Model-Centric Smart Grid: CBA ORU Case Study

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"How would a utility's smart grid investment decisions change if they had a detailed integrated network model, and if they could analyze that model leveraging any and all measurement data?"

Operating predominantly in the state of New York, Orange & Rockland Utilities is required by the Public Service Commission to provide a Cost Benefit Analysis (CBA) to justify any smart grid investments. Using a single **Integrated System Model (ISM)**, ORU is able to develop a layered investment approach that minimizes the need for expensive "new smart grid devices," while maximizing the use of existing assets. DOE has termed this approach *model-centric smart grid*, and EPRI has referred to it as *model-based grid modernization* (1).

Standard practice for utilities is to deploy different models that organize data to solve a particular problem. Examples are: GIS – mapping & asset information; OMS – outage tracking and crew management; SCADA/DMS – distribution primary device control; Engineering Analysis – system planning and operations support; TLM – transformer loading; CVR/volt/var optimization – voltage control; P&C – Protection & Coordination analysis; FLISR – automatic fault location, isolation and sectionalizing; and others. Significant capital and operating dollars are spent integrating these systems together so that data can be passed between them, and in massaging data quality among systems. In contrast, the **ISM** provides an environment in which the same model can be used to support many functions from planning to design to operation to control.

The model-centric CBA uses a layered or incremental approach to the cost benefit analysis, illustrated in Figure 1. For power engineers, phase balancing, capacitor design, feeder control and feeder automation are typical solutions that are deployed to meet power quality and reliability requirements. What model-centric CBA has unlocked is the additional value from implementing these solutions in an ordered fashion. That is, the results of the Phase Balance layer will affect decisions in the Capacitor Design layer, and the results of the Capacitor Design layer will in turn affect what happens in the Coordinated Control and Distribution Automation layers.

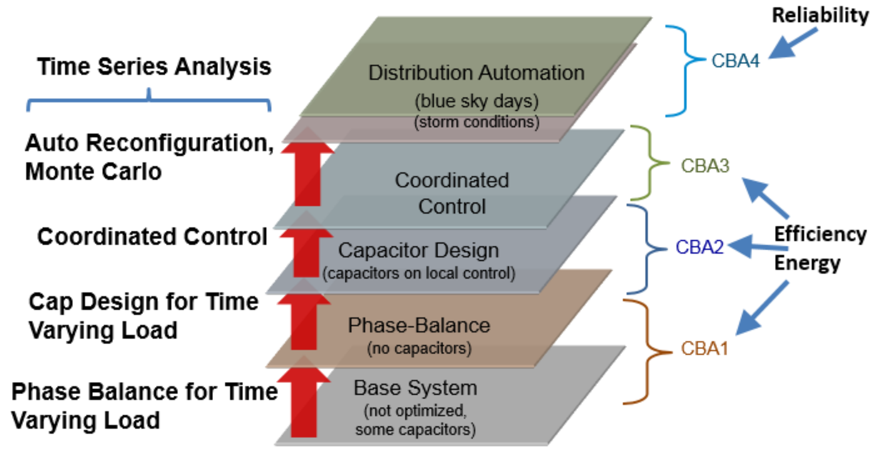

Figure 1 Dependency Ordering of Investment Evaluations, where decisions made in layer i depend upon decisions made in layer i-1
CBAi = Cost Benefit Analysis of layer i relative to layer i-1

Thus, the cost/benefit analysis performed here is structured as a series of economic questions that address the subject in stages or layers, rather than providing a single lump-sum cost/benefit evaluation for the overall project.

The first two investments, Phase Balance and Cap Design, are made without making large investments in typical smart grid equipment. The **ISM**, with all of the measurement data included, allows ORU to optimize the phase moves and capacitor sizing/ placement against the time varying load, which results in improved feeder efficiency and controllability. The cost of the Phase Balance is the crew time spent to make the phase moves. The benefits are improvements in feeder efficiency, reduction in energy to supply the load, and an increase in feeder capacity. The reduction in the energy supplied results from using a 1% voltage dependency factor for the loads. Figure 2 shows one particular feeder's validation results, where the SCADA phase measurements come together following the phase moves.

The cost of the Cap Design layer is the cost of purchasing and installing the capacitor banks. The new designs improved the time varying feeder voltage profiles, and enabled a reduction in the substation LTC voltage set point by two volts. ORU worked with the equipment supplier to develop a capacitor bank with individual phase control instead of the traditional 3-phase gang control. The field validation of Cap Design measured power factor improvement at the substations, where some individual substations improved from 93% to 98%. ORU's system efficiency has been 97.5% for two consecutive years.

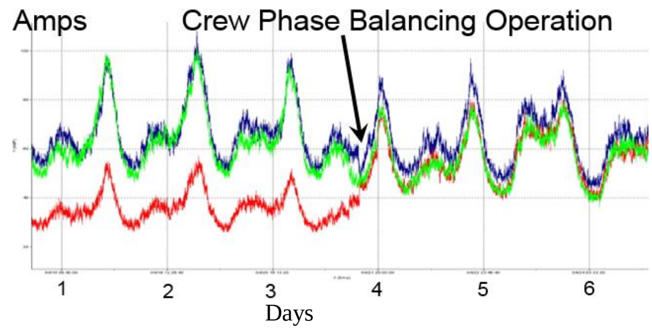

Figure 2 Phase balancing validation showing phase A (red), B (blue), C (green) currents closely tracking after the phase balancing operation by the field crew

A 14-feeder system was selected to pilot the Coordinated Control and Distribution Automation (**DA**) investments. To implement the Coordinated Control, communication and actuation devices were placed on the switched capacitor banks, voltage regulators, and LTCs. Coordinated Control and Distribution Automation calculations are performed on the **ISM** located in the Distribution Control Center. The **ISM** provides set points and control solutions to the automated control devices. To implement the DA layer, 63 automated switches were located to sectionalize about 250 customers for each switch. The automated switches are implemented with low cost devices that do not have software programming and software maintenance requirements. The **ISM** calculates the control solutions, which are sent to the devices through a secure SCADA interface. As the system is reconfigured or new equipment like DER's are added to the network, the **ISM** model manages the changing feeder topology and provides control solutions from the central control center without having to reprogram field devices.

To validate the Distribution Automation layer both "blue sky days" and storm conditions were considered. Monte Carlo simulations were performed using actual historical storm outage data gathered from six different types of storms over a ten-year period. The simulations for each type of storm were repeated 6,000 times using the Distribution Automation modeled in the **ISM**.

Figure 3 presents a summary of the ***Economic Performance*** of the 14 feeder pilot system, where the values shown in the table are present worth values for a 10-year period. Load growth and increases in cost of energy are taken into account. The hourly energy cost uses the Locational Marginal Price for the Hudson Valley, escalated with the price of gas as forecasted by the US Energy Information Administration.

The savings are divided into five categories – efficiency, customer energy reduction, reduced capital investments, operations, and customer interruptions (CI). For example, in the efficiency column for CBA2 the $227K represents the incremental savings that accrue just for the investment in the capacitors, and the $321K includes the savings from both phase balancing and capacitors. Consider the $Saved/$Invested column for CBA3. The $31.65 indicates that for the layer 3 investments there is $31.65

saved for every $1 invested, and the $5.74 indicates that there is $5.74 saved for every $1 invested considering the total investment in layers 1-3.

Societal benefits are also listed. CO2 reduction over the 10-year period is estimated to be 76,330 tons. The DOE Interruption Cost Estimate Calculator was used to calculate customer savings from reduced interruptions. As shown, residential customers saved on average $1.40, commercial $230, and industrial $650 (note these figures are on an annual basis).

Case	Cost (Inc/Total) ($000)	Savings Type: Efficiency (Inc/Total) ($000)	Savings Type: Energy (Inc/Total) ($000)	Savings Type: Capital ($000)	Savings Type: Operation ($000)	Savings Type: CI ($000)	Case Savings ($000)	$ Saved / $ Invested (Inc/Total)
CA1	163/163	94/94	29/29	NA	NA	NA	123	0.75/0.75
CA2	564/727	227/321	2,234/2,263	NA	NA	NA	2461	4.36/3.55
CA3	68/795	88/409	2,064/4,328	NA	NA	NA	2,132	31.65/5.74
CA4	1,953/2,748	NA	NA	7,014	7,646	9,566	24,226	12.4/10.54

Estimated CO_2 reduction = 76,330 tons

Societal Benefits

$1.4 ~ Residential
$230 ~ Commercial
$650 ~ Industrial

Figure 3 Present Value Savings from Investments over 10 Years
Abbreviations: Inc = increment; CI = Customer Interruptions

For the CBA1 investment (phase balancing) there is only $0.75 saved per $0.75 invested, but phase balancing is necessary to achieve subsequent savings. The feeders used for the 14 feeder pilot system are about 5 miles in length. For longer feeders this investment would produce a positive return by itself.

DA benefits arise from deferrals of system capital investments that would have otherwise been required to maintain reliability within planning criteria. The “hard-dollar” savings accrue over a period of time, beginning when upgrades are deferred from the base case. DA benefits also arise from operational savings, especially during storm response.

CBA1 – CBA3 investments affect feeder efficiency and energy supplied to the load. The CBA4 investment affects reliability. It should be noted that the savings associated with the reliability investment; $24,226,000, are very large compared to the savings from CBA1 – CBA3. However, the CBA4 savings are dependent upon the CBA1 – CBA3 investments

In other industries it has been demonstrated time-and-time again that automation makes financial sense. Similar to these other industries, model-centric smart grid automation makes financial sense for the ORU distribution system. Today, ORU is not the only utility pursuing ISMs. Utilities, from municipals to large investor owned, are building ISMs to solve problems that cannot be solved with traditional analysis models. The ORU model-centric smart grid solution provides more than a self-healing system - it provides a self-healing system that is operated optimally.

References:

1- “Analysis of the Costs and Benefits of Model-Based Grid Modernization for Orange and Rockland Utilities,” EPRI report.