Digital Transformation Through Integrated Process and Power

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# Table of Contents

Introduction ...................................................................................................................... 3  
Value Driver 1: Integrated Asset Data Intelligence ............................................................... 4  
Value Driver 2: Power System Optimization ........................................................................ 6  
Value Driver 3: Unified Simulation .................................................................................... 7  
Value Driver 4: Single Project Execution - Main Automation and Electrical Partner ...... 9  
Value Driver 5: Power and Process Systems Integration .................................................. 10  
Value Driver 6: Integrated Asset Management .................................................................. 11  
Value Driver 7: Process Energy Optimization ................................................................... 13  
Conclusion .................................................................................................................... 14
Traditionally, process control/automation and electrical power management have been designed and operated independently throughout the lifecycle of a plant. The historical development of these two domains is understandable: Process control has longer response times (lasting seconds or more), is continuous, and based on a prescribed control strategy for a defined process and plant configuration. In contrast, electrical automation is generally asynchronous, event-driven, and occurring in the millisecond (ms) time frame. However, an obvious interaction between electrical equipment and process control is seen in generators, pumps, compressors, fans, valve equipment, and process heating equipment.

The confluence of technology development and the constant pressure to reduce CAPEX and OPEX is driving an initiative to rethink the separation between process automation and power management. There is strong evidence that integrating these two domains throughout the lifecycle of a plant, commencing at the plant design phase to the operational phase, will offer dramatic benefits. This paper sets out seven points of integration between process automation and power management, referred to herein as “value drivers” and based on examples from the EcoStruxure Power and Process approach by Schneider Electric. These value drivers include the following seven strategies which span the lifecycle of the plant asset, from initial design through commissioning and start-up and into operation.

Seven value drivers from integrated power and process:
1. Integrated asset data intelligence
2. Power system optimization
3. Unified simulation
4. Single project execution
5. Power and process systems integration
6. Integrated asset management
7. Process energy optimization

This paper also describes what it means to integrate the historically separate domains of process automation and electrical management, with due regard for the sometimes-differing mindsets and cultures between the two. Each value driver is described in terms of five principal attributes:

- The “Connection” between these two domains
- The gaps or “Challenges” that exists in the absence of integration
- A description of how the two domains relate and are brought together
- An outline of the “Solution” – how the two domains could be implemented
- The business value – “Benefits” – to be realized through an integrated approach

Figure 1 below depicts the seven value drivers in terms of the life of the plant asset, from initial conceptual design and FEED studies, through commissioning and ongoing operations, while Figure 2 shows a typical power and process infrastructure in a refinery.
The landscape of all seven value drivers is brought together through Digital Transformation, which leverages connected devices, i.e., the Industrial Internet of Things (IIoT). Digital Transformation can extend the life of the asset and reduce both CAPEX and OPEX significantly. A single view of asset management, energy management, automation - both power and process - and safety monitoring systems is enabled through IIoT. Remote/centralized monitoring and analysis of process information can allow real-time decisions through cloud-based solutions. Knowledge from various plant teams is no longer siloed or inaccessible, thus creating insights through the Digital Transformation.

Digital Transformation links connected products, such as field devices, and edge control systems to apps and analytic services which must be robust and secure. Interoperability and data analytics can deliver value across the entire enterprise supply chain, but security and reliability are foundational to connected products and edge controls. The two fundamental capabilities must be inherent throughout the digitization platform to support applications that reduce cost and optimize production.

One of the value drivers with the highest priority for Digital Transformation discussed in this paper is prescriptive analytics for asset management. Prescriptive analytics is model-based and often uses machine learning algorithms which learn from historical and real-time data, recognizing patterns that can enable detection of anomalous conditions in equipment or processes, and recommend next steps. Machine learning or Artificial Intelligence (AI) monitors plant behavior from both the process and electrical systems supporting continuous operation, locally and remotely.

**Figure 2**

Typical plant power and process infrastructure in a refinery. The two historically separate functions of process control and power management can be integrated to reduce CAPEX, OPEX, risk, and increase performance across the lifecycle of an asset.

**Value Driver 1**  
Integrated Asset Data Intelligence

**Connection**: The Integration of Asset Data Intelligence includes both the power and process of the plant from early design of the digital twin into a Unified Simulation Platform.

**Challenge**: Traditionally, models of the plant were developed during the design phase but not maintained through the lifecycle of the plant as the physical plant configuration was modified. EPCs (Engineering, Procurement, and Construction) worked with a comprehensive virtual 3D model of the plant, but the development of any models that were created during design often stopped being matured at construction. This resulted in gaps in understanding the plant asset, limited operator training, and reduced engineering efficiency. Disconnects existed between process design and 3D engineering as parties worked in silos. Iteration loops between design groups were not synchronized, resulting in duplicate work practices. Process automation and electrical power management often worked independently with separate personnel, databases, and work methodology. Altogether, these gaps resulted in mistakes, rework, delays, and cost overruns.
Description: Integrated Asset Data Intelligence is a single data intelligence infrastructure for both manufacturing processes and electrical distribution and equipment. This value driver provides customizable, multi-discipline 3D design tools to aid in the construction of process plants, as depicted in Figure 3. This solution creates a digital twin of the plant – a three-dimensional model of the physical plant equipment and associated process that can be utilized throughout the business lifecycle of a plant asset for design, training, maintenance, expansion, etc. The digital twin matures through stages of FEED studies, detailed design, construction, and optimization.

A helpful example is a variable speed drive. Traditional specifications for a drive might include dimensions, heat loss, instruction manuals, and terminations. The digital twin includes this information and a 3D model of the drive along with details like standard configurations. In the future, the digital twin of this equipment item will support simulation capabilities, such as embedding function blocks for process simulations, power utilization data for electrical system simulation, and more.

Solution: The digital twin incorporates the whole of the plant asset, including process and electrical distribution equipment. The digital twin also serves as a foundation that can be expanded to include dynamic simulation, augmented reality (AR), virtual reality (VR), and cloud computing. Embodied in the digital twin, the Integrated Asset Data Intelligence solution is built on a single database that is maintained in real-time. Changes in properties of assets propagate automatically, reducing human error and improving efficiency. This foundational technology will support a seamless evolution into a Unified Simulation Platform described in value driver 3.

Benefits: Building and maintaining a digital twin has profound and sustainable benefits, particularly at the intersection of process automation and power management of the plant. Engineering efficiency is realized, and construction costs are reduced through the use of a current, high-fidelity 3D model of the plant that includes process and electrical distribution equipment. The generation of project documents (e.g., P&IDs, process flow diagrams, load lists, dimensional layouts) can be automated, improving the change management process and reducing design errors. This increases overall plant safety and reliability.
Connection: There is a strong interdependence between the domains of process automation and electrical power systems management. Additionally, plant power requirements are determined mainly by the demands of process equipment.

Challenge: According to William Vukovich, Patrick Christensen, and Thomas Yeung (AICHE 2015, HydrocarbonProcessing), between 2009 and 2013 there were 2,200 unplanned shutdowns in U.S. refineries alone, and 21% of these process disruptions were caused by electrical power system failures. Uncertainties in process electrical demand encourage the design of excess power system supply and distribution, increasing CAPEX in construction and OPEX during plant operation.

Description: Power system optimization enables the design of power supply and distribution equipment that matches expected plant power demands, ensuring that the power system is not over designed. This is accomplished through early engagement with Schneider Electric energy management experts and through the aid of process and electrical simulation modeling tools.

Solution: A significant source of project cost can be the power generation and electrical distribution equipment. Given that the power generation facilities can cost four to five times that of the electrical distribution equipment, optimizing generation requirements is critical to the financial performance of the overall project. For example, the capacities of the power generation equipment, including gas turbines and motor-generator sets, are often integrated in a large facility; therefore, minimizing the physical footprint of generation equipment affects the surrounding facilities. The space requirements for power generation and electrical distribution equipment may be reduced through power system optimization, which is important where space is a premium, such as within a prefabricated modular power building (E-House), on an offshore platform, or on an FPSO facility. Likewise, where an E-House is used, the control equipment for both power and process may be co-located, and these too are subject to being optimized.

To have the most significant benefit and impact, this work should be done early with the EPC firm and owner/operator of the facility. Early engagement has the obvious advantage of affecting the scope and size of the power system while tuning the whole system. By modeling the power requirements, tradeoff decisions can be optimized, such as generating or taking power from the grid or managing loads differently. In turn, these options impact the size and layout of power generation and electrical distribution equipment, such as transformers, switchgear, bus bars, etc. Some of the standard elements within the power system model that are impacted by the power system optimization project include the following:

- Transformers - including tap changing
- Induction motors
- Generators - interchangeable automatic voltage regulator
- Breakers with built-in protection logic

As depicted in Figure 4, the design process results in an optimized MV/LV architecture that provides sufficient equipment and feeder capacities, such that systems are integrated and ready to install when required by the project schedule.
Benefits: Upstream, midstream, and downstream assets are large energy (electricity and steam) consumers. Matching power consumption with more efficient power systems enables savings in CAPEX and OPEX, including maintenance of facilities. Some specific examples of benefits include:

- Reduced CAPEX by up to 20% of electrical infrastructure
- Faster project design, start-up, and commissioning
- Improved efficiency of the plant’s operations, reducing OPEX

By applying an integrated power and process architecture early in the plant lifecycle, operating companies can determine the power system requirement and footprint for an E-House, for instance, that will meet process power demands safely and cost-effectively. CAPEX is reduced as the design reflects only the power requirements necessary to satisfy process requirements and safety margins. Supporting this point, Figure 5 compares the initial cost and sustainability of the electrical infrastructure for a typical offshore project before and after optimization, showing a significant reduction in four major areas.

Figure 5
Chart of typical cost savings of 20% by optimizing the electrical infrastructure of an offshore platform.

Value Driver 3
Unified Simulation

Once developed, the 3D model combined with a Unified Simulation becomes a living digital twin that is applied through the asset lifecycle.

Connection: Building on the digital twin in value driver 1, Unified Simulation models both power and process conditions. The digital backbone is a crucial component to unify the simulation platform. This provides a dynamic model that is applied throughout the lifecycle of the plant. The 3D model combined with a Unified Simulation becomes a “living” digital twin, possessing both specification and performance likeness.

Description: The Unified Simulation of the plant is used for engineering and commissioning, operator training, and real-time optimization. The model becomes a vital digital asset, an essential tool in the life of the facility. The “living” digital twin possesses reliable predictive capabilities over a wide range of design and operating parameters. Once developed, the Unified Simulation is applied and upgraded as necessary, without having to recreate the models.
**Challenge:** Typically, dynamic simulations include only chemical and physical processes, not electrical system responses. And, where dynamic models have been developed, they are not integrated with the 3D design models which were developed initially during plant design. This value driver establishes a step-change in the evolution of the digital twin by including both process and power in the unified simulation. This concept embodies the design of the plant and is able to simulate responses to changes in process conditions and directives. Therefore, value is created from the integration of three principal domains that have historically been distinct:

- 3D designs of the process equipment
- Fundamental physics and chemistry of the process
- Electrical system infrastructure, including distribution and equipment

**Solution:** Unified Simulation enables dynamic studies of startup and shutdown, control scheme design, controls checkout, operator training, and real-time optimization. The rigorous dynamic can be integrated with the 3D models described in value driver 1 to animate the 3D digital twin with the fundamental physics and chemistry of the process. The dynamic simulation starts in the conceptual design phase, which provides a macro view of the design options. As the details of the simulation develop in the front-end engineering and design (FEED) stage, the dynamic model expands to include standard general asset intelligence for the plant with an auto-generated common engineering database that includes power and process equipment. During the detailed design phase, the simulation platform uses the engineering database to streamline work while enabling continuous testing of the power and process design. The power and process system logic is integrated into the model – now a digital twin of the plant. Engineering design becomes more agile as changes to the model are made and tested. Start-up and commissioning will take advantage of the digital twin to deploy operator training without the need to rebuild models for a separate operator training simulator (OTS), saving time and money. As described, the digital twin embodies an asset and can evolve to reflect the same power system and process control logic as in the corresponding plant systems.

**Benefits:** The model created during plant design is leveraged during plant operations as one unified platform, eliminating rework such as rebuilding models. The Unified Simulation Platform and digital twin serve to train operators, evaluate unit performance against the model, and provide real-time optimization, enabling energy efficiency and process improvements. As depicted in Figure 6, the digital twin that is empowered by a rigorous dynamic model delivers value throughout the lifecycle of the plant, reducing CAPEX during the design phases and OPEX during operations while increasing safety. Process reliability and energy efficiency increase while risk is reduced using model-based decisions.

**Figure 6**
Lowering CAPEX and OPEX across the lifecycle of an asset with unified simulation model.
Connection: The role of the Main Automation Contractor (MAC) emerged in the early 2000s. While effective, the MAC and Main Electrical Contractor (MEC) were still two distinct roles with separate responsibilities. Reflecting the integration of power and process automation, the Main Automation and Electrical Partner (MAEP) would be responsible for both process automation and electrical distribution equipment, including the electrical management control system (EMCS).

Description: The MAEP works closely with the EPC firm in the design phase around a broader scope of the project. This new role consolidates scope under the MAEP, thereby enabling better coordination and integration of systems and reducing project risk, especially during plant commissioning. This new approach simplifies the process from early design to project management for the EPC and owner.

Challenge: Historically, these two contrasting roles were separate, as were the methods that guided their design and construction work, introducing added expense and additional time to project completion.

Solution: Schneider Electric uses the Flexible Lean Execution Services (FLEX) approach to deliver projects, an innovative concept from design to construction. As illustrated in Figure 7, FLEX includes the ability to continuously test the system throughout the design stages through virtualization in a cloud environment. The combination of methodology and technology has the potential to reduce changes substantially and minimize risk to the critical path, reducing time to operations. A prime example of the MAEP is the E-House, which combines power and automation in a single, modular building. The E-House, as depicted in Figure 8, is also referred to as a local equipment room (LER), power control room (PCR), or remote instrument enclosure (RIE).

The integrated automation and electrical E-House can be designed and constructed at the MAEP facilities, with integrated testing completed before it is shipped to the site.

The MAEP program leverages the technologies and methodologies set out herein, including value drivers 1, 2, and 3. This approach builds on the power of the digital twin to plan, design, and optimize the process and electrical infrastructure. Critical project documents such as P&IDs and electrical diagrams are automatically updated and generated on demand, reducing engineering hours and changes up to 25%. The time and resources for testing, commissioning, and validation are likewise reduced. Moreover, the whole project is supported by comprehensive project management tools.

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<th>Value Driver 4</th>
<th>Single Project Execution - Main Automation and Electrical Partner</th>
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**Figure 7**

Stages of the FLEX project execution methodology and supporting technology by Schneider Electric.
Benefits: As a result of implementing the methods described in this paper, the MAEP assumes and mitigates those sources of risk that would otherwise be borne by the EPC and owner. Having the planning, design, and commissioning overseen by a single project management office, under the auspices of the MAEP, serves to reduce surprises in the project schedule further. Uncertainties are reduced as process conditions, process automation systems, and the supporting power distribution facilities are aligned and optimized by the MAEP using the tools and methods described herein. As a result, the MAEP approach will typically reduce related CAPEX and schedule by up to 30%.

Connection: The integration of power and process systems combines the capabilities of the Distributed Control System (DCS), Safety Instrumented System (SIS), and the Electrical Management Control System (EMCS) in a unified control architecture.

Description: The integration of process control systems and electrical power management systems includes a unification and rationalization of DCS, EMCS, networks, controllers, alarms, historians, and Intelligent Electronic Devices (IEDs).

Challenge: With separate DCS and EMCS, engineers and process operators have less visibility into the status of electrical systems, and the impact of power systems on process units. The two separate systems introduce unnecessary redundancy in control and monitoring infrastructure. For example, an integrated system can advise the operator before starting a process of a condition that may compromise the electrical distribution network. Another challenge is an inability to obtain quick diagnostics on process disruptions caused by electrical and mechanical systems and equipment. Separate systems introduce greater complexity in the form of multiple databases, additional engineering tools, separate operator stations, hardwiring, and network components.

Some of the consequential challenges presented with separate process and power systems include the following:

- Obscures cybersecurity threat detection and reporting
- Produces redundant engineering work and extended commissioning
- Impedes traceability of events and discovery of causes in incidents
- Increases infrastructure cost and delays deployment
- Introduces complexity and multiple system interfaces
- Limits maintenance priorities and preventive maintenance
- Reduces flexibility to reconfigure as the plant scales up

Solution: Schneider Electric is one of the few control system suppliers that can deliver an integrated control platform spanning both power and process. Figure 9 depicts such an integrated control platform, showing a distributed controller communicating with an intelligent motor control center via Modbus TCP and electrical switchgear via IEC 61850.
To avoid unplanned power disruptions, an integrated system provides the control room operators with full visibility of how the intelligent Fast Load Shedding (iFLS) Electrical Management Control System will impact the process and enable process operations to account for the real-time status of the electrical system.

**Benefits:** The reduced cabinet space and cabling created by an integrated control architecture is essential in many installations, particularly facilities with limited space constraints like offshore platforms and FPSO facilities. Redundant field control stations, gateways, and servers can also be rationalized. The time required for commissioning and troubleshooting is likewise reduced. Improvements in operations and maintenance efficiency will be realized through faster and greater insights between the process and electrical systems. Ultimately, the time required to diagnose and troubleshoot the motor control center will be reduced.

**Connection:** Integrated asset management applies to all plant equipment, including process automation, power generation, and electrical distribution alike.

**Description:** Asset Management is about diagnostic monitoring and maintenance of plant assets including electrical supply/distribution, process equipment, turbomachinery, and the automation infrastructure that monitors and controls these assets. Asset performance management collects data about how equipment is performing and provides the tools and applications that enable how to predict the best use of assets to achieve operational goals at minimum cost.

Complementing traditional asset management applications, the Industrial Internet of Things (IIoT) enables the use of real-time, condition-based monitoring, diagnostics, reporting, performance monitoring, and prescriptive maintenance. This goes beyond predictive analytics to prescribe recommended next steps for maintenance. Analytics and machine learning applications, as referenced in Figure 10, can take advantage of the large body of asset data that is collected and organized on private or commercial cloud services, such as Amazon Web Services or Microsoft Azure. A remote service bureau, such as available with the EcoStruxure Power and Process service offering, applies these tools to increase equipment and plant reliability and make recommendations for prescriptive maintenance.

The following capabilities are core to materials management and optimization. These have traditionally been associated with enterprise asset management (EAM) or computerized maintenance management systems (CMMS) applications:
• Maintenance, repair, and operations (MRO) materials management and optimization
• Data capture and analytics most often characterized as condition-based maintenance (CBM), reliability-centered maintenance (RCM), and predictive (or prescriptive) maintenance
• Specialized functionality such as vibration analysis for rotating machinery, thermography, corrosion monitoring, or other advanced predictive technologies
• Remote diagnostics of systems performance and software version upgrade recommendation

**Challenge:** Traditionally, the processes and tools for asset management have been applied independently and used different asset management systems, which meant that data was maintained in different databases and locations. An integrated approach that encompasses both process and power provides an asset-centric view of operations, enabling maintenance teams to collaborate where potential disruptions involve multiple equipment types.

**Solution:** The application of an integrated asset management system is proven and well understood, including the following work processes:

• Maintenance - improve the planning and scheduling of maintenance activities
• Approvals - streamline operations with flexible and automated workflow approvals
• Inventory - forecast inventory usage and automate the reorder process
• Procurement - improve insight to manage MRO inventory and ensure timely availability

Advanced cloud-based analytics and remote services enhance these traditional functions in a way that creates new insights in the cause-and-effect relationships between equipment conditions and failure modes. Data is integrated within a single platform where it can be leveraged by data analytics and machine learning technologies to distill important relationships that would otherwise be overlooked. Cloud-based condition monitoring and predictive analytics can include insight from equipment across multiple systems and disciplines, including electrical distribution, process equipment, turbomachinery, and automation infrastructure.

**Benefits:** According to the ARC Advisory Group, “The global process industry loses about $20 billion annually, or five percent of annual production, with an average hourly cost of about $12,500.” This benchmark is a good indicator of the savings from an integrated asset management capability and is easily supported when the broad sources of value from integrated asset management are considered, including:

• Improved environmental, health, and safety work practices
• Increased production uptime and return on assets
• Extended equipment life and availability
• Streamlined procurement processes
• Increased labor productivity

Integrant power and process provides an asset-centric view of operations, enabling maintenance teams to collaborate.
Connection: Energy consumption at a major industrial facility includes electrical, gas or fuel, and steam power, all of which are significant operational expenses, second only to raw materials. Therefore, energy must be managed across the asset.

Description: The fundamental physics and chemistry of the process mean that there are relationships between electrical, gas, steam, and chilled water. Process energy optimization is about managing the tradeoffs between these energy types throughout the processes to minimize cost and the carbon footprint of the plant.

Challenge: Operational decisions are often based on periodic views of materials and energy, maintenance and reliability reports, and environmental events, not on a real-time basis. Moreover, power is managed separately from other sources of energy being supplied to the process and facility; however, according to a study of German industry by Tallal Javied and others published in 2016, electric motors typically account for 70% of electrical consumption in a plant. And, operators have limited visibility and accountability in decisions that impact energy cost, material cost, and product value. This gap is addressed through an integrated process energy optimization solution that monitors and optimizes the major forms of energy usage.

Solution: With improved efficiencies and profitability as the overarching objective, the effective energy optimization solution is built on three technologies (Figure 11):

- A Big Data analytical engine that takes process and energy data from the historian, then applies analytics to gain insight into the process.

- A mathematical model predicts the optimum mix of electricity, gas or fuel, and steam usage that minimizes cost per unit of production. The model includes the efficiencies of each major piece of equipment, such as steam turbines, and prescribes the order in which these pieces of equipment should let down steam, for instance. A model-based approach enables plant-wide optimization of energy that is not achievable through more conventional control methods. The model typically uses multivariate predictive control (MPC) or another form of advanced process control (APC) and real-time optimization (RTO) that accounts for the simultaneous interaction of multiple inputs and outputs.
A real-time accounting model extracts process and energy data from the plant historian and measures the financial performance of an industrial operation in real time. The real-time accounting model incorporates data from the equipment asset level of a plant up to the process unit, plant area, plant site, and enterprise levels. The results are presented in dashboards and charts such that operators see how their decisions can make significant improvements to profitability.

The supply of power is also critical, especially for optimization of energy-intensive processes. As discussed in value driver 2, this consultative solution includes a determination of power supply for the facility, starting in the design phase. In the case of a brownfield plant, the assessment evaluates power from the grid vs. local power generation arbitration, monitoring consumption, submetering by activity, and processes.

**Benefits:** Operators are presented with real-time information on energy economics, instilling accountability in operations. Optimized energy management increases process efficiency by reducing the total cost of energy per unit of output (e.g., balancing demands for electricity, gas, and steam consumption). The tradeoff between energy sources is optimized and stakeholders throughout the organization are provided timely information on the cost of energy and the impact on profits due to changes in operating conditions. Plant reliability and profitability increase as the process and equipment are aligned and optimized for energy consumption.

**Conclusion**

This paper presents a vision of convergence between what have historically been separate or loosely integrated domains: process control and electrical power management. Converging these two spaces reduces complexity and system components while making project execution more manageable with a common platform for collaboration between those responsible for process and power. The value of integration is not limited to commissioning or plant operations. As shown in Figure 12, value is generated in the initial FEED studies where an integrated approach can have its most profound, long-term financial effect on the asset. Therefore, value is realized throughout the lifecycle of the asset when all seven value drivers are applied and used together, increasing savings in both CAPEX and OPEX throughout the plant lifecycle.
All seven value drivers summarized above and detailed herein are achieved through a combination of different technologies and engineering disciplines; however, perhaps the most significant single hurdle in realizing the vision of Digital Transformation is not technical, but organizational and cultural. Digital Transformation is as much about organization and business process changes as it is about technology. The technologies comprising the seven value drivers can be expected to catalyze organizational and process changes that bring together historically separate disciplines of process automation, power management, and others in ways that will enable the vision set out here to be realized. Business leadership will direct the journey toward Digital Transformation and the requisite organizational and cultural changes to achieve this vision, based on measured, sustainable value for shareholders, employees, and communities. To be effective, Digital Transformation must be a well-thought-out roadmap that is realized progressively through the application of fit-for-purpose technologies applied through a systematic project methodology, and all cast in a cohesive framework. This paper has described a vision for a dramatic step-change in the process enterprise, one that can serve as a guide for Digital Transformation.