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

9.2.2 Tools for integrating sustainability KPIs in virtual commissioning

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The integration of sustainability Key Performance Indicators (KPIs) into virtual commissioning represents a sophisticated fusion of environmental assessment with production system design. This integration is facilitated by a comprehensive suite of tools and standards that enable seamless incorporation of sustainability metrics throughout the virtual commissioning process.

The Functional Mock-up Interface (FMI) standard serves as the cornerstone for sustainability integration in the MODAPTO framework., FMI is becoming an important building block in the efficient creation of interdisciplinary, multi-level digital twins of our entire portfolio – from rail and gas turbine engineering to virtual commissioning in the process industry and operational support in manufacturing plants.

FMI provides a standardized way to package simulation models as Functional Mock-up Units (FMUs), which can be easily shared and integrated across different simulation platforms. This standardization is crucial for sustainability assessment, as it allows specialized energy and emission models to be developed once and reused across multiple projects and platforms.

The development of sustainability-focused FMUs follows a rigorous methodology within the MODAPTO framework. These FMUs encapsulate complex mathematical models that calculate energy consumption based on detailed equipment specifications and operational parameters. For robotic systems, this includes kinematic models that consider not just position and velocity but also acceleration, deceleration, and the forces required to move payloads. The models account for regenerative braking in modern servo drives, standby power consumption, and the efficiency curves of motors and drives across their operational range.

The Sustainability Analytics Service within MODAPTO provides a comprehensive platform for managing and deploying these sustainability models. This service interfaces with the FA³ST Service software, which implements the Asset Administration Shell (AAS) standard for Industry 4.0. Through this integration, sustainability data becomes part of the digital twin's information model, accessible through standardized interfaces and queryable using semantic technologies. This architectural approach ensures that sustainability information is not siloed but integrated into the broader digital manufacturing ecosystem.

The RF::SUITE provides specific tools for sustainability data collection and analysis. The RF::Recorder v2 captures comprehensive operational data at high temporal resolution – up to 17,000 signals at 20-millisecond intervals. This granular data forms the foundation for accurate sustainability modelling. The recorded data includes not just energy consumption but also process parameters that affect efficiency, such as acceleration profiles, Machine learning algorithms can analyze this data to identify patterns and opportunities for improvement that might not be apparent through traditional analysis.

The visualization tools for sustainability KPIs transform complex data into actionable insights. Interactive dashboards display real-time energy consumption, carbon emissions, and resource utilization during virtual commissioning simulations. Heat maps overlay sustainability metrics onto 3D models of production systems, making it immediately apparent which equipment or processes contribute most to environmental impact. Trend analysis tools show how sustainability metrics evolve throughout production cycles, revealing opportunities for optimization that might only become apparent over extended operation.