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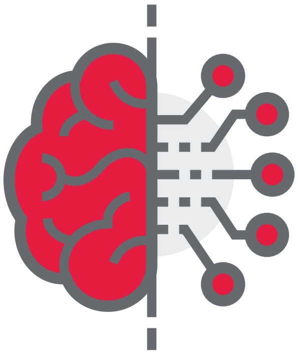
WHITEPAPER

DELIVERING BETTER DECISIONS, FASTER FOR PLANNING, SCHEDULING AND TRADING OF ENERGY

February 2019

All about EXCELLENCE



Introduction

Across organizations, decision-making should be about seeking to improve performance. The challenge is that decisions comprise of different layers of factors, all on different timescales, each with different levels of uncertainty and varying degrees of impact.

When any part of a decision-making process is not fully known, assumptions must be made. With assumptions comes increased levels of uncertainty of achieving the desired outcome. In many cases it is not possible to have absolute confidence about the behavior of all key variables, so decisions are forced to depend on the assumptions associated with them.

Digitalization is about automating workflows and reducing the degree of assumptions in decision-making, enabling more precise executions at all levels to provide higher assurance of delivering the desired outcome. Digitally-wise operators are benefitting from being more real-time, nimble and agile.

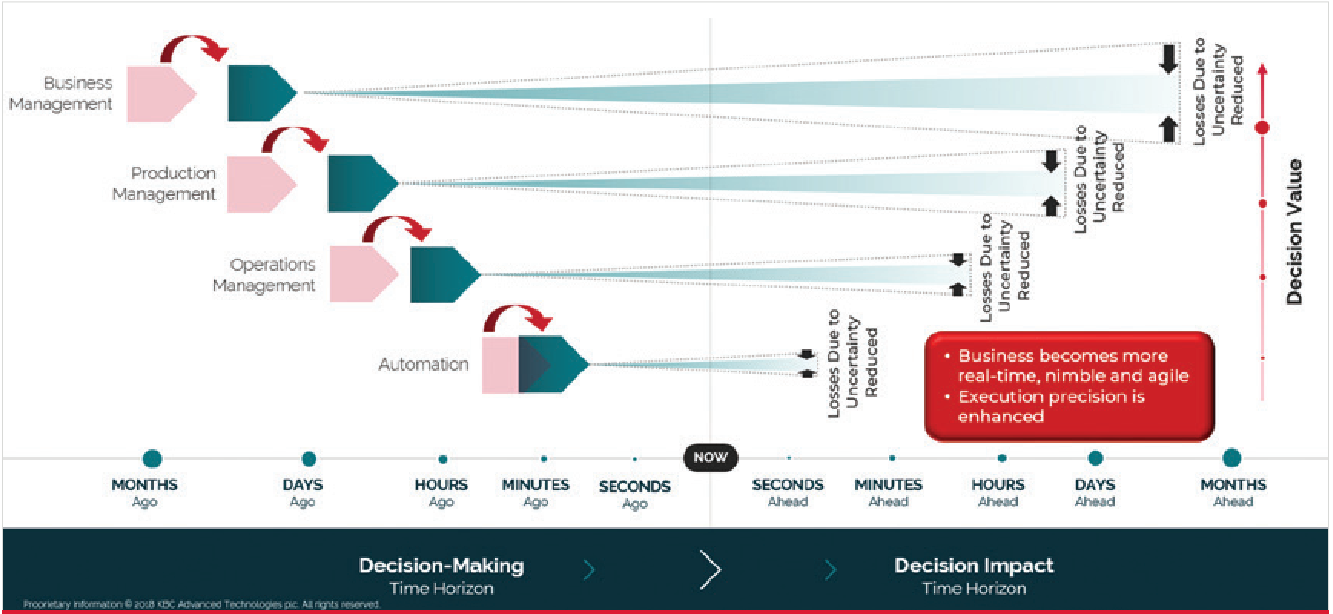


FIGURE 1: THE IMPACT OF DIGITALIZATION ON THE DECISION-MAKING PROCESS

KBC
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In the decision-making process, four key areas are being improved:

- Higher sufficiency and fidelity of data
- Deeper understanding of patterns and inter-relationships
- More effective dissemination of key information
- More action-oriented foresight

The first two areas ensure that the correct decisions are made in all circumstances.

The second two areas enable action to be taken faster and more consistently, to capture the value available.

Real-time optimization of energy systems has proven fairly effective to date, typically saving 2-5% of site energy costs.

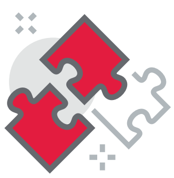
However, 'real-time' optimization is still at heart, reactive, and while it allows the correct response at a snapshot in time, it can be a challenge to accommodate time-sensitive constraints, or external volatility that varies faster than the agility of the asset itself. Factors such as changes in electricity price contracts (e.g. real-time pricing, time of use pricing, critical peak pricing), variability of natural gas prices, and the capability of process plants to become electricity providers to the grid while managing a wide variety of energy sources (fossil fuels, renewables, etc.) imposed unprecedented challenges to scheduling engineers aiming to deliver the most economic dispatch of energy to meet demand.

Visual MESA™ Multi-Period Optimizer (VM-MPO) reduces costly uncertainty in planning, scheduling and trading of energy over multiple time periods across portfolios of generation assets and different asset classes. It provides proactive look-ahead optimization by bringing together data analytics, first principles digital twins of energy systems and multi-period constraints in a purpose-built mixed integer optimization to continually ensure that the right decisions are made about which generation assets to start up, shut down and where to deploy energy at lowest economic cost. It allows scheduling engineers and operators to incorporate more precise forecasts into their decision-making processes, enabling more aggressive actions to achieve the optimum, thereby yielding incremental benefits.

VM-MPO constitutes a major upgrade of already proven technology that enhances the industry's leading real-time optimization technology, Visual MESA Energy Real-Time Optimizer (VM-ERTO) by adding an upper decision layer where the time-sensitive variables are optimally defined. VM-MPO benefits from enhanced connectivity between data sources, forecasting methods, model structure and multi-period constraint capabilities for solving at speed.

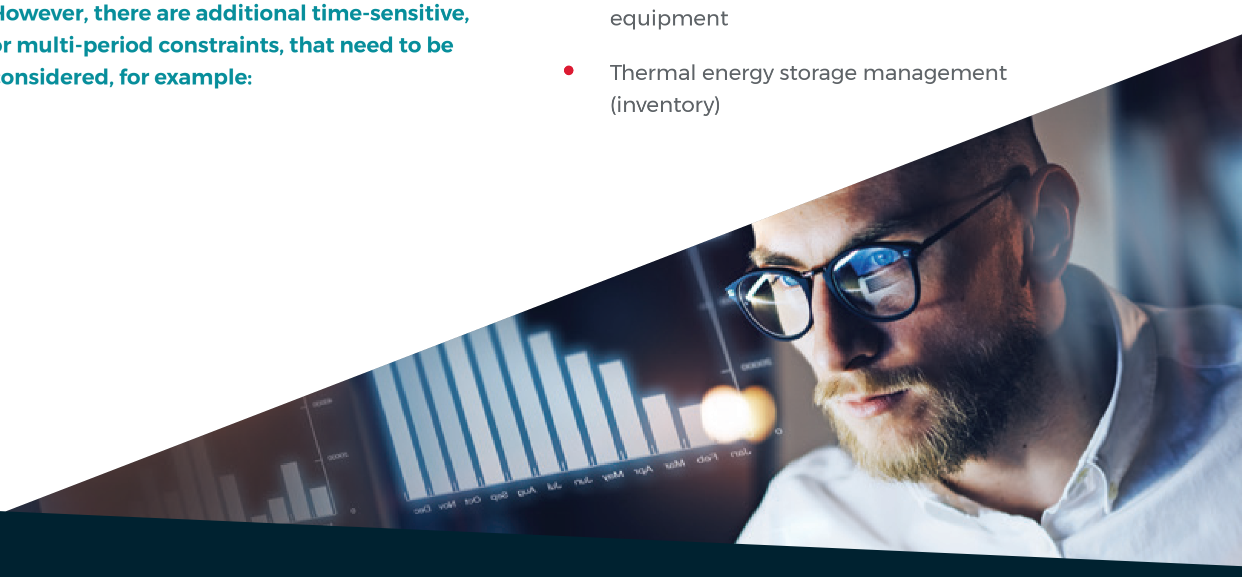
The technology links the data and the forecasts to the model, which is then optimized into beneficial actions. This ensures that decisions made now deliver the optimum performance based on variables in the present, as well as the future. For example, storing fuel to be used later in generating power when deregulated electricity prices rise.

Working at your best within your constraints



Thriving in any situation involves knowing the interrelationships and working within your constraints. Hard constraints in energy systems such as pump capacity, temperature limits and specifications are well understood and easy to incorporate in a multi-period optimization. However, there are additional time-sensitive, or multi-period constraints, that need to be considered, for example:

- Planned out-of-service periods
- Caps on emissions
- Fuel tank farms management (inventory)
- Minimum / maximum start / stop time of equipment
- Thermal energy storage management (inventory)



The multi-period constraints are typically classified into two categories, single unit and multi-unit; the difference being the level of complexity driven by the number of dependencies associated with each.

TABLE 1: EXAMPLES OF MULTI-PERIOD CONSTRAINTS

Category	Constraint Type	Description	Example
Single unit	On / Off	Forces a unit on or off at any time in the schedule	Gas turbine unavailable due to maintenance from 3pm to 5pm
	Minimum downtime	Ensures a unit is not turned back on unless a predefined resting time has passed	If a chiller was turned off, it should rest a given amount of time before the optimizer can recommend turning it on.
	Minimum uptime	Ensures a unit is not turned off unless it has operated a predefined amount of time	If a gas turbine was turned on, it should be up for a given amount of time before the optimizer can recommend turning it off.
	Minimum/ Maximum operation	Sets the minimum/maximum total time a unit should work	A piece of equipment with low efficiency will never be recommended to be on unless a minimum operation time constraint is set. This is important if this equipment is used as a backup and must operate some of the time to keep healthy.
Multi-unit	If A is ON B is OFF	Defines the on-off state of a unit based on the on-off state of another unit	Two twin boilers may be forced to be used one at a time.
	B starts after A	Ensures a unit starts after another unit starts plus a predefined delay	A steam turbine needing to start up after a boiler has started.
	A and B start simultaneously (but not end together)	Ensures a unit starts when another unit starts	Group of turbines may work simultaneously.

In addition to the above single and multi-unit constraints, businesses must always strive to maintain their "license to operate". To achieve this, VM-MPO accommodates inclusion of operational, safety, legal, environmental and contractual constraints, such as CO_2 emissions trading quotas, changes of loads, yield shifts and product qualities.

There is no limit to the number of constraints that can be accommodated for in VM-MPO.

Using the constraints, the VM-MPO model is built as a digital twin, representing the physical behavior of the system under different operating conditions. The use of first principles-based analytics tools for achieving situational awareness is important: first principles models respect the laws of nature, can handle non-linearities and complex relationships and they can significantly enrich data by inferring information that cannot be directly measured. Measured data is also used, with quick connections to a wide variety of data sources. VM-MPO then structures the data such that the interdependency of the variables through time can be identified and the optimization can solve at speed

With the data collected, constraints defined, system modelled then optimization recommendations that are grounded in reality can be generated.

Going beyond the horizon

Over time there has been an evolution in the level of accuracy of forecasting analytics in optimization problems:

- From assuming last month's performance will be repeated;
- To simple spreadsheet-based calculations;
- To statistical data analytics predictions with cause and effect;
- To a sophisticated ensemble which fuses statistical data analytics, high fidelity first principles digital twins of energy systems and multi-period constraints in a purpose-built, mixed integer optimization.

Consequently, there is a variety of energy management and analytics solutions available. Figure 2 illustrates the layers of analytics technology advancement with the key difference being the depth of action-oriented foresight associated with each.

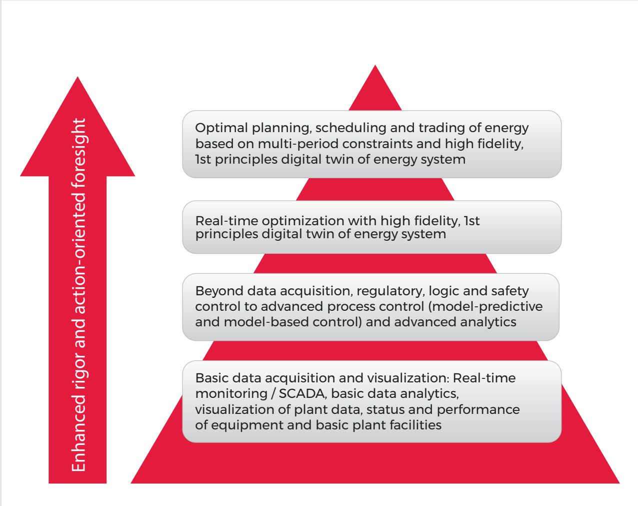


FIGURE 2: LAYERS OF FORECASTING ANALYTICAL RIGOR

Assuring your ability to execute decisions

Value is only ever captured when the right decision is made and there is effective follow-up on execution of resulting actions. However, in many cases action execution is what limits value capture.

Human factors and technology are equally important in realizing the value from digitalization solutions. Technology is supposed to support and empower the human; it is supposed to capture and enable the spread of human knowledge and experience. VM-MPO maximizes this to the fullest extent possible by providing tailored outputs and actions to operators - in open-loop mode – with clear descriptions of actions to be taken, time frames to execute the actions and quantification of benefits of action execution.

However, often site-wide actions are required by different organizations making it difficult to achieve coordinated execution. So, there is always the option to remove reliance on operators and organizational silos altogether by shifting to closed-loop optimization. This approach has been proven to be successful with sites that have improved computational capabilities, a culture that treats real-time data as an asset (so that data sources are available and reliable), and improvements in continual technical usability of the solutions.

VM-MPO is also available as part of KBC's Co-Pilot Program where connected experts can support and develop on-site capabilities to run, maintain and act on the model.

Case study – Oil Refinery

A 200,000 barrel per day refinery had already achieved good base layer control, based on VM-ERTO, which had been deployed for open-loop, real-time optimization of the site's energy system. Site management wanted to consider a more aggressive energy strategy and so the site's energy system was modelled using VM-MPO, including its main subsystems (steam, fuel, condensate and electricity).

There were three steam levels (600#, 150# and 40#), with the main power generators being multi-fuel boilers and two cogeneration units. The model incorporated four fuel types (coal, natural gas, fuel oil and fuel gas). Except for fuel gas, all other fuel types for the refinery were acquired externally at a corresponding cost. CO_2 and flue gas emissions were estimated at each burner.

The electricity system had two main producers, the cogeneration unit and the steam turbine generator. Depending on electricity demand and pricing in the neighboring area, the refinery's electricity system was prepared to purchase or sell electricity to the grid.

The refinery benefitted by allocating the boiler and cogeneration fuels and loads to minimize the total operating cost of the system while satisfying typical operating constraints for a 12-hour horizon.

With these different energy systems across the refinery, the only way to exploit maximum economic arbitrage was to consider the entire, site-wide energy system as a whole, with each subsystem and piece of equipment robustly represented in VM-MPO.

VM-MPO provided the necessary tools to model typical pieces of equipment for the steam, electricity, fuel and condensate subsystems, see Figure 3. In addition, as the refinery's energy system configuration could be upgraded over time, the high modelling flexibility in VM-MPO would enable easy changes to ensure the model remained accurate (e.g. temporary shutdown of a boiler unit or change in a fuel source).

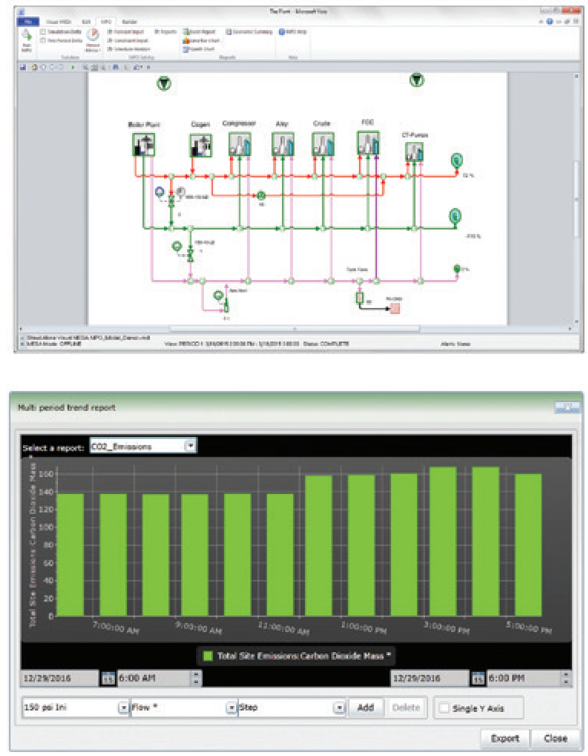


FIGURE 3: VM-MPO EXAMPLE MODEL AND REPORT

Case study – District Energy System

Houston-based Thermal Energy Corporation (TECO) has provided cooling and heating to institutions in the Texas Medical Center since 1969. TECO uses district energy and CHP technology to produce chilled water and steam, which it pipes underground to more than 19 million square feet of customer buildings at 18 institutions. TECO has used the Visual MESA suite to guide the optimal operation of the plant since 2010.

In the first stage of the implementation, VM-ERTO was used. The main goal was to provide the optimal load of chillers and boilers to minimize the total operating cost. Table 2 shows the $1.1 million per year savings that are expected when implementing the optimal recommendations from VM-ERTO.

TABLE 2: VM-ERTO EXPECTED SAVINGS

VM-ERTO expected savings			
	Current ($ per hr)	Optimal ($ per hr)	Savings ($ per hr)
Total	1592	1457	135

In the second stage of the Visual MESA Energy Management System (VM-EMS) implementation, the optimal operation of the thermal energy storage was included. The main objective was to identify how much chilled water should be stored or used at each time of the day in order to minimize the electric power that is consumed to generate it.

Selecting the required un-modeled data variables to be forecasted was dependent on the problem at hand. Engineering knowledge of TECO's system as well as experience on model limitations played an important role in the process.

Given that the main energy source of this system was electric power, predicting its day-ahead price was very important to clearly define the expected costs. To achieve this the VM-MPO application accessed day-ahead market electricity price forecasts for different hubs as well as real-time price information through the state of Texas electric grid operator, ERCOT (Electric Reliability Council of Texas).

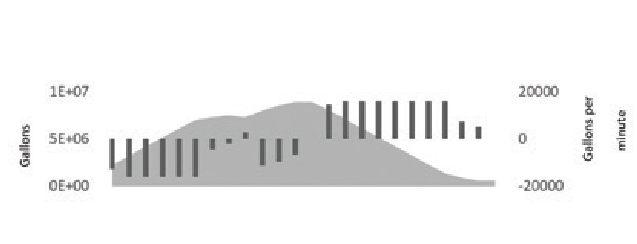


FIGURE 4: OPTIMAL TES OPERATION

In Figure 4, an illustration of the optimal operation is shown. Notice that the dark grey bars represent the charge/discharge of the TES, whereas the light grey area represents the TES accumulation of chilled water. Adding this extra layer in the decision-making process would increase the benefits by about $100,000/year representing approximately 10% of VM-ERTO savings.

Summary

VM-MPO brings together data, first principles and multi-period constraints in a purpose-built multi-period, mixed integer optimization to continually ensure that the right decisions are made about which generation assets to start up, shut down and where to deploy energy at lowest economic cost over the time horizon.

VM-MPO enhances the industry's leading real-time optimization technology, Visual Mesa Energy Real-Time Optimizer by adding an upper decision layer where the time-sensitive variables are optimally defined to be able to solve for multi-period constraints. VM-MPO forms an important part of an integrated optimal scheduling and real-time optimization offering for energy systems. It enables better decisions, faster for planning, scheduling and trading of energy.

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