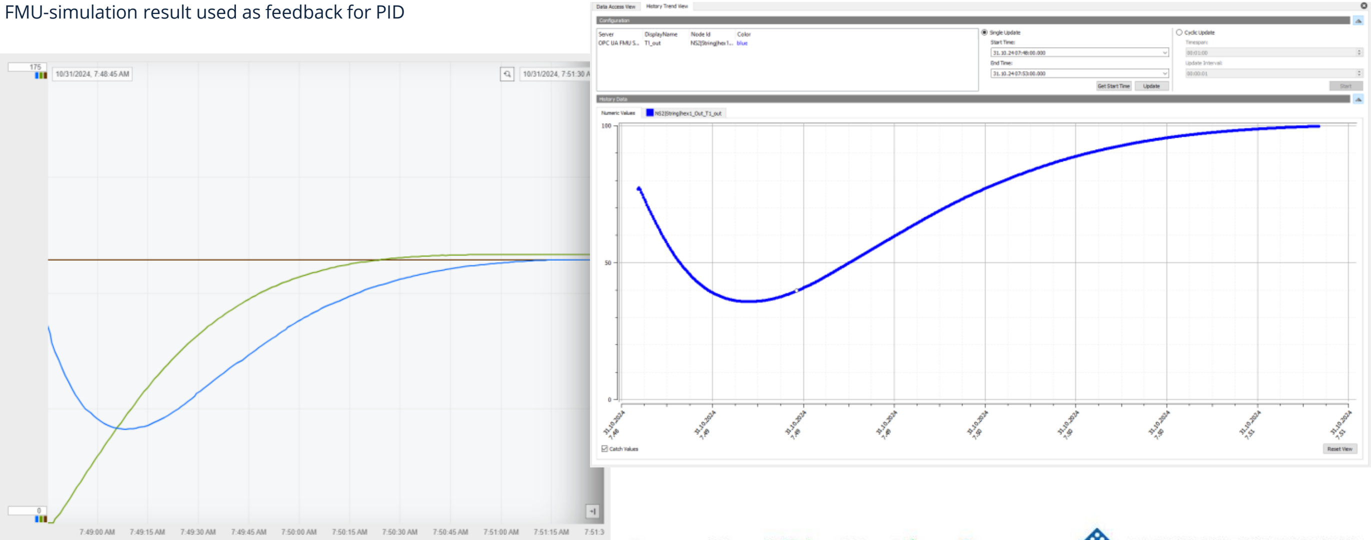
Example: An alternating measurement level





Example: FMU-simulation controlled by PID

FMU-simulation result used as feedback for PID



Conclusion

- FMUs and their simulations can be used to interact with PLC-applications of an automation system
- The POC demonstrates how FMUs can use real-world data as inputs for the simulations
- The outputs of the simulations can be used to control a real-world system, providing bidirectional dataflow between the digital and physical world with OPC UA
- OPC UA acts as a suitable data transfer technology between the PLC-applications and FMU-simulations

Thank you!

Tuomas, please come to stage!

Detailed questions to actual man

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