Software Defined Machines (SDM)

Summary

Software Defined Machines (SDM) is Energy Internet Corporation's (EIC) underlying technology that help customers harvest value from inexpensive, commodity hardware by sophisticated group-intelligent behavior.

SDM dynamically configures Hydro-Pneumatic (HP) and Electric Circuits of varying complexity. HP Circuits are standard hardware blocks that use Liquid Pump Heat Engine[1] (LPHE) as its basic building blocks. The Electrical Circuits are also standard hardware blocks consisting of commercially available components such as, batteries, rectifier/inverters and switches. SDM enables:

- Use of common HP segments, for different functions, such as, energy generation, energy storage, desalination, and liquefaction of gases.
- Integration with industry standard control interfaces such as, Open Platform for Communication (OPC).
- Use of standardized interfaces to connect with grids and third-party management systems, such as, data centers, utility, renewable generating plants, and gas liquefaction plants.

SDM helps realize large reductions in costs and schedule, from avoidance of bespoke design, procurement and construction. Customers also benefit from an intelligent system that improves operational performance and availability through continuous improvement enabled by data analysis and machine learning across all deployed systems.

Introduction to SDM

Industrial designs, specifically designs for large industrial plants in the energy industry, tend to be semi-fixed during operational phase. The goal of SDM is to bring the benefits of distributed learning, optimizing and self-healing systems to energy system design and operation.

SDM enables the software defined operation of elements in an energy system to allow it to perform different functions. SDM's capability stems from its software control plane that abstracts physical implementations by modeling them in predictive, decision and analytic software.

SDM Layers

SDM is a multi-layered architecture allowing increasingly complex systems to be built from

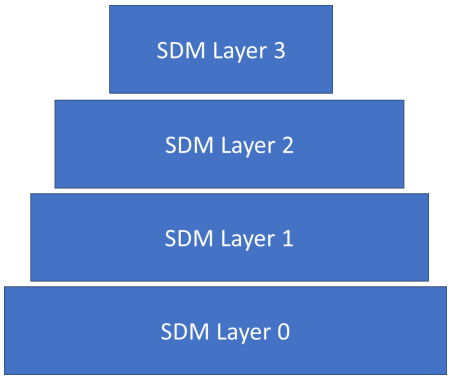

Figure 1: SDM Tiered Model

[1] (LPHEs are hardware systems performing thermodynamic exchanges of energy between a liquid and a gas in pressure vessels).

each successive layer. Each SDM layer builds on the previous layer as shown in Figure 1. In this regard, SDM is analogous to the Processor Instruction Set Architecture (ISA) which forms the basis for arbitrarily complex software using ISA in layers. (true for many other architectures – the internet backbone, mobile applications, social networks, etc.).

Every progressive subsystem, aggregated from described components, in a specified Topology, or Rules of Construction, is itself described functionally by the SDM algebra. Each layer has its own ontology – a set of models that describe operations in the layer, and the relevant interfaces and systems. SDM in operation is a self-learning (Machine Learning) system that utilizes telemetry data collected to optimize system operation over time as illustrated in Figure 2.

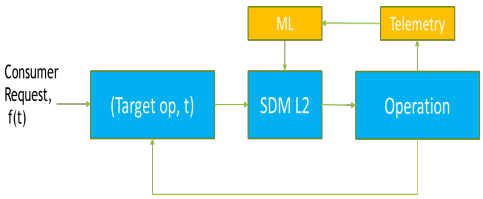

Figure 2: SDM Self Optimization Loop

Composability

SDM allows industrial designs to break from single role solutions. SDM provides the flexibility for the same building blocks of standard hardware to be used for different purposes. This allows standard hardware to be utilized differently between sites and over time to meet varying goals.

Digital Twin

Industrial systems cannot be subject to what-if analysis in production for a number of scenarios such as mission criticality of their function, safety concerns, and environmental issues. Traditional software simulations are limited by being based on a fixed set of data. A Digital Twin is a simulation that operates using real-time data gathered from its real-world counterpart.

Since SDM abstracts the hardware into sensors and actuators and is able to collect telemetry from these entities, the same SDM principles can be used to create a Digital Twin. By continuously feeding real-world data to the SDM simulation, we can replicate any installation in a virtual environment for the purpose of predictive analysis, problem solving and root cause analysis, as well as optimization.

Figure 3: Digital Twin using SDM

Digital Twin using SDM is illustrated in Figure 3.

Conclusions

The SDM concept - using software to dynamically configure standardized hardware building blocks to perform different functions- is central to EIC architecture. EIC solutions utilize commercial off-the-shelf hardware to deliver complex, scale-agnostic solutions, ranging from energy storage, energy generation, composable power, gas liquefaction and water desalination.