



MODAPTO [101091996]: Modular Manufacturing and Distributed Control via Interoperable Digital Twins



13.1.2 Module interface definition and compatibility assessment

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Introduction

Module interface definition and compatibility assessment represent critical technical activities that determine the success of MODAPTO system integration and reconfiguration capabilities. Interfaces serve as the standardized connection points between modules, enabling communication, control, material flow, and energy transfer while maintaining safety and operational integrity. Comprehensive interface definition ensures that modules from different manufacturers can work together seamlessly, supporting the fundamental interoperability goals of reconfigurable manufacturing systems.

Physical interfaces encompass the mechanical, electrical, and fluid connections that enable modules to integrate within production systems. Mechanical interfaces include mounting points, alignment systems, material handling connections, and safety interlocks that ensure secure and precise module positioning. Digital twins offer a powerful framework for gaining insights, optimizing performance and driving innovation across various industries, with applications in manufacturing, energy, transportation, healthcare and smart cities, enabling predictive maintenance, autonomous operation, and optimization of complex systems.

Standardized mechanical interfaces reduce integration complexity and enable rapid reconfiguration by eliminating custom mounting and positioning requirements.

Electrical interfaces define power supply requirements, control signal connections, and safety circuit integration. These interfaces must accommodate varying power requirements while providing consistent signal quality and electromagnetic compatibility. Safety circuits integrate with facility-wide safety systems to ensure that module operations remain coordinated and secure during both normal operation and emergency conditions.

Fluid interfaces address compressed air, hydraulic, cooling, and process fluid connections required for module operation. Standardized quick-connect fittings enable rapid reconfiguration while maintaining leak-free operation and consistent pressure regulation. These interfaces must accommodate different flow rates, pressures, and fluid types while providing reliable operation throughout the module lifecycle.

Communication interfaces represent the digital connections that enable modules to participate in coordinated manufacturing operations. OPC UA is an open and royalty-free interoperability framework with state-of-the-art security, fault-tolerant communication protocols, and object-oriented information modeling, which when combined with semantic models such as Asset Administration Shell makes it easier for end users to access data via generic commercial applications.

MODAPTO employs standardized industrial communication protocols including OPC UA, Ethernet/IP to ensure reliable data exchange and control coordination between modules and supervisory systems.

Data interfaces specify the information structures, exchange formats, and semantic definitions that enable modules to share operational data, status information, and control parameters. These interfaces must support both real-time operational communication and



historical data collection for performance analysis and optimization. Standardized data models ensure that information can be consistently interpreted across different modules and system components.

Compatibility assessment involves systematic evaluation of interface requirements and capabilities to determine whether specific modules can be successfully integrated within existing or planned production configurations. Technical compatibility assessment examines physical dimensions, connection types, power requirements, communication protocols, and performance characteristics to identify potential integration issues before implementation.

Functional compatibility assessment evaluates whether module capabilities align with production requirements, including processing speeds, quality standards, material handling requirements, and operational flexibility. This assessment considers both current production needs and anticipated future requirements to ensure that module investments provide long-term value and reconfiguration flexibility.

Operational compatibility assessment addresses factors such as maintenance requirements, operator skill levels, safety procedures, and integration with existing manufacturing execution systems. Reconfigurable manufacturing systems require a large number of modifications and changes handled by workforces who must have adequate qualification and skills, with workforce qualification frameworks ensuring skills needed for performing activities.

This comprehensive evaluation ensures that new modules can be effectively operated and maintained within the existing organizational capabilities and procedures.

Economic compatibility assessment examines the total cost of ownership including initial investment, integration costs, operating expenses, and expected return on investment. This analysis considers both direct costs such as hardware and installation expenses, and indirect costs including training, maintenance, and potential production disruptions during implementation.

Testing and validation procedures ensure that interface implementations meet MODAPTO specifications and provide reliable operation under actual manufacturing conditions. These procedures include bench testing of individual interfaces, system-level integration testing, and long-term reliability validation under production conditions. Comprehensive testing reduces implementation risks and ensures that reconfiguration activities can be completed with minimal disruption to ongoing production operations.

References

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