Highlights: Final Report, California Energy Commission (CEC) / New Power Technologies (NPT) / Southern California Edison (SCE) Project Using GRIDfast™

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GRIDiant

Making Your Smart Grid Brilliant!

CALIFORNIA ENERGY COMMISSION PROJECT SUMMARY

This project was funded by the California Energy Commission Public Interest Energy Research (CEC PIER) program. It was hosted by Southern California Edison (SCE) and performed by New Power Technologies (NPT),[1] with GRIDiant Corporation as a key technology subcontractor. In the Project, an integrated model of a portion of SCE's T&D system (fictitiously-named the "Hobby System") is developed (see Sections G & H, below). Then, GRIDfast power system optimization and analysis software is applied to the T&D network model, for the purpose of (1) identifying and assessing various non-wires and wires/hardware measures, including most advantageous placement, sizing and integrated dispatch of Distributed Energy Resources (DER), which include demand response, capacitance, distributed generation (including renewables), and storage, (2) for improvement of T&D network efficiency, voltage, reliability, network capacity or load-serving capability, and other specific network operational goals and parameters. Navigant Consulting Inc. (NCI) applied a Cost/Benefit methodology for estimating monetary values for the identified network performance improvements.

A. PROJECT OBJECTIVES

- Demonstrate the value of enhanced power network decision-making and problem solving to users and decision-makers.
- Assess the direct and indirect impacts and costs/benefits on T&D network efficiency, reliability, and other specific operational goals and parameters of various non-wires and wires/hardware measures.
- Develop a methodology for using GRIDfast and the Energynet model to show ways to improve system reliability.
- For a projected 2011 load forecast for the Hobby System, evaluate non-wires measures such as idealized re-controls, and re-dispatch of existing DER, new wires/hardware measures such as new capacitance, new Distributed Energy Resources, and ideal topology configuration (new and automated switches), and select conventional network expansion measures (substation additions or upgrades, new circuits, etc.).

B. INDICATORS OF NETWORK PERFORMANCE USED IN THIS STUDY

- Change in system-wide real and reactive losses
- Voltage impacts (generally, impact on system-wide minimum voltage and low voltage buses)
- Reliability impacts (generally, the change in expected un-served energy)
- Loading impacts (e.g., the change in the number of overloaded circuits; load relief value)
- Power quality impacts
- The project evaluated individual network performance enhancement measures for their added capacity in megawatts (MW) and energy output in megawatt-hours per year (MWh/yr).
- Conventional power flow results allowed the project to determine changes to a modeled system in terms of real (P) and reactive (Q) losses, voltage, and equipment or line loading relative to normal or emergency ratings.

The project's primary tool for identifying performance-enhancing measures beyond power-flow modeling was GRIDiant Corporation's GRIDfast power system analysis software. GRIDfast is driven by a nonlinear network analysis and optimization algorithm application, designed specifically for electric power systems. GRIDfast allows an engineer to accurately evaluate, distinguish among, and rank resources for their effect on a power system in terms of multiple grid performance goals. In this

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[1] This Summary is based entirely on, and it excerpts or paraphrases directly from, the final project report: Evans, Peter (New Power Technologies) 2010. Verification of Energynet® Methodology, California Energy Commission, PIER Energy Systems Integration Program, CEC-500-2010-021, found at http://www.energy.ca.gov/2010publications/CEC-500-2010-021/CEC-500-2010-021.PDF. GRIDiant is solely responsible for any inaccuracies in summarizing or paraphrasing the full report.

project, GRIDfast™ calculated "resource sensitivity indices" (RSI) values describing the net impact of loads and resources at each point (bus or node) in the network in terms of the network's performance.

C. RELIABILITY

The Project developed a new methodology using GRIDfast for assessing system reliability improvement as a quantifiable indicator of network performance improvement resulting from any given improvement measure. The approach seeks to reduce impacts of given contingencies, provide enhanced post-fault restoration (reducing outage time), and identify demand response and distributed generation capacity additions with specific benefits in reducing the impacts of given contingencies or enhance post-fault service restoration. The approach evaluates the specific impact of each network performance improvement measure on reliability through three mechanisms: (1) reductions in load that expand post-contingency load shift opportunities, (2) reductions in load that permit substations with constrained ex-substation ties to operate through loss-of-bank contingencies, and (3) load reductions reducing otherwise elevated line failure risk.

The Report concluded that although theoretical reliability differences arise from topology, including circuit layout and post-contingency load shift opportunities, levels of loading on transformers and lines, substation design, and levels of automation, the most import of these factors is load shift opportunities, rather than individual component loading.

D. PERFORMANCE IMPROVEMENT OUTCOMES AND FINANCIAL BENEFITS

Using GRIDfast, the Project undertook network performance improvement according to a cost-effective, "loading order" of successive grid-improvement measures, including in rough order: network efficiency measures for <u>existing</u> grid resources; most advantageous placement, sizing, and integration of <u>new</u> demand response, capacitance, distributed generation (including renewables), and storage; ideal re-configuration of system topology; and addition of traditional capital assets.

1) IDEALIZED NETWORK RE-CONTROLS

GRIDfast analysis showed that device re-controls (e.g., re-control of station and line capacitors, tap changers under load (TCULs), line voltage regulators, reactive power output of existing embedded generators) offer quantifiable and valuable benefits in several benefit categories, with little or no new wires or hardware. Re-controls projects are cost-effective measures. Such projects are largely operational in nature, but may involve capital costs for additional distribution automation to the most advantageous re-control dispatch.

2) CAPACITOR ADDITIONS

GRIDfast analysis showed capacitor additions offering several types of network benefits as a major contributor to the DER Portfolio resource additions for the Hobby System project networks.

3) DER ADDITIONS (DEMAND RESPONSE, DG, DISTRIBUTED STORAGE)

Using GRIDfast analysis, the Project identified specific DER additions that could enhance the performance of the subject system in quantifiable ways. Beneficial projects are individually identified by location, size, and operating profile, and are suited to the characteristics of the "host" customer at that site. The researchers concluded that within a power system not all DER projects are beneficial, while some are very beneficial, and that their locations and characteristics are important.

<u>Demand Response</u>: DR was found to have both load reduction and system operating values (loss reduction and voltage improvement). As with other DER, a small percentage of all possible potential DR sites in a network deliver the most significant contributions to improved system performance.

<u>Distributed Generation</u>: The Project found that the benefits of DG vary greatly depending on their specific feeder location, and on the grid conditions. The most significant system benefits from DG are provided by a subset of all DG projects and potential DG sites.

<u>Distributed Storage</u>: the Project found evidence that (1) the loads associated with storage devices can have adverse effects on a power delivery system during off-peak periods at least under

some conditions. Specifically, if storage devices are placed where their capacity can yield network benefits, the off-peak load associated with those storage devices may cause stress in those locations; and (2) relatively speaking, smaller, more distributed storage that is ideally placed may yield greater overall network benefits or benefits in a greater number of benefit categories than storage placed at already sturdy points of the network.

4) NETWORK EXPANSION PROJECTS

The Project considered and modeled, in the context of system recontrols and other potential system DER improvements, a number of specific substation additions and upgrades, and circuit changes, for their impacts on the Hobby network under forecast 2011 normal summer peak loads. Benefits evaluated included loss reductions, system-wide voltage improvements, load relief, and system reliability impacts.

5) TABLE OF BENEFITS

The table below presents annual monetary values for different categories of system benefits resulting from the several types of Project-identified network improvements through system recontrols, capacitor additions, and DER additions, using a methodology developed and applied by Navigant Consulting Inc. Although in the table the aggregated "totals" are presented, in reality, not all of the projects are additive, and therefore the totals must be considered estimates.

Hobby System: 2011 Forecast

	Recontrols	Capacitor Additions	DER Additions		Network Expansion	Total
			DR	DG		
Power Quality ($/yr)	$654,912	$241,814	$324,937	$554,156	$224,181	$2,000,000
CVR Value ($/yr)	$13,278	$4,903		$11,235	$4,545	$33,961
P Loss Reduction Value ($/yr)	$408,883	$151,477	$186,962	$2,812,764	$3,537,776	$7,097,862
Emission Reduction Value ($/yr)	$4,852	$1,798	$48,593	$132,755	$42,300	$230,298
Bulk System Capacity Value ($/yr)			$984,148	$3,198,992		$4,183,140
Ancillary Services Value ($/yr)			$671,962			$671,962
Energy Value ($/yr)			$192,184	$21,944,520		$22,136,704
Congestion Relief Value ($/yr)			$1,339	$180,606		$181,945
Total Customer + Society Value ($/yr)	$659,764	$733,444	$1,013,253			$2,406,461
Total Utility + Utility Ratepayer Value ($/yr)	$422,161	$24,625,989	$30,184,712			$55,232,862
Total U + U/R Value Excl. Energy ($/yr)			$8,048,008			$8,048,008
Customer Reliability Value ($/yr)			$5,373,973			$5,373,973
Utility/Ratepayer Reliability Value ($/yr)			$3,637,010		$223,351	$3,637,010
Reliability Impact in Customer VOS ($/yr)					$155,420	$223,351
Reliability Impact in Utility/Ratepayer VOS ($/yr)					$20,771,850	$155,420
Load Relief Value ($/yr)						$20,771,850
						$132,384,807

E. ALTERNATIVE NETWORK TOPOLOGIES

Using the Energynet models and GRIDfast, the Project was able to identify all individual tie switches cross-connecting each circuit. The Project demonstrated topologies different from the generally radial topology of the Hobby system that would provide improved network performance in terms of losses and voltage profile. These topologies are partially networked and radial, both of which are feasible, and use only existing switches. The Project also demonstrated systematic methodologies using the Energynet® simulation and GRIDfast™ to identify the individual switches to be manipulated to obtain these benefits and quantified the performance improvement.

The Project proceeded through a series of sequential switch closures or networking "steps" implemented in order of their posited impact on system performance as estimated through a GRIDfast™ optimization. The Project looked at both optimized networking and optimized radial topologic alternatives. Each successive step results in an increasingly networked system. The researchers can concluded that there are clear voltage and loss benefits from load shifting through use of networked topology. For improving system minimum voltage and reducing system losses, nearly all of the impact on the system is achieved from a relatively small subset of the top-ranked alternative possible steps. The Project concluded that even lightly networked topology is a more potent approach than even optimized radial topology in terms of mitigation of low voltage and loss reduction.

F. FIELD VERIFICATION OF PROJECT ANALYSES

- The project demonstrated a side-by-side engineering evaluation with a benefit-cost evaluation adapted from a Navigant Consulting, Inc. methodology to provide a rigorous, data-driven comparison of different network performance improvement measures identified by GRIDfast.
- NPT then developed a wide-area integrated sensor network on the SCE Hobby system, using legacy system sensors and, to fill monitoring gaps, new GridSense LineTracker current-sensing instrumentation and voltage sensors.
- Field data from the sensor network verified the simulation model as a statistically valid predictor of field conditions: The variation of simulated voltage from field voltage at widely dispersed points in the subject system averaged 1.5%, well within the acceptable ± 5% operational voltage variation range.

G. PROJECT INTEGRATED T&D NETWORK

The project system that was modeled and analyzed was a substantial portion of the Southern California Edison distribution system, fictitiously named the "Hobby System" for purposes of the Final Report, integrated with the SCE local transmission system and the Western Interconnection (WECC) transmission system. The Hobby System was comprised of:

- 280,000 customers served at about 46,000 customer service distribution transformers
- 1,000 square-mile service area
- System peak load approximately 1,300 MW
- 58 local transmission and sub-transmission substations
- 241 radial distribution feeders or circuits, voltages ranging from 33 kV to 2.4 kV
- 102 voltage-regulating devices (transformer taps and voltage regulators)
- 839 reactive power sources (capacitors)
- 30 embedded generation resources, some also sources of reactive power;
- 4,684 individually-addressable demand response resources
- Hobby System comprised nearly 100,000 buses (and associated lines, transformers, loads and resources), integrated with approximately 15,000 buses of a regional transmission model provided by the WECC.

H. PROJECT INTEGRATED T&D NETWORK MODELS

- The researchers produced 15 separate Hobby System models, 7 reflecting the system on different "system dates," and 8 reflecting different possible future system configurations. All the models were verified as having no unintended islands or inter-circuit ties. Most interim cases were populated with loads derived from actual SCADA records for a variety of conditions or forecasts, and represented fully solved power flow simulations.
- The models are believed to be the only examples of successful development of integrated T&D power flow models of this scale using repurposed utility equipment and system data.
- GRIDiant engineers used GRIDfast software to perform simulations of the system models in seconds. GRIDfast provided the engineers with strong direction as to next system resource or load adjustments to serve assigned system performance goals, and allowed such modeling adjustments to be made easily.