A California Solar Initiative (CSI) Research, Development, Demonstration, and Deployment Program Grant

Task 4.3 Deliverable: Report on Enhancement of VPower™ to Provide Active Realtime Management of DER

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Grant Title:

Innovative Business Models, Rates and Incentives that Promote Integration of High Penetration PV with Real-Time Management of Customer Sited Distributed Energy Resources.

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Definitions and Abbreviations

Name or Abbreviation	Definition
Ancillary services	In the electric energy industry, electric energy (MWs) is the primary product. In contrast, an ancillary service is something that supports the transmission of electricity from its generation site to the customer, e.g., regulation, spinning reserve, non-spinning reserve, replacement reserve and voltage support.
BMS	Building Management System
CAISO	California Independent system operator
Chiller	A component of HVAC systems, the chiller can remove heat energy from a medium (such as water), to be used in cooling buildings, water, etc. Some of the chillers at UCSD are be driven by electricity and some by steam.
CSI	California Solar Initiative
DA	Day Ahead. Many energy markets are cleared in the day prior to the day of operations.
DER	Distributed Energy Resources.
Electric Storage	A battery for storing electrical energy.
Fuel Cell	A device that generates electricity through chemical processes, in some ways similar to a battery, but uses an external fuel source.
GUI	Graphical User Interface.
HVAC	Heating Ventilation and Air Conditioning.
LMP	Locational Marginal Price. Electric energy prices enhanced to show the value of energy based on transmission congestion impacts.
MW	Megawatt. A unit of electric power. MWh is a Megawatt-hour a measure of electric energy.
PV	Photovoltaic electrical generation (A solar panel).
RT	Real Time. Many energy markets have a clearing near to real time using very short term load forecasts to predict the amount of generation and load to be on the electrical grid.
Thermal Storage	Maintaining or modeling the quantity of thermal energy in some medium for later use. The storage could be accomplished by cooling or heating. The medium could be water, ice, building construction materials, etc.
UCSD	University of California at San Diego

History of VPower at UCSD

In 2010, Viridity Energy proposed using its VPower solution at the UCSD microgrid as part of the Renewable Energy Secure Communities (RESCO) Project and to extend UCSD's desire to develop a comprehensive and sustainable microgrid. In the Fall of 2010, site-survey's were conducted that gathered information which supported the resource modeling. Viridity and EDSA/Power Analytics worked to integrate their software solutions to leverage their existing and complementary functionality. In January of 2011, the first delivery of the VPower and Paladin solution was installed on UCSD servers at the Rimac Supercomputer Center. VPower is currently used by UCSD operators as a view-only tool with suggested manual actions and no direct interaction with the California Independent System Operator (CAISO) energy market.

In May an enhanced version of VPower with improved modeling of steam and chilled water was installed at UCSD.

Background

VPower is Viridity Energy's advanced software and hardware solution that leverages customer's distributed energy resources, energy storage systems and controllable loads to achieve maximum economic value. Vpower is installed at University of California, San Diego, a large university that is leader in green energy. At UCSD VPower is integrated with Power Analytics' Paladin software to ensure the economically optimized schedules result in a stable and secure microgrid. VPower analyzes the value of UCSD's traditional electric generation, steam production, thermal energy storage, solar energy, electric vehicle fleet, and building management and control systems in meeting electrical and thermal demands. VPower's schedules can reduce peak demand through load shifting, and increase reliability by pairing flexible storage systems with intermittent resources (e.g., solar generation during cloud-cover).

Table 1. UCSD Resources Modeled in VPower.

Name	Type
PADR Supply Contract	Supply Contract
PV-1_At_XFMR-336	Solar Generator
PV-2_Campus_Services	Solar Generator
PV-3_Price_Center	Solar Generator
PV-4_Gilman_Parking	Solar Generator
PV-5_Powell_Lab	Solar Generator
PV-6_Hopkins_Parking	Solar Generator
PV-7_School_of_Management	Solar Generator
PV-1MW	Solar Generator
Boiler_Steam	Generator
GT1_COGEN_Steam	Generator
GT2_COGEN_Steam	Generator
GT1_COGEN_Electric	Generator
GT2_COGEN_Electric	Generator
Steam_Turbine_ST1	Generator

GEN-DIESEL4kV-1	Generator
GEN-DIESEL4kV-2	Generator
GEN-DIESEL4kV-3	Generator
GEN-DIESEL-1	Generator
GEN-DIESEL-2	Generator
Fuel_Cell_1_LE	Generator
SUB-1A_Chiller_1	Chiller
SUB-1A_Chiller_2	Chiller
XFMR-233__Chiller_5_(WC5)	Chiller
XFMR-233__Chiller_7_(WC7)	Chiller
XFMR-TA___Chiller_3_(WC3)	Chiller
XFMR-TA___Chiller_6_(WC6)	Chiller
XFMR-US9_Chiller_9_(WC9)	Chiller
WC-1_Steam_Chiller	Chiller
WC-2_Steam_Chiller	Chiller
WC-3_Steam_Chiller	Chiller
Heat_Exchanger	Generator
EV_Rapid_Charge_Station_Public	Electric Storage
EV_Slow_Charge_Station_Public	Electric Storage
EV_Rapid_Charge_Station_UCSD	Electric Storage
EV_Slow_Charge_Station_UCSD	Electric Storage
EV_Rapid_Charge_Station_Buses	Electric Storage
EV_Slow_Charge_Station_Buses	Electric Storage
Energy_Storage_7.6MWH	Electric Storage
TES_Stratefied_Cold_Water_Tank	Thermal Storage
UCSD Hot Water System	Thermal Storage
UCSD Cold Water System	Thermal Storage
Comfort_Index_Johnson_Control	Interruptible Load
Hot Water Strategy	Generator
STEAM_HEADER	Generator
IntegratedPvStorage_Battery	Electric Storage
IntegratedPvStorage_Solar	Solar Generator
Trade_Street_Warehouse_PV	Solar Generator

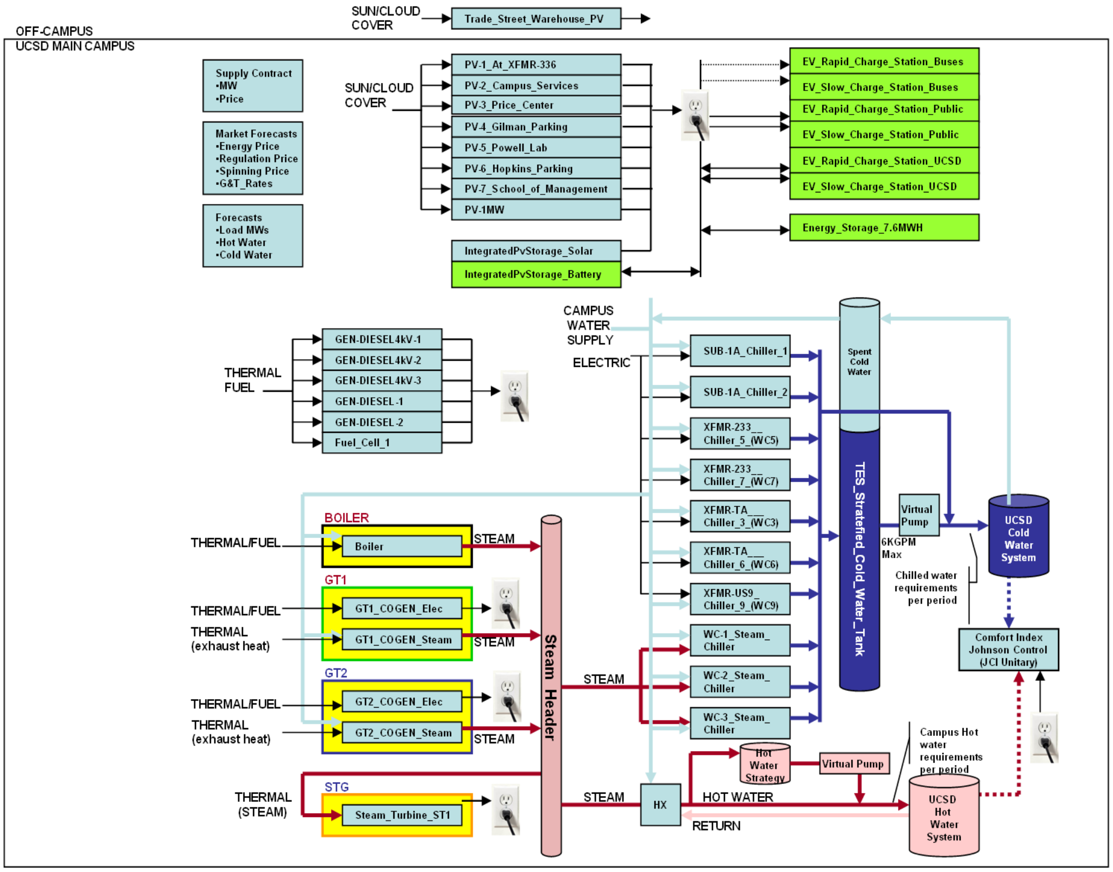


Figure 1. Representative Block Diagram of UCSD Resources.

VPower™ Enhancements

The first VPower™ delivery to UCSD utilized a simplified model of the UCSD system. To improve the accuracy of the solutions, to achieve additional economic savings, and to provide additional flexibility in the resources to be modeled, enhancements were made. These include enhancements to VPower™, and corresponding enhancements to the UCSD resource model.

Thermal Energy Production: VPower™ was enhanced to specifically model the production of thermal outputs such as steam, chilled water, or hot water. This was essential since UCSD must supply from the same set of resources electrical demand as well as hot and cold water to the HVAC system. This enhancement allowed VPower™ to economically balance the schedules for steam to the steam turbine generator, the steam chillers, and the heat exchangers.

Thermal Energy Storage: VPower™ was enhanced to specifically model the storage of thermal outputs. This allowed VPower™ to more accurately model the chilling of water during the off peak period, which can then later be scheduled along with on-line chilling to meet the period to period chilled water demand. Additionally it enabled some flexibility in the hot water requirements, allowing a temporary reduction in temperature to reduce system loading during peak periods.

Enhanced Load Curtailing: VPower™ was enhanced to model the campus HVAC control system as a unitary curtailable load. USCD uses a Johnson Control System provided building management system that can switch the controls between three modes: occupied, standby, and unoccupied. By switching from occupied mode to unoccupied, the campus load can drop by up to 1.5 MWs for a few hours. This enhancement improved curtailable load modeling in VPower™ for those installations where VPower™ is not integrated with the building management system directly.

Multiple Inputs/Outputs: VPower™'s model of generation resources that utilize multiple inputs and produce multiple outputs was enhanced. An example of resources with multiple outputs could be a fueled generator which produces electricity that additionally produces steam from its heat recovery steam generator (HRSG). An example of a resource with multiple inputs could include a generator which uses a mix of two types of fuel, or a resource model in which the water used for cooling along with the fuel needed to be modeled as an explicit input.

Input/Output Ratios: With the VPower™ enhancements, during modeling time the analyst can configure VPower™ to schedule the consumption of multiple inputs either automatically in a way that is economically optimal, assuming the resources are so-capable. Or they can be set to consume the inputs in a fixed ratio. Likewise the outputs associated with a multiple output resource can schedule the outputs in whatever ratio determined to be economically optimal, or they can be assigned a fixed ratio.

Thermal Energy Topology: Additional VPower™ enhancements were made to the connection modeling between thermal resource outputs and the destination of the thermal product. The connection model allows a generator of steam, or chilled water, to feed that output to a specified device (or devices). Once again, the enhancement allows the destination of outputs to be specified as a fixed ratio, or to be determined as part of the optimization.

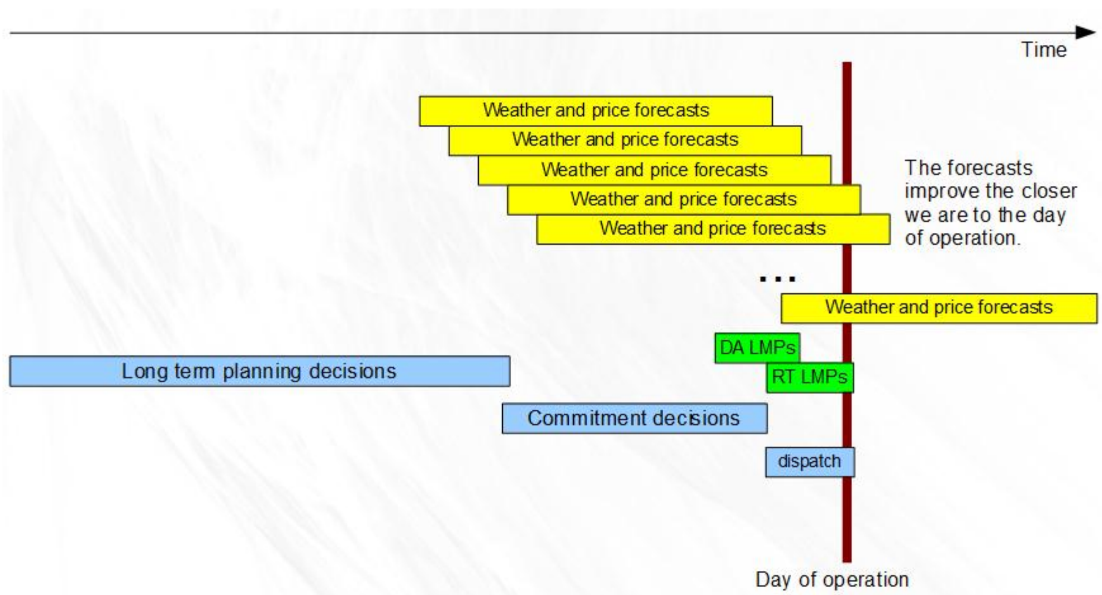
Weather and Price: To support the UCSD resource analysis, a commercial grade weather service was configured to import the latest forecasts for San Diego. Additionally during the CSI project, VPower™ was extended with modules to download and process both locational marginal prices from the real-time and day ahead energy markets.

VPower™ GUI Enhancements: The user interfaces were extended during the project to provide a better global picture to the VPower Operator. Enhancements included resource specific, period by period estimates of emissions (e.g., carbon dioxide); summary of the period-by-period steam production being modeled; and additional information pushed to the dashboard UI in Power Analytics Paladin application.

Real-time Management of DER Resources

Decision Time-frames: Because of the characteristics of electrical and thermal generation, decisions regarding the economic operation of the resources occur on various timelines. Power at UCSD can be executed for user defined durations of up to a few days, the typical usage is to look at a day or two in advance of the day of operation for determining the optimal commitment.

- **Planning:** In the long run, decisions might be made about whether to install new equipment, lock in long term fuel contract, and projects to improve efficiency.
- **Commitment:** In the less than one week ahead time frame, the decisions about which of the resources should be turned on at what time can be made in an economically optimal way. (This is generally termed unit commitment.)
- **Near Real Time:** In the short term the resources previously committed, are dispatched to levels that can just meet the electrical and thermal demands. The need to continue to refine the plan exists because the quality of the input information (e.g. price and weather forecasts, demand forecasts) generally improves the closer we are to the day of operations, and more specifically the time of generation "real-time". VPower can periodically perform optimizations covering the next several hours of the day of operation.
- **Real-Time:** UCSD does not use VPower for real-time control, but the decisions made in near real-time influence which resources are used to balance supply with demand.



Dispatchable Vs Intermittent Resources: The output of intermittent resources such as wind and solar can be hard to predict, and must be balanced with generation from flexibly scheduled resources. For UCSD the flexibly scheduled resources include the natural gas turbines, the external electrical supply from the grid, the ability to charge and/or discharge thermal and electric storage devices. For those resources whose output cannot be known *a priori*, e.g., the solar arrays on a partly cloudy day, capacity from flexibly scheduled resources needs to be at the ready.

VPower™ can schedule to mitigate the impact of intermittent resources by pairing an appropriate amount of flexible generation or storage with the intermittent generation. During near real time optimization, the latest resource availability and status are considered. The forecasted availability by resource for future periods is considered. Maximum output of devices can be scaled or manually fixed by period, at the discretion of the operator. The latest weather forecasts are available and can be utilized. The user can scale solar generation and/or associated storage capacity to account for the period-by-period solar irradiance and percent cloud cover found in the forecast.

Lessons Learned

The ability to control or influence dispatch in real-time is hampered by the lack of a connection to the SCADA system, and/or even up-to-date status information in the historian. Unfortunately the project to connect bring telemetry into the PI historian (from which Power Analytics pulls the latest status to pass to VPower) was substantially delayed.

Improving the accuracy of the VPower output requires testing, and modifying the models. It also uncovered some issues with software with the constraints being returned from Paladin. These issues were addressed, but required a certain amount of debugging effort.
Verifying that the model reflects reality requires being able to capture data from the field, as well as a thorough examination of historical data. The amount of time to gather the data can be greater than anticipated. It is wise to plan appropriately.

It was assumed that hardware and software will be fully available to perform the required testing and modeling. In reality, there were connectivity issues, a license that elapsed, and servers that were taken offline temporarily to support other projects.

The opportunity to spend time with the customer who will be the end-user, is very valuable, and should to be scheduled much in advance.