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Energy Research and Development Division

FINAL PROJECT REPORT

Water Sector Energy Efficiency Through an Integrated Energy Management System

Gavin Newsom, Governor

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PREFACE

The California Energy Commission's Energy Research and Development Division supports energy research and development programs to spur innovation in energy efficiency, renewable energy and advanced clean generation, energy-related environmental protection, energy transmission and distribution and transportation.

In 2012, the Electric Program Investment Charge (EPIC) was established by the California Public Utilities Commission to fund public investments in research to create and advance new energy solutions, foster regional innovation and bring ideas from the lab to the marketplace. The California Energy Commission and the state's three largest investor-owned utilities—Pacific Gas and Electric Company, San Diego Gas & Electric Company and Southern California Edison Company—were selected to administer the EPIC funds and advance novel technologies, tools, and strategies that provide benefits to their electric ratepayers.

The Energy Commission is committed to ensuring public participation in its research and development programs that promote greater reliability, lower costs, and increase safety for the California electric ratepayer and include:

- Providing societal benefits.
- Reducing greenhouse gas emission in the electricity sector at the lowest possible cost.
- Supporting California's loading order to meet energy needs first with energy efficiency and demand response, next with renewable energy (distributed generation and utility scale), and finally with clean, conventional electricity supply.
- Supporting low-emission vehicles and transportation.
- Providing economic development.
- Using ratepayer funds efficiently.

Water Sector Energy Efficiency Through an Integrated Energy Management System is the final report for the Bringing Energy Efficiency Solutions to California's Water Sector with the Use of Customized Energy Management System and Supervisory Control and Data Acquisition project (Contract Number EPC-14-062) conducted by the University of California, Riverside. The information from this project contributes to the Energy Research and Development Division's EPIC Program.

For more information about the Energy Research and Development Division, please visit the Energy Commission's research website (www.energy.ca.gov/research/) or contact the Energy Commission at 916-327-1551.

ABSTRACT

California water agencies account for 5.1 percent of the state's electricity consumption. The systems these agencies use for pumping and treating both fresh and wastewater use equipment of varying ages, from a variety of vendors. This equipment is not controlled as a coherent system to minimize electrical demand. In this project, researchers from University of California, Riverside, built data analysis systems using data acquisition components made by Opto 22, and historian software from OSIsoft. The researchers developed software to display and analyze energy use for three water agencies in Southern California. The goal was to minimize total electric energy and demand cost, based on time-of-use or real-time electric rates. The software provides timely information to operators to guide their operational decisions towards reducing electric demand charges. In the Cucamonga Valley Water District, with an average monthly peak use of 1.18 megawatts, the system guided operators to a demand charge reduction of 41 percent, yielding more than $100,000 of facility-related demand charges and more than $40,000 of time-related demand charges. A proportional reduction across all of California's water agencies, with a total demand of around 3,000 megawatts, could yield statewide savings of more than $31 million, in addition to reduced air pollution and other environmental and economic benefits.

Keywords: Energy Management System, Supervisory Control and Data Acquisition, Water, Wastewater, Electricity, Demand Response, Integrated Demand Side Management.

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EXECUTIVE SUMMARY

Introduction

Over the past 100 years, water and wastewater systems in California have developed without much coordination, using as much as 19 percent of the state's electricity consumption for pumping, treating, collecting, and discharging wastewater, as well as for customer uses. Most of these systems have older legacy equipment provided by many vendors that is inefficient and needs to be replaced or upgraded. Upgrades and modernization face the challenges of integrating equipment of various ages with the difficulty communicating among different vendors' protocols. Water district personnel are often reluctant to adopt new technology because they fear loss of reliable service for their customers. During the past three years, University of California, Riverside, researchers from the College of Engineering's Center for Environmental Research developed software and control algorithms customized for energy management system applications and integrated them with components made by Opto 22, a company based in Temecula (Riverside County). In December 2013, the researchers integrated these components to update the university's existing energy management system to reduce peak electric energy demand. The researchers report a 5 to 6 percent decline in total electricity use since system implementation in 2013. The researchers worked with Inland Empire Utilities Agency, Chino; Cucamonga Valley Water District, Rancho Cucamonga; and the Olivenhain Municipal Water District, Encinitas.

Project Purpose

California water agencies account for 5.1 percent of the state's electricity consumption (based on excluding electricity consumption for water end uses from the 19 percent total referenced earlier), making them one of the largest electricity users in the state. For efficient, safe and reliable operation of these water systems, energy management systems are necessary for continuous real-time monitoring and control. However, most of the systems have historically inherited legacy equipment provided by different vendors at different times for individual projects. Over the years, requirements for minimum bids and local sourcing, for example, have resulted in systems that rely on poorly matched components. Upgrades and modernization efforts face the challenges of integrating control equipment of various vintage along with the serious difficulty of communicating among different vendors protocols.

University of California, Riverside, integrated the new energy management system within its existing supervisory control and acquisition system (a software application program for process control that gathers data in real-time from remote locations to control equipment and conditions) without disrupting current operations at each demonstration site. The demonstration project highlights a pathway for water agencies in California to reduce their peak energy consumption substantially with no decline or interruption in service or reliability. The university also expects the project to identify "real-world" implementation issues that have not emerged in previous proof-of-concept research.

The project involved three water agencies in California's two investor-owned utility territories that manage groundwater, surface water, and reclaimed water in large, medium, and small quantities.

Project Approach

The researchers developed software and control algorithms customized for site-specific supervisory control and acquisition system and energy management system. After reviewing available products from various vendors, the university used suitable components designed and manufactured in Southern California by Opto 22, a company whose products have an established reputation worldwide for ease of use, innovation, quality, and reliability. This company's products use standard, commercially available networking and computer technologies used by automation users, equipment manufacturers, and information technology and operations personnel. Similarly, OSIsoft is also a California-based leading provider of enterprise historian software, a software solution that collects data from different sources and gathers the information in a central office, data center, or other location other than the production facility. A limited number of water districts in California have adapted both of these companies' products for their supervisory control and acquisition system and energy management system applications. The energy management system also incorporated a real-time energy use display with a UC Riverside-designed scheduling algorithm that minimizes the total cost of energy consumed at each water district based on time-of-use or real-time-pricing electricity rates. The researchers designed and implemented an optimization algorithm at wastewater plants and pumping stations. The overall project design helped operators determine pump operation based on associated energy use to avoid creating new demand peaks.

Each of the three water districts has its own priority and system requirements for development of custom applications by UC Riverside.

The technical approach consisted of four major project components:

1. Assessment and inventory of current supervisory control and acquisition system and energy management system infrastructure at each facility
2. Design of site-specific configuration
3. System integration of Opto 22 and OSIsoft PI software and site installation
4. Operation and validation

The supervisory control and acquisition and energy management systems were integrated to function together and complement each other under the control of the OSIsoft PI software.

Project Results

Most water and wastewater systems in California were developed over the past 100 years as a way to satisfy local needs while inheriting dated equipment along the way in an ad-hoc manner. As a result, California's water sector employs mismatched systems that are inefficient and hard to globally manage. To increase efficiencies and reliability and reduce costs, supervisory control and acquisition-based system upgrades are needed for continuous real-time monitoring and control. However, most supervisory control and acquisition-based management systems cannot accommodate the various vintages of equipment and are unable to communicate among different vendors protocols. Because of mismatched systems, an optimal integration solution was presented to each water district and described a supervisory control and acquisition-based management system that allowed the flexibility to work with the variety of existing equipment.

An example of site-specific implementation was an algorithm-based solution and supervisory control and acquisition system dashboard that could be programmed into an existing supervisory control and acquisition system to allow a water district to monitor real-time and historical energy use. The goals of this project were:

1. Add instrumentation to monitor systems in real-time wherever beneficial.
2. Program the supervisory control and acquisition monitoring system by integrating with existing meters to manage energy use while meeting system demands.
3. Display the energy use data and store historical data in supervisory control and acquisition system operations so the operators can attain real-time energy use.
4. Gain knowledge to understand billing and equipment energy use and expand the lessons learned to other sites

The project team introduced these proposed improvements at all three water districts, and the report outlines how each water district's goals and results were achieved while demonstrating reduced energy use and increasing system performance and reliability.

After improvements were implemented and a year's worth of data captured for each water district, the project team had to properly analyze and determine the performance and benefits achieved by the energy management and supervisory control and acquisition systems. The team implemented a seven-step measurement and verification plan. The plan had two primary purposes:

- To allow the participating partners (the demonstration site) to calculate and document energy and cost savings by identifying critical performance metrics and by using appropriate analytical methods and procedures.
- To collect, store, manage, and openly share the performance data and analysis procedures with all participating partners, including an independent third party, for verification of savings achieved by this project.

By the end of the project, the university was able to provide technological development, integration, and operational strategies that were implemented at each water district. Because of this accomplishment, UC Riverside hosted a water workshop February 27, 2019, that allowed the research team to disseminate project results to other water districts. The outreach provided an opportunity for water district technical and managerial personnel to experience firsthand innovative technologies operating in systems similar to their own. Because of this project, it is now possible to expand and propose a solution to other water districts that integrate the supervisory control and acquisition and energy management systems with electric utilities time-of-use electric rate structures with the potential for reducing peak demand and lower electric bills.

Technology/Knowledge Transfer/Market Adoption (Advancing the Research to Market)

The following technology and knowledge activities were developed as a result of this project:

- An overview of technology detailed in fact sheets prepared for California Energy Commission distribution channels
- A detailed technology and knowledge transfer plan identifying the targeted market sector and outreach to users, utilities, regulatory agencies, and others
- A description of the intended uses and applications that would benefit from adoption of the developed technology
- A discussion of policy development that affects the adoption of supervisory control and acquisition system-integrated energy management technology
- Developing presentation materials for a California Energy Commission-sponsored conference/workshop on the project results

The water workshop portion of the technology and knowledge transfer was hosted at the Center for Environmental Research on February 27, 2019, and provided an environment for faculty, researchers, community leaders, and project partners from each water district to share the benefits of energy management and the manner that shaped the way each water district operates. Not only was the event made public via the center's website, several social media platforms, such as Twitter and LinkedIn, were also used to provide information about the event or share visual images of the event in real time.

Benefits to California

California ratepayers will achieve short-term and long-term benefits from the project. Because the project deployed prototype technology in a practical and critical application, the delivery and treatment of water at multiple facilities, ratepayers will see the real benefit in reliability and cost-effective use of energy management systems and supervisory control and acquisition systems. The energy demand savings of the technology also lead to less electricity consumption from the grid during times of peak demand.

The analysis performed for Cucamonga Valley Water District showed 41 percent peak electric demand reduction. This average demand peak reduction with an average monthly demand peak of 1,180 kilowatts would provide annual savings of $107,694 in facility-related demand charges alone and a reduction of $41,452 in time-related demand charges for summer months. The demand costs are based on the Southern California Edison's General Service TOU-8 Option B tariff.

Extending these demand savings to all water and wastewater treatment plants in California with a minimum of 3,000 megawatts of peak demand would translate to $273,798,000 annual savings of facility demand charges and $105,386,400 annual savings in time-of-use demand charges based on Southern California Edison's tariff used at the Cucamonga Valley Water District's site.

Electricity generation, transmission, and distribution systems in California face maximum stress during peak demand periods. During the September 2014 heat wave, many areas of Southern California set new peak demand records, surpassing previous records set in 2006-2007. By reducing peak demand from a major electricity-consuming sector, this project can alleviate the need for expensive and inefficient peaker generation units. The demand reduction technology implemented through this project has helped reduce the need for new plants, increasing reliability with very little additional cost.

In addition, outreach conducted for the project raised public awareness of the science and engineering behind EPIC-funded projects. As a national and global leader in the energy industry, California's contribution to energy innovation in the water industries sets an example for future research to curb climate change, meet policy goals, and spur economic growth.

CHAPTER 1: Introduction

1.1 Inland Empire Utilities Agency

1.1.1 Background

Inland Empire Utilities Agency (IEUA) is a regional wastewater treatment agency and wholesale distributor of imported water. The agency is responsible for serving approximately 844,000 people covering more than 242 square miles in western San Bernardino County, California. The agency is focused on providing three key services:

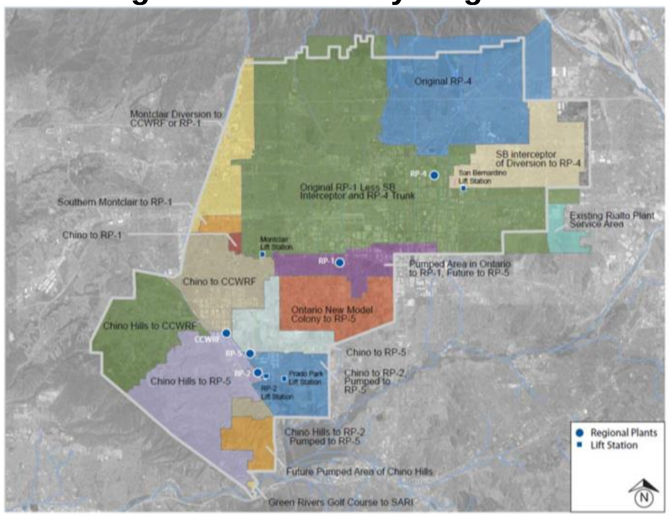
1. Treating wastewater and developing recycled water, local water resources, and conservation programs to reduce the region's dependence on imported water supplies and provide local supply resiliency to the service area
2. Converting biosolids and waste products into a high-quality compost made from recycled materials
3. Generating electrical energy from renewable sources

1.1.2 Operations

IEUA has four regional water recycling plants (RWRPs) which produce recycled water that meet Title 22 standards for indirect reuse and groundwater recharge. All of the RWRPs have primary, secondary, and tertiary treatment and recycled water pumping facilities that are interconnected in a regional network. Agency staff uses influent bypass and diversion facilities, such as the San Bernardino Lift Station, Montclair Diversion Structure, Etiwanda Trunk Line, and Carbon Canyon bypass, to optimize the Agency's flows and capacity use. In general, flows are routed between regional plants to maximize recycled water deliveries while minimizing overall pumping and treatment costs. Figure 1 illustrates the service area boundaries for the agency's four RWRPs.

The four Regional facilities are: Regional Water Recycling Plant No. 1 (RP-1), Regional Water Recycling Plant No. 4 (RP-4), Regional Water Recycling Plant No. 5 (RP-5), and Carbon Canyon Wastewater Recycling Facility (CCWRF). Discussions with IEUA staff have identified RP-4 and CCWRF as initial evaluation facility locations for energy enhancements and potential site use locations. Additionally, the pumping operations for recycled water distribution was identified for analysis associated with operations at CCWRF to the associated reservoir in the 930-pressure zone

Figure 1: Service Area Boundaries for Inland Empire Utilities Agency Regional Water Recycling Plants



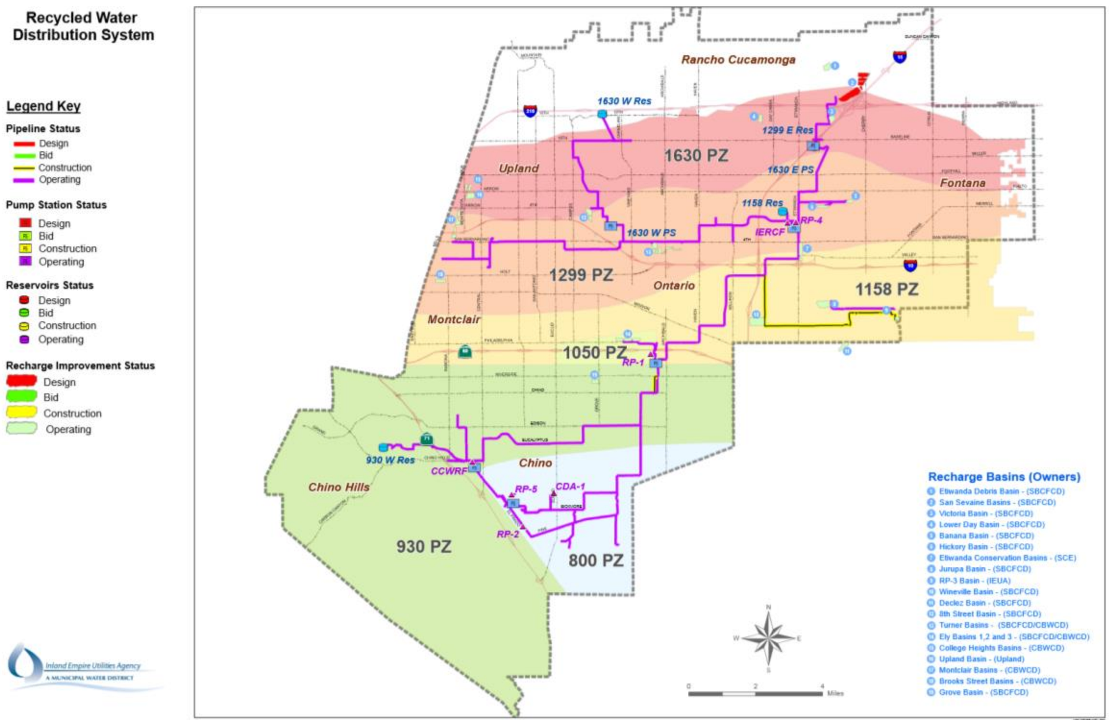
Source: Inland Empire Utilities Agency

The CCWRF is located in the City of Chino and has been in operation since May 1992. The CCWRF works in tandem with RP-2 and RP-5 to serve the areas of Chino, Chino Hills, Montclair, and Upland. Wastewater is treated at CCWRF while the biosolids removed from the wastewater flow are pumped to RP-2 for processing. The CCWRF is designed to treat an annual average flow of 11.4 million gallons per day (MGD) and treats approximately 7.1 MGD. Based on wastewater flow projection surveys by member agencies, plant flows are expected to reach between 7.8 and 8.1 MGD by fiscal year 2024/2025.

Regional Water Recycling Plant No. 4 (RP-4) is located in Rancho Cucamonga and has been in operation treating wastewater and producing recycled water since 1997. The RP-4 facility capacity expanded from 7 MGD to 14 MGD in 2009. Waste sludge generated at RP-4 is discharged back to the sewer and flows by gravity to RP-1. RP-4 serves areas of Fontana and Cucamonga Valley Water District, treating approximately 10.0 MGD. Based on wastewater flow projection surveys by member agencies, plant flows are expected to reach between 13.0 and 14.0 MGD by fiscal year 2024/2025.

The Recycled Water Distribution Facilities consists of a network of pipelines, pump stations and reservoirs that allow the Agency to deliver recycled water throughout the service area. The facilities allow recycled water to be distributed into six pressure zones (Figure 2), for direct use and groundwater recharge. Recycled water projects fall into distribution improvements, groundwater recharge expansion, operational flexibility, rehabilitation and replacement, and program administration. IEUA operational staff and UC Riverside have reviewed the recycled water distribution system and operational details for potential energy enhancements. More specifically, the control strategy associated with pumping activity between CCWRF and the 930-pressure zone pump station was selected for energy management optimization.

Figure 2: Six Pressure Zones for Direct Use and Groundwater Recharge



Source: Inland Empire Utilities Agency

1.1.3 Baseline Control Method

The CCRWPS consists of five 2,585 gallons per minute (gpm) pumps. The pump station peak pumping capacity is 10,340 gpm (14.9 MGD) with four pumps ruing at full speed with one standby pump. The CCRPS supplies recycled water to IEUA's 930 pressure zone. The 930-pressure zone is also supplied by the RP-1's recycled water 930-pressure zone pump station, the 1050 to 930 pressure reducing valve (PRV), and the 930 Reservoir. A 5 million gallon reservoir is installed for this zone with a high water hydraulic grade line of 930 feed. The reservoir helps improve system stability. The primary demands on the 930-pressure zone are large scale agricultural users who use flood irrigation. Most of the irrigation demand in this zone draws water on a 12-hour basis, with the greatest demand in the summer. The control philosophy for the CCRWPS must be coordinated with the operation of the RP-1 930-pressure zone pump station, the 1050 to 930 PRV, and the 930 Reservoir to meet the system requirements during the dry season, wet season, and the variable demands between the two seasons.

The Recycled Water Pump Station draws from a wet well that is fed from the CCWRF Contact Basin. A minimum flow to creek (through the dechlorination minimum flow control valve installed from the chlorination basin to the dechlorination basin) is to be maintained to prevent the dechlorination system from stopping under normal circumstances. A fairly constant flow of less than 1.0 MGD is supplied from the chlorination basin to the dechlorination basin through the automated butterfly valve location on the pipe penetration below the dechlorination weir gate and is operated by a motorized actuator. The Recycled Water Pump Station must maintain a pressure between 55 pounds per square inch (psi) and 150 psi. The Pump Station has two modes: level and pressure. Both modes reflect a discharge pressure that represents the 930-pressure zone that it serves. In pressure mode, the set pinot is approximately 130-140 psi.

To operate in the level control mode, at least one pump must be placed into program mode. While operation in this mode, pumps stage on and off based on the level in the reservoir in relation to the current derived setpoint and level deadband stage. The derived setpoint and deadband stages update each minute and are based on the hourly level setpoint table and level deadband. During an hour the Programmable Automation Controller (PAC) calculates the delta between the current and next hour's setpoint and then adds 1/60th of the delta to the current hour each minute until, at minute 50, the level equals the next hour setpoint where the delta is recalculated. The deadband stages are calculated from the current setpoint minus multiples of the deadband. Additional pumps are called at each deadband stage and called off at one level greater than the stage that called it on. If the reservoir level is less than the setpoint minus the deadband the PAC will turn on the lead pump. The PAC will continue to turn on additional pumps at each deadband stage as long as the number of pumps called is less than or equal to the maximum number of pumps setpoint. Each called pump will be called off at one deadband stage level greater than the stage that called it on. If the wet well falls below the inhibit setpoint, a wet well level Proportional-Integral-Derivative (PID) control is incorporated to control both Variable Frequency Drive (VFD) speed and shed pumps that were called on through the level control. If both VFD's are unavailable, the wet well level PID control will continue to run and shed the non-VFD pumps. When the wet well PID output is less than the minimum pump speed setpoint, the PAC will shed a called pump and reset the PID to 95%. All pump start/stops are delayed by the start/stop delay setpoint. Whenever a pump is added the PAC will force all running VFD's to 85 percent and forces the PID loop to recalculate based on the new system parameters to minimize surging.

To operate in the pressure control mode, at least one VFD must be available and placed in program mode. While operating in pressure mode, the VFD's and soft starts will attempt to maintain a pressure setpoint entered by the operator. VFD speed is controlled by a PID loop that uses the RWPS discharge pressure as the process variable. Whenever a pump is added, the VFD(s) will change their speed to 75 percent and the PID will be forced to recalculate based on the new system parameters to minimize surging. Whenever a pump is shed, the VFD(s) will be forced to run at 95 percent and the PID will be forced to recalculate base on the new system parameters. Should the wet well level reach the wet well level inhibit setpoint, the PAC will begin reducing the pressure setpoint by 0.1 psi every second until the wet well balances out. When the wet well PID output is less than the minimum pump speed setpoint the PAC will shed a called pump and reset the PID to 95 percent. The pressure setpoint is allowed to reduce down to the maximum pressure drop setpoint.

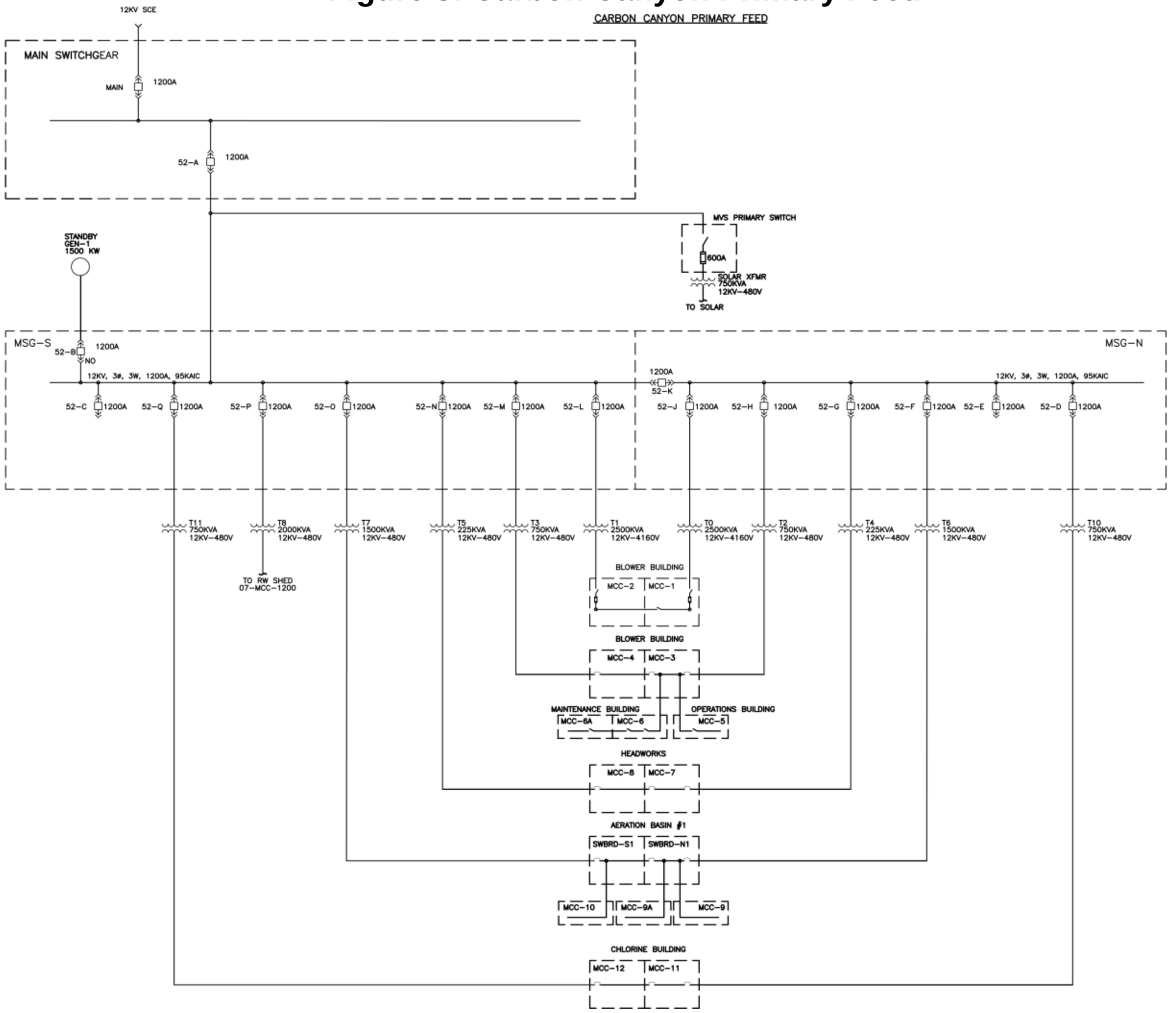
The selected EMS installations for IEUA occurred at the CCWRF located in the City of Chino. The CCWRF works in tandem with RP-2 and RP-5 to serve the areas of Chino, Chino Hills, Montclair, and Upland. Wastewater is treated at CCWRF while the biosolids removed from the wastewater flow are pumped to RP-2 for processing. The CCWRF is designed to treat an annual average flow of 11.4 MGD and treats approximately 7.1 MGD. Based on wastewater flow projection surveys by member agencies, plant flows are expected to reach between 7.8 and 8.1 MGD by FY 24/25.

1.1.4 Energy Management System Integration

The IDSM practices at IEUA were accomplished with an EMS integrated within CCWRF operations. The existing SCADA system at CCWRF uses OSIsoft PI data historian for recording and logging plant operations and system component status. The energy consumption associated with overall facility operations had not previously monitored, recorded, or logged. The energy data is captured on the customer side of the meter and transmitted within the SCADA network to the Process Information (PI) data historian.

The energy monitoring captured the total facility energy used by the primary feed (Figure 3). EMS calculations occurs within the PI database and forwards instantaneous and historical energy profiles to the SCADA integrated energy display. The energy display is used by CCWRF operational staff to mitigate excess energy consumption. The IEUA existing color scheme and sample analog display bars are shown in Figure 4. The details associated with EMS architecture are described in Chapter 2, section 2.1.1

Figure 3: Carbon Canyon Primary Feed



Source: Inland Empire Utilities Agency

Figure 4: Inland Empire Utilities Agency Human Machine Interfaces Standards for SCADA Graphical User Interface Display

Symbol	Border and Label Background	Description
I	No change in color	Alarm inhibited
	White	Return to normal (no alarm), but a previous alarm has not been acknowledged.
4	Blue	Low severity
3	Yellow	Medium severity
2	Red	High severity
1	Magenta	Urgent severity

Source: Inland Empire Utilities Agency

The CCWRF and CCRWPS operation is managed by an on-site SCADA system with operator assisted strategies for Demand Response (DR) and uncontrolled events. Two energy management strategies have been implemented and coordinated for the IEUA facilities. The first strategy is to minimize the occurrences, frequency, and duration when the maximum number of pumps are operating at the CCRWPS. The second strategy is to provide an integrated notification system of current energy demand and prior energy histories.

To minimize the occurrence and frequency, and duration of high pump activity for CCRWPS an operational history of energy meter data and corresponding SCADA data was reviewed and evaluated. The review has identified specific operational events leading to brief periods of elevated energy use, which may be mitigated through moderated pumping activity. To assist in alleviating high pump activity events the system operational mode in conjunction with energy consumption was evaluated. The proposed control method is to reduce pump activity when recovering from DR and similar uncontrolled events. Situations leading to unusually low reservoir levels will initiate maximum pumping response atypical for daily operation. These occasional events produce unusually high short-term energy consumption levels and correspondingly high energy costs. A proposed control strategy was coordinated to moderate pumping activity when compensating for atypical events. The control strategy does not compromise the overall system operation or recycled water supply.

The second management strategy is to integrate an energy advisory notification display to alert SCADA operators of real-time and historical energy use. The plant operators use the energy notification to aid in reducing real-time facility energy demand. The advisory notification provides alerts and feedback associated with peak operation energy demand for the specific meter rate schedule. The advisory notification displays the following:

- Real-time energy demand kilowatt (kW)
- Current and prior billing cycle maximum demand (kW)
- Current and prior year maximum demand (kW)
- Time of use billing period (for example, peak, off-peak, mid-peak)
- Previous billing cycle maximum demand
- Projected 15 minute on-peak energy demand (kW)

The energy advisory notification provides direct and immediate feedback on energy utilization associated with facility operations. Plant operators are responsible for complex plant operations of numerous processes performing simultaneous functions. The plant operators are equipped to integrate energy demand as an operational consideration when energy demand would otherwise reach elevated levels.

1.2 Olivenhain Municipal Water District

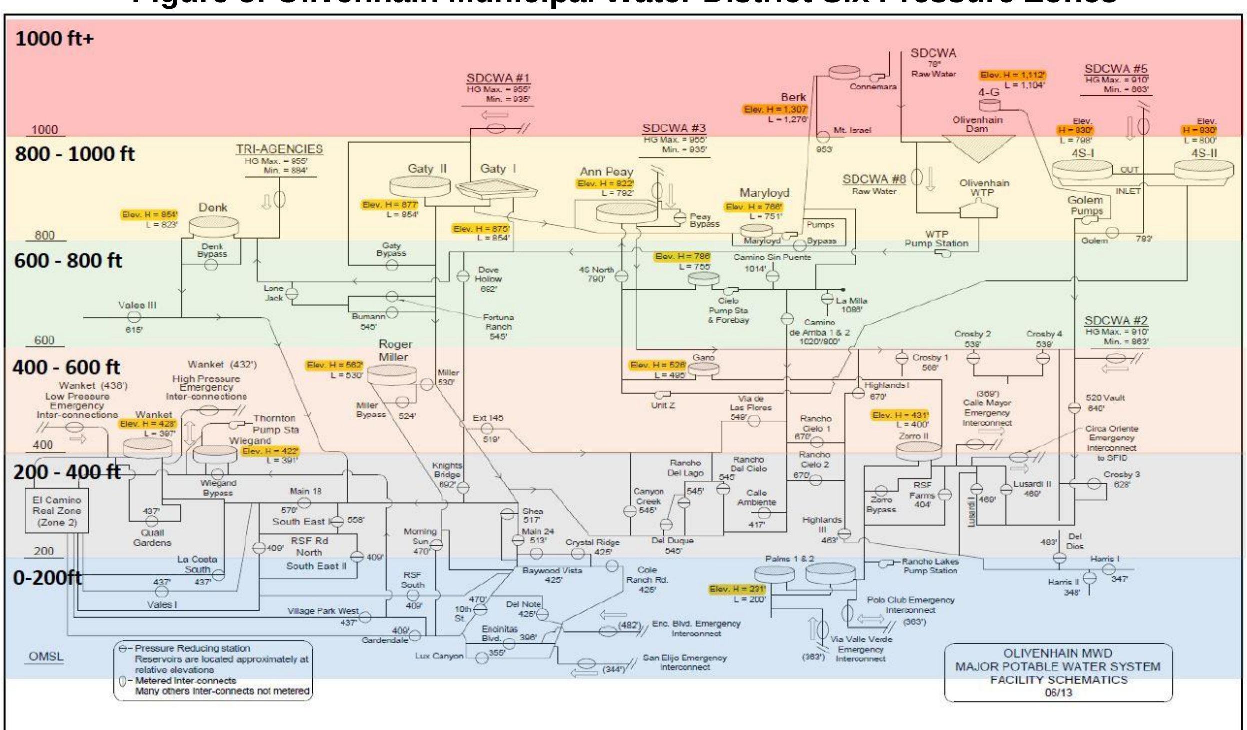
1.2.1 Background

Olivenhain Municipal Water District was incorporated on April 9, 1959 to develop an adequate water supply for landowners and residents. At more than 48 square miles, OMWD currently serves a population of approximately 84,000 residents in northern San Diego County. OMWD consists of 17 water storage reservoirs with a capacity of nearly 80 million gallons of water using more than 400 miles of potable water pipelines. OMWD's David C. McCollom Water Treatment Plant treats up to 34 million gallons of water each day. In addition, OMWD 4S Water Reclamation Facility produces up to 2 million gallons per day of recycled water.

1.2.2 Operations

As part of the California Energy Commission's (CEC) Project Opportunity Notice-304, Bringing Energy Efficiency Solutions to California's Water Sector with the Use of Customized Energy Management System and Supervisory Control and Data Acquisition System, a number of review meetings were held at OMWD headquarters. Figure 5 shows the Olivenhain system map including the water treatment plant.

Figure 5: Olivenhain Municipal Water District Six Pressure Zones

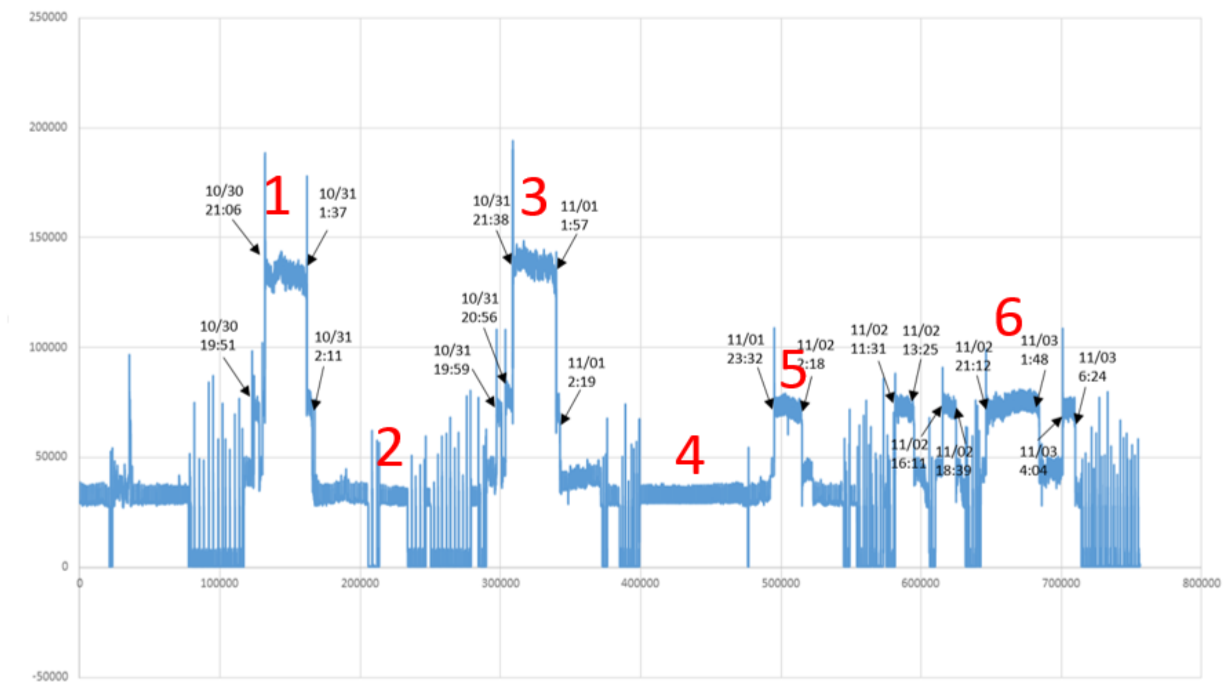


Source: Olivenhain Municipal Water District

UCR engineers completed a general review of OMWD's electrical bills and selected the bills from seven facilities for detailed evaluation. Examining summer and winter electrical bills indicated that four sites may be worth a detailed study for potential electrical energy saving. FLUKE 435 Series II Power Quality and Energy Analyzer recording monitors were installed in two of these locations. These monitors were relocated to two new locations after three weeks.

Figure 6 shows the actual measurement results of power use for Santa Fe Valley Pumping Station. Salient features are listed in Table 1 which shows peak demand happened only twice over the five-day period.

Figure 6: Santa Fe Valley Waste Water Pumping Station Electric Use



Source: University of California, Riverside

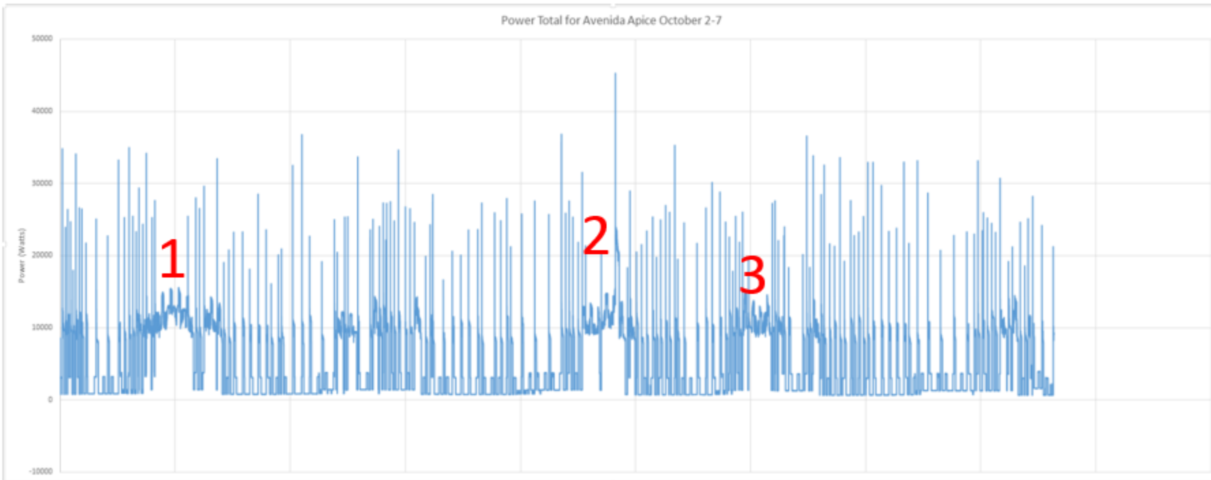
Table 1: Santa Fe Key Features of Waste Water Power Consumption

Number	Date	Day	Start Time	Power	Duration (Approximate)	kWh
1	Oct 30	Friday	9pm	75kW	4hrs	300
2	Oct 31	Saturday	2am	35kW	17hrs	595
3	Oct 31	Saturday	9pm	125kW	5hrs	625
4	Nov 1	Sunday	2am	35kW	21hrs	735
5	Nov 2	Monday	11pm	75kW	3hrs	225
6	Nov 3	Tuesday	9pm	75kW	5hrs	375
Average/Total				~70 kW		2.855 MWh

Source: University of California, Riverside

Figure 7 shows similar measurement results for Avenida Apice Pumping Station, where peak demand happened three times over a five day period.

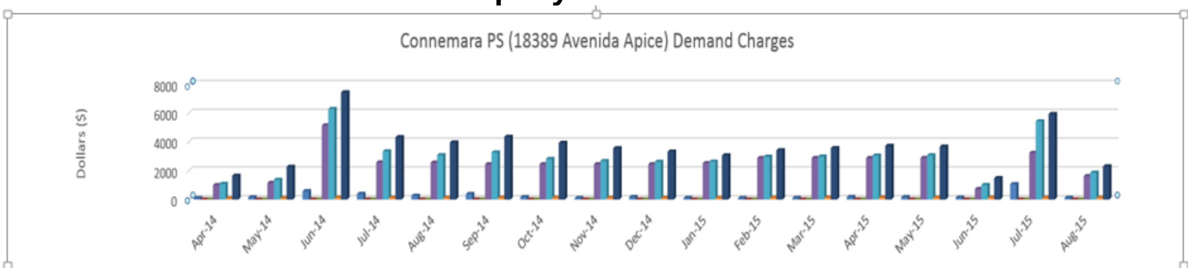
Figure 7: Avenida Apice Electric Use



Source: University of California, Riverside

Figure 8 shows demands charges from San Diego Gas and Electric's (SDG&E) electric bills for Avenida Apice Pumping Station. It shows Non-Coincidental (NC) Demand for June 2014 and July 2015 is approximately double that of other months. .. May 2015 NC Demand was $2,877.85 and June 2015 was $730.46, a difference of $2,147.39. Which means that approximately $25,000 could be saved per year. Further investigation is needed to determine the cause of these high demand occurrences. Table 2 shows Avenida Apice Electrical use breakdown for three days in October 2014.

Figure 8: Avenida Apice Demand Charges from San Diego Gas and Electric Company Electric Bills



	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15
On-Peak Demand $	90.29	145.69	578.3	388.55	259.18	379.26	165.38	100.34	171.36	102.01	93.45	108.01	176.18	161.98	132.74	1061.89	116.14
Semi-Peak Demand $	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Max Demand $	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NC Demand $	990.02	1148.08	5143.32	2572.75	2555.37	2446.71	2446.71	2446.71	2446.71	2525.1	2877.86	2877.85	2877.85	2877.85	730.46	3236.98	1619.71
Total Demand $	1083.01	1365.45	6284.37	3339.4	3073.06	3263.28	2807.58	2670.65	2618.07	2627.11	2971.31	2985.86	3054.03	3068.07	1004.38	5428.34	1859.39
Other $	80.88	95.43	128.67	122.75	117.84	122.1	123.37	115.4	111.37	105.88	127.56	132.32	134.92	132.31	127.02	127.84	125.95
Total SDGE $	1642.07	2265.7	7439.32	4323.37	3956.59	4355.87	3931.1	3558.35	3319.95	3065.34	3417.32	3570.41	3719.81	3667.17	1481.1	5932.33	2298.42

On-Peak Demand $ Semi-Peak Demand $ Max Demand $ NC Demand $ Total Demand $ Other $ Total SDGE $

Source: University of California, Riverside

Table 2: Avenida Apice Electric Usage Breakdown

Number	Date	Day	Start Time	Power	Duration (Approximate)	kWh
1	Oct 3	Saturday	10pm	14kW	6hrs	84
2	Oct 5	Monday	2am	12kW	6hrs	72
3	Oct 6	Tuesday	10pm	12kW	6hrs	72

Source: University of California, Riverside

1.2.3 Baseline System

OMWD uses Allen-Bradley Programmable Logic Controllers (PLC) 505 based controllers for their pumping systems control and display. The system was installed by Inductive Automation of Folsom, California. The system is relatively new and approximately four years old.

1.2.4 Energy Management System Integration

The operators indicated that integration of time-of-use (TOU) utility rate schedule into their SCADA and EMS system is of high value. The plant operators used the energy monitoring to aid in reducing real-time facility energy demand. The advisory system also provides notification and feedback associated with peak operation energy demand for the specific meter rate schedule. The advisory system displays the following:

- Real-time energy demand (kW)
- Current and prior billing cycle maximum demand (kW)
- Current and prior year maximum demand (kW)
- Time of use billing period (peak, off-peak, mid-peak)
- Previous billing cycle maximum demand
- Projected 15 minute on-peak energy demand (kW)

The energy advisory notification provides direct and immediate feedback on energy use associated with facility operations. The addition of power quality information, showing voltage dips and swells, especially during large motor start-ups, is of strong interest. The integration of power quality information adds to the facilities' resiliency to operational-related energy fluctuations. The UCR team deployed and validated an EMS, data acquisition, and supervisory control strategy that improved operational efficiency and reduced peak loads and electricity at the DCM Water Treatment Plant. The proposed system overlays and incorporates existing EMS and SCADA systems without disrupting current operations at the DCM Water Treatment Plant. The system design approach is compatible with existing equipment at the plant, and works alongside of their current SCADA system.

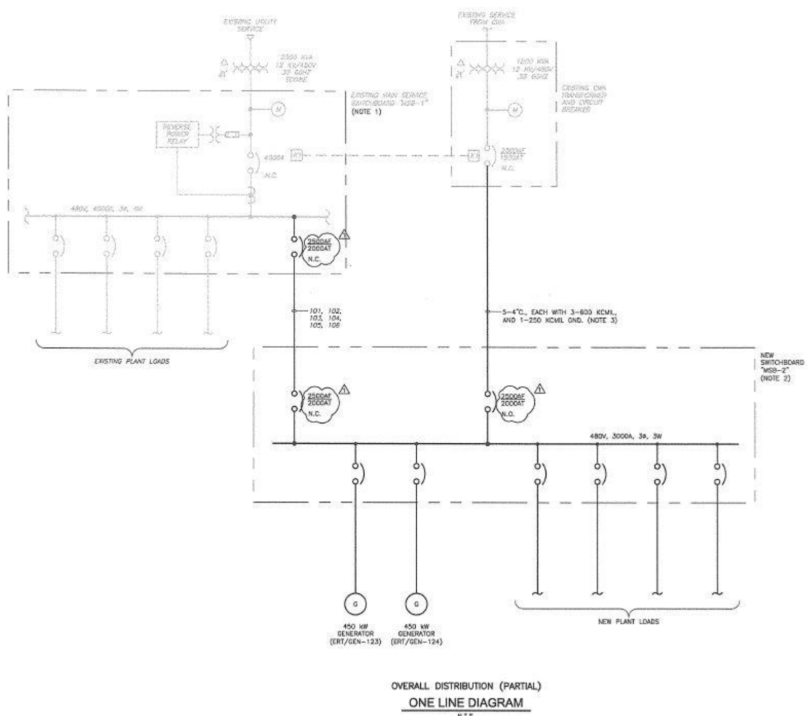
Currently the system is designed to be installed at DCM and includes instrumentation to monitor energy use in real-time. Existing system one line diagram is shown in Figure 9. UCR provide a process control narrative so OMWD can program and display real-time energy data and store it historically at an Olivenhain server.

The overall objective of integrating an EMS system is to be able to reduce the amount of power demand (kW) that is used during peak times year round. UCR accomplished this by shifting energy use from on-peak to off-peak times at DCM (Via Ambiante), based on water demand and water treatment requirements.

The main project components and EMS architecture are described in detail in Chapter 2, and include the following system design components:

- Assessment and inventory of current SCADA and EMS infrastructure at the Water Treatment Plant
- Design of site-specific EMS to display real-time energy data
- Operation results and validation

Figure 9: One Line Diagram for DCM Water Treatment Plant at Olivenhain Municipal Water District



Source: Olivenhain Municipal Water District

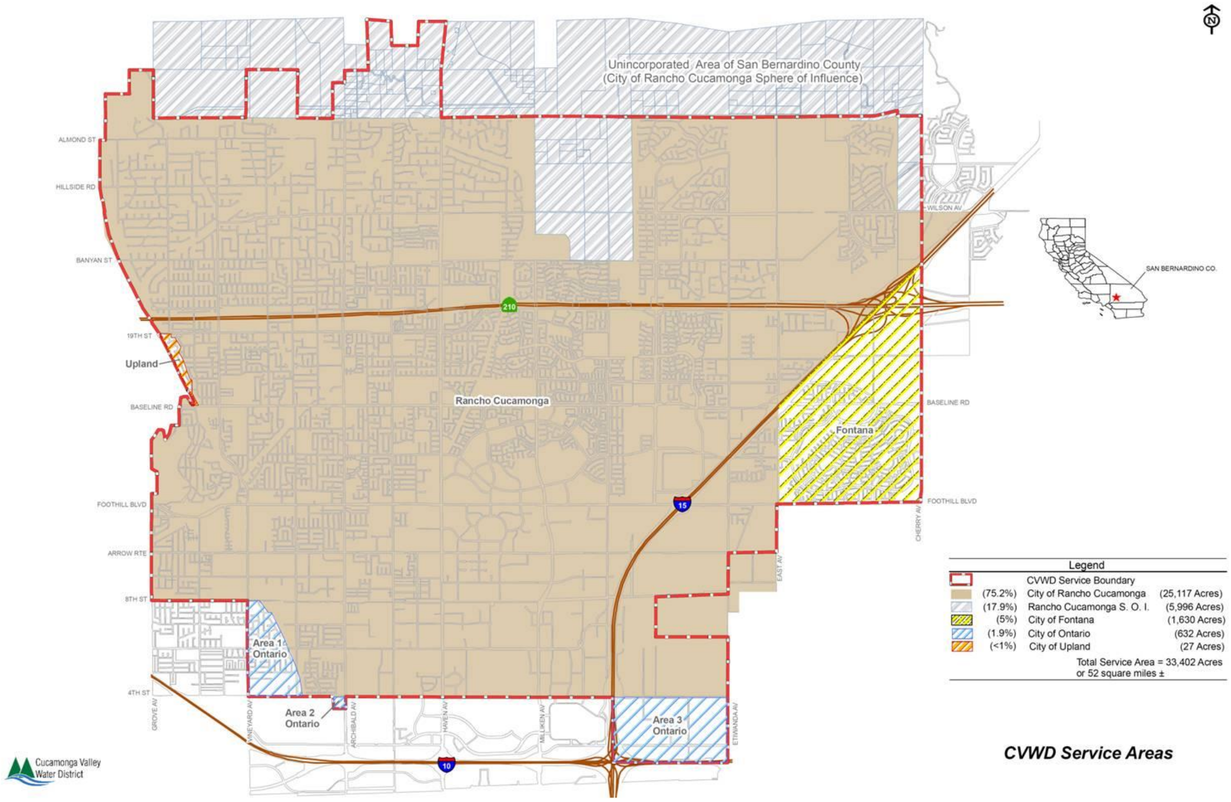
1.3 Cucamonga Valley Water District

1.3.1 Background

The Cucamonga Valley Water District (CVWD) was created as a "special district" in 1955, and developed from 23 smaller water companies. The CVWD is authorized by the Local Agency Formation Commission (LAFCO) to provide and manage water and sewer services. The district's 47 square mile service area lies in southwestern San Bernardino County and includes the City of Rancho Cucamonga, portions of the cities of Fontana, Upland, Ontario and some unincorporated areas.

Figure 10 illustrates the service area boundaries for the CVWD.

Figure 10: Cucamonga Valley Water District Service Areas

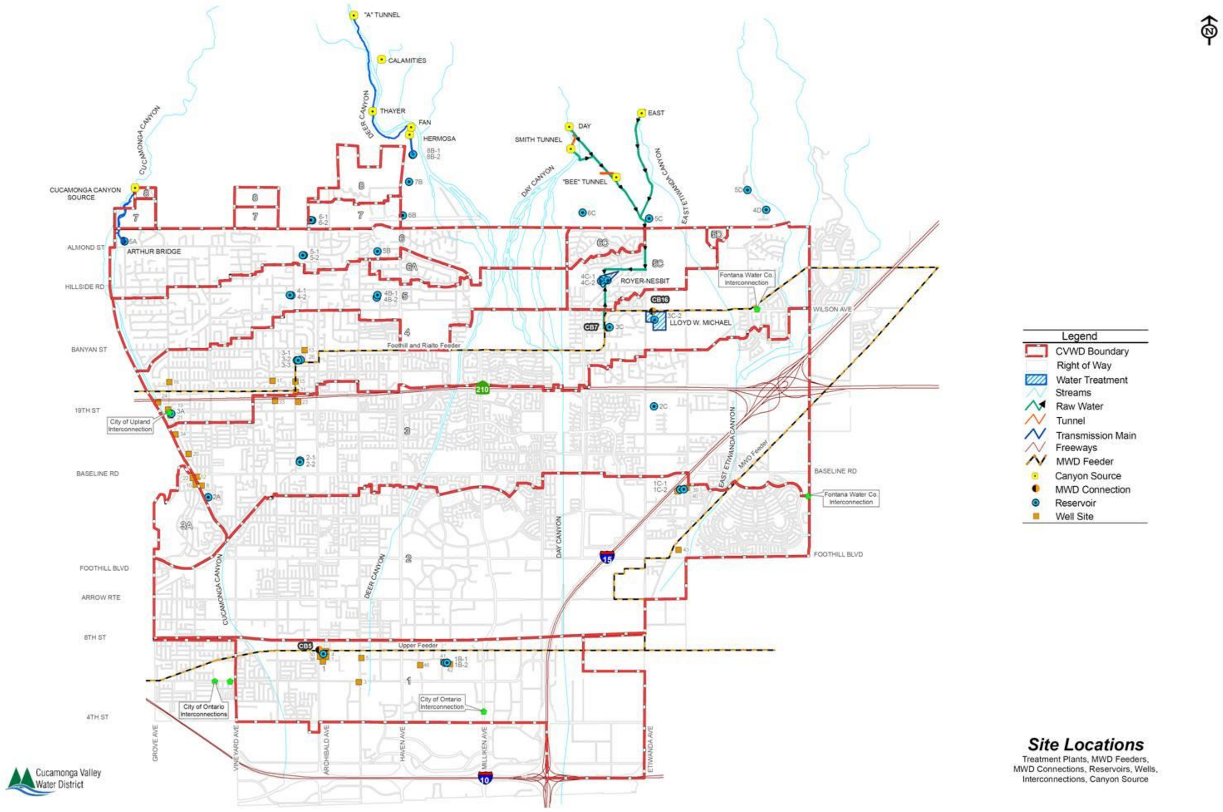


Source: Cucamonga Valley Water District

CVWD serves more than 190,000 customers, through 49,000 water connections, and has an average daily demand of approximately 50 million gallons per day (GPD), and a peak demand of 75 GPD. To meet this demand, CVWD relies on source water consisting of local runoff, groundwater, and seasonal canyon water, recycled water, and purchased water. CVWD's topography purposes water production in the lower elevations to be moved to upper elevations for storage and pressure. Water production, storage, and distribution system operations follow an automated demand-based control scheme which is executed using SCADA.

CVWD operates 20 pump stations, 28 wells, and three treatment plants, using more than 720 miles of potable waterlines, 10 miles of recycled waterlines, and 450 miles of sewer lines. Figure 11 illustrates the site locations for the water treatment plants, reservoirs, and well sites.

Figure 11: Cucamonga Valley Water District Site Locations



Source: Cucamonga Valley Water District

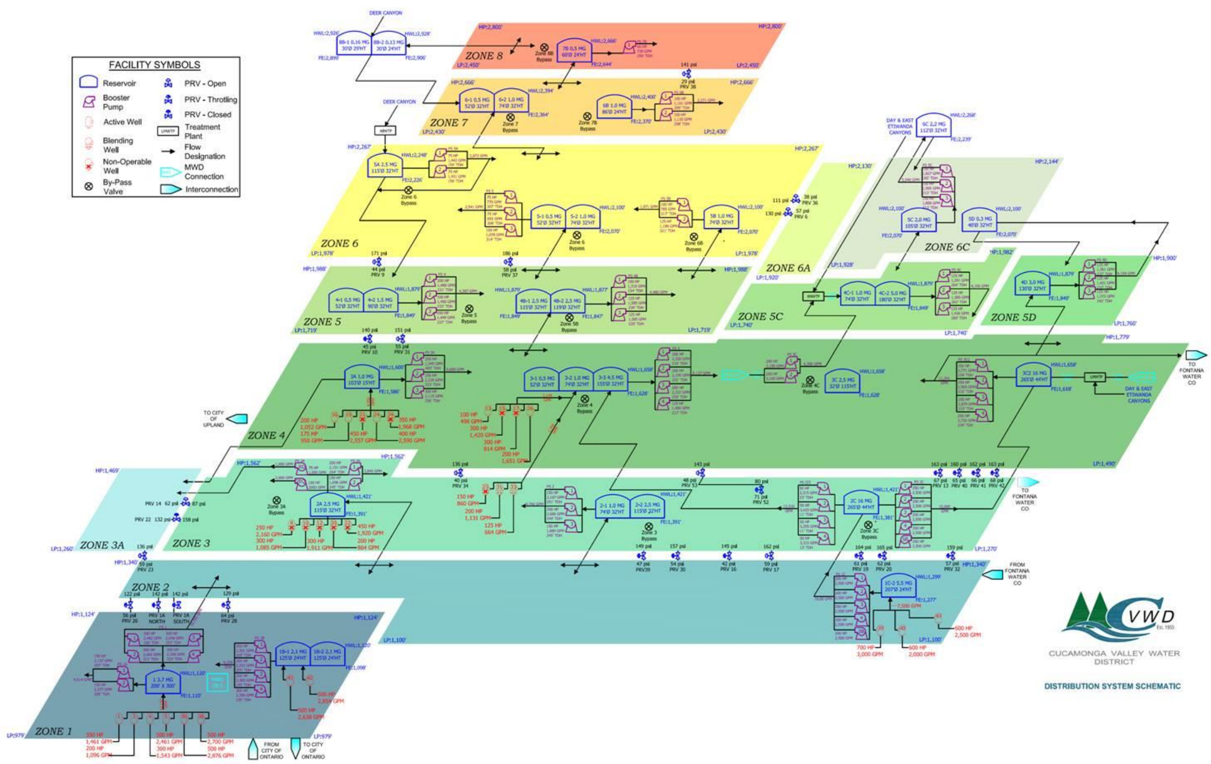
1.3.2 Operations

CVWD production infrastructure encompasses: eight pressure zones, 24 reservoir sites, 36 reservoirs, 95 MG storage, 19 booster stations, seven chorine generators, 28 wells (20 operating), 25,800 acre feet per year (Acft/yr) (ground water), 24,700 Acft/yr (imported water), and 1,100 Acft/yr (surface water). Existing operations include the following departments:

- Water Treatment: Responsibilities of this division include district-wide water quality monitoring, state and federal drinking water regulatory compliance, and the operation and maintenance of three surface water treatment facilities: the Lloyd W. Michael Treatment Plant, a 60-MGD conventional treatment facility, the Royer-Nesbit Treatment Plant, an 11-MGD conventional treatment facility, and the Arthur H. Bridge Treatment Plant, a 4-MGD filtration treatment facility. Water sources include local ground water, local surface water, and imported surface water.

- Water Maintenance: Responsibilities of this division include the maintenance and repair of the District’s water system infrastructure that includes mainlines, hydrants, valves, services, and implementation of preventative maintenance programs.
- Sewer Maintenance: Responsibilities of this division include the maintenance and repair of the District’s sewer collection system infrastructure that includes sewer mains, sewer laterals, lift stations, and implementation of preventative maintenance programs to monitor flows and clean the system.
- Production: Responsibilities of this division include the operation, maintenance, and repair of the District’s groundwater wells, pumping facilities, reservoirs, chlorination stations and telemetry (instrumentation and controls). Figure 12 illustrates the schematic of CVWD's distribution system.

Figure 12: Cucamonga Valley Water District Distribution System Schematic

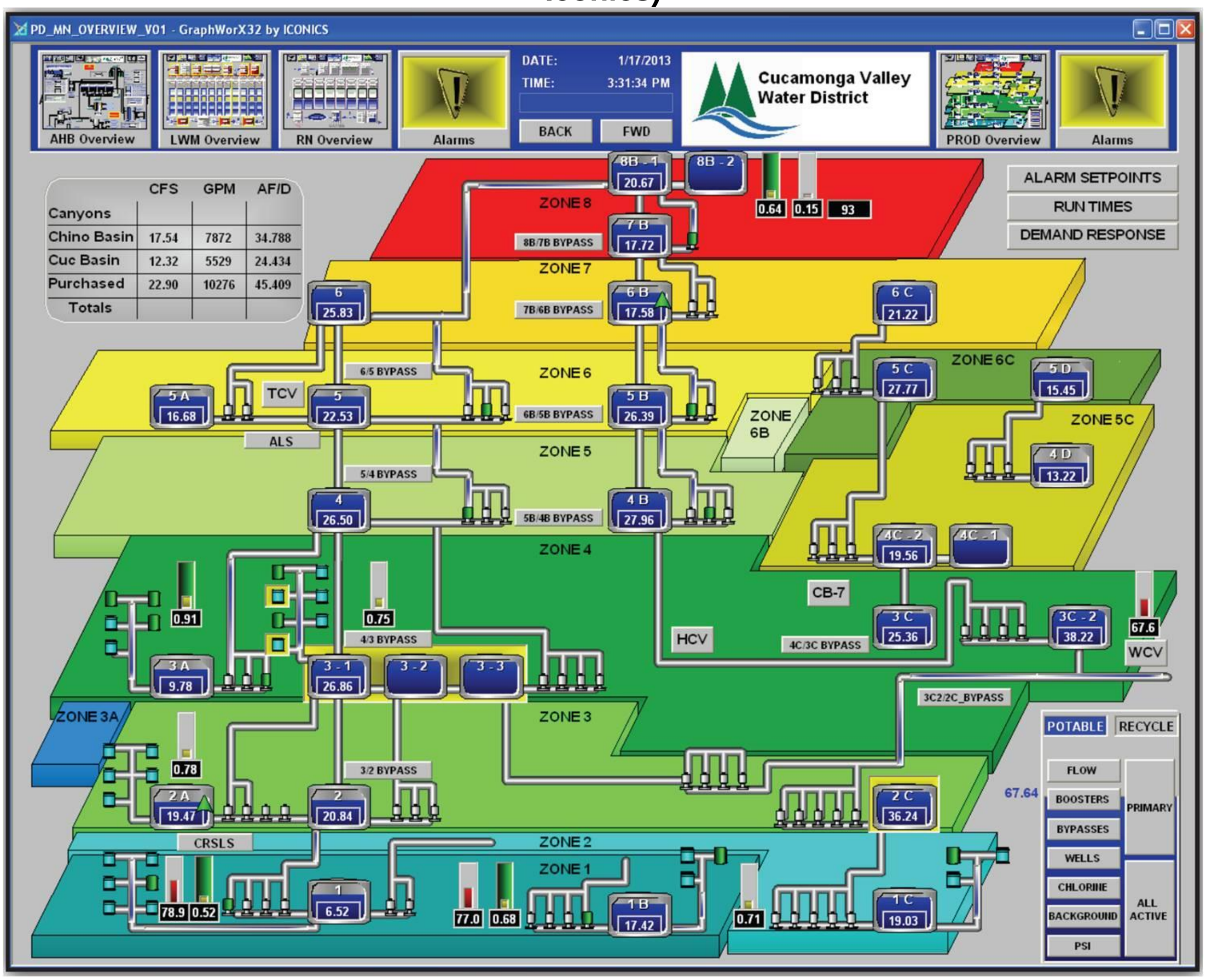


Source: Cucamonga Valley Water District

1.3.3 Baseline Control Method

CVWD Production/Telemetry consists of 52 remote sites including reservoirs, wells, water treatment facilities, and sewer lift stations. All remote sites are monitored/controlled using PLCs, HMIs, and are networked together with communications consisting of fiber, Ethernet, wireless, and serial. CVWD uses the Iconics GENESIS32™ (v.9.14) SCADA platform. GENESIS32™ is a scalable suite of OPC, SNMP, BACnet and Web-enabled HMI and SCADA applications. The GENESIS32 Automation Suite is designed from the ground up to take advantage of the entire range of Microsoft Windows® operating systems, providing reliable integration with the most popular communication infrastructures. It delivers ease-of-use, performance and cost savings due to its open standards-based design. Figure 13 illustrates the Iconics HMI at CVWD

Figure 13: Cucamonga Valley Water District Production and Telemetry HMI (by Iconics)



Source: Cucamonga Valley Water District

After review of CVWD distribution system and operational details, the control strategy associated with pumping activity between reservoir sites 3 and 3A was identified as energy management and operational optimization by CVWD operational staff and UC Riverside

Reservoir 3 consists of a group of three reservoirs (3-1, 3-2, and 3-3), pump station 3, and well 26 (on-site). Reservoirs 3-1, 3-2, and 3-3 have a storage capacity of 0.5, 1.0, and 4.5 MG, respectively. The sources of water are Reservoir 2, Reservoir 2C, by-pass from Reservoir 4, and Wells 13, 15, 17, 23, 31, and 33. Pumping Station 3 has four pumps designated as 3-1, 3-2, 3-3, and 3-4 with pump motor sizes of 200 horsepower (HP), 200 HP, 200 HP, and 125 HP, and pump capacities of 2,320 gallons per minute (GPM), 2,195 GPM, 2,222 GPM, and 1,400 GPM, respectively. Wells 13, 15, 17, 23, 26, 31, 33 have pump motor sizes of 100 HP, 300 HP, 200 HP, 150 HP, 300 HP, 200 HP, and 125 HP, and well capacities of 498 GPM, 1,420 GPM, 814 GPM, 860 GPM, 1,651 GPM, 1,131 GPM, and 664 GPM, respectively.

Reservoir 3A consists of Reservoir 3A, Pump Station 3A, and Well 21 (on-site). Reservoirs 3A has a storage capacity of 1.0 MG. The sources of water are Reservoir 2A, and Wells 16, 19, 21, 24, and 34. Pumping Station 3 has three pumps designated as 3A-1, 3A-2, and 3A-3, with pump motor sizes of 250 HP, 250 HP, and 350 HP, and pump capacities of 1,345 GPM, 2,228 GPM, and 2,115 GPM, respectively. Wells 16, 19, 21, 24, 26, and 34 have pump motor sizes of 200 HP, 175 HP, 450 HP, 400 HP, and 350 HP, and well capacities of 1,052 GPM, 950 GPM, 2,557 GPM, 2,590 GPM, and 1,968 GPM, respectively.

Existing control method at Reservoirs 3 and 3A includes manual, semi-automatic, and fully automatic control. Manual control allows for local operation of all equipment. Semi-automatic control allows for remote manual control. Automatic control is based on reservoir levels. Each reservoir controls the actions of upstream pumps and downstream valves. When a reservoir level is low, pumps are called on to fill the reservoir and when a reservoir is high, valves are called on to drain the reservoir to the downstream site. As indicated, pumping activity does not factor in time of day, existing tariffs, or demand charges.

1.3.4 Energy Management System Integration

CVWD's distribution system was designed to meet daily water needs/use of its service territory, rather than with energy efficiency in mind, and is completely detached from electricity bills. Therefore, the control scheme of the CVWD SCADA system is to meet daily water demands. The current demand-based scheme does not factor real-time energy usage, energy pricing or motor and pump efficiencies in operational algorithms or control strategies.

The creation of a migration path to move from a demand-based control scheme to a scheme capable of demand- and efficiency-based controls is the goal of this particular project. This migration path and implementation require hardware installation, software installation/integration, and engineering. Hardware requirements include the installation of discharge pressures transducers, flow meters, and electrical submetering to produce real-time efficiency data. Transmitters must be capable of transmitting communications onto a communications network to ultimately reside on the existing SCADA network. Software requirements would include an EMS compatible with the existing Human Machine Interface (HMI) and the integration of the EMS and HMI. Currently CVWD uses the GENESIS32™ HMI software. Genesis32 is capable of upgrading to include the functionality of an EMS using Energy Analytix.

CVWD has experience in energy programs and recognizes the benefits of operating in an efficient manner. CVWD has recently completed an energy program allowing participation with automated demand response (ADR). On completion of this project, the SCADA system has instantaneous data allowing for a migration from the existing demand base control scheme to a scheme capable of demand-and efficiency-based controls. With these controls in place, CVWD is able to operate at a more efficient level to minimize electrical use and optimize operational efficiency.

Similar to the proposed approach with IEUA, an advisory notification display was be integrated into their existing SCADA system to provide operators the following information:

- Real-time energy demand (kW)
- Current and prior billing cycle maximum demand (kW)
- Current and prior year maximum demand (kW)
- Time of use billing period (on-peak, off-peak, mid-peak)
- Previous billing cycle maximum demand
- Projected 15 minute on-peak energy demand (kW)

CVWD has worked with UC Riverside to determine SCADA instrumentation design, required upgrades, and integration at existing facilities, including reservoir, well, and booster pump stations. Additional goals are: 1) optimize pumping activity by decreasing kWh/acft ratio; 2) integrate live tariffs into control algorithms; 3) monitor water traveling between zones, and 4) determine the true cost of getting water from one point to another.

CHAPTER 2: Project Approach

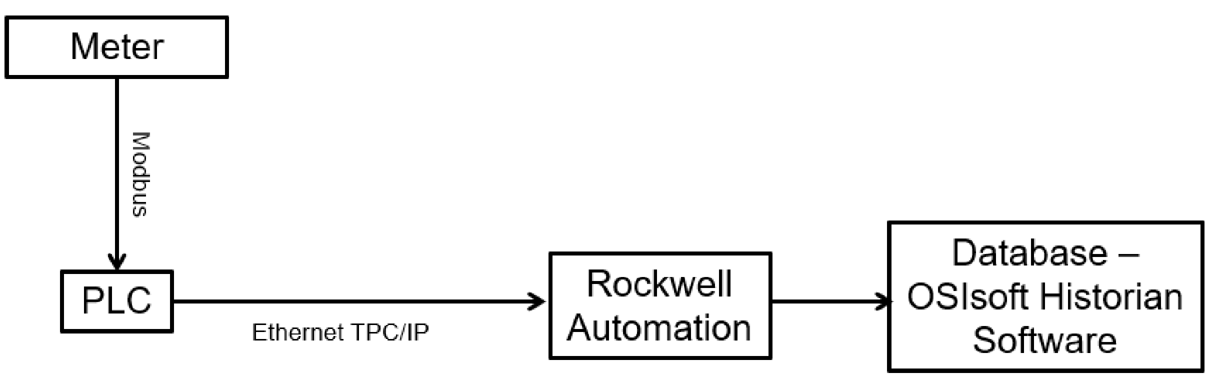
2.1 Initial System Design and Approach

UCR's energy management system was designed to integrate with a variety of industry-standard systems and equipment, regardless of equipment manufacturer, including:

- Building automation and management systems
- SCADA and other industrial monitoring systems
- Bill management systems
- New and existing metering equipment

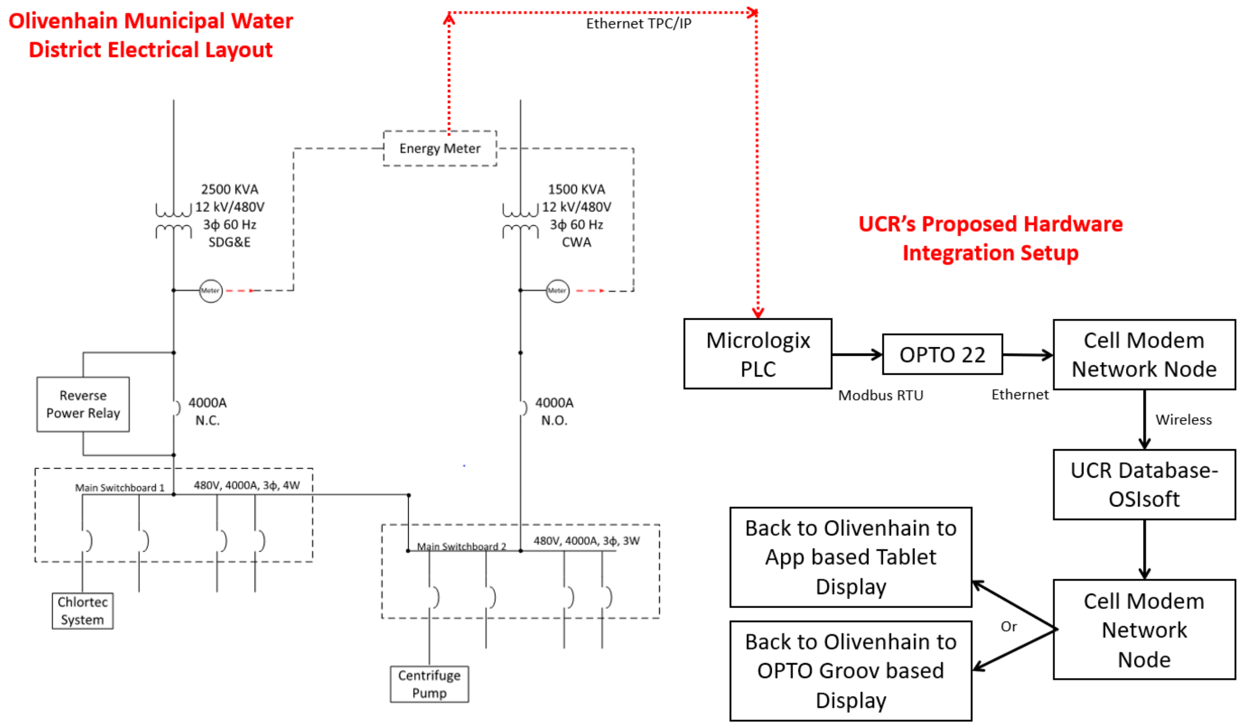
The original design concept was created based on each of the water district's overall configuration and their needs. The components originally chosen to be used include MicroLogix PLC, Opto 22, Cellular Modem and OSIsoft PI Server. The EMS installations include systems fully integrated on-site at IEUA as shown in Figure 14, and systems integrated with a UC-based data management system for OMWD and CCVWD (Figure 15 and Figure 16). Each system deployment and configuration requires a system integrated energy measurement located on the customer side of the meter for the location of interest.

Figure 14: Inland Empire Utilities Agency System Showing Integration with University of California Proposed Hardware Solution



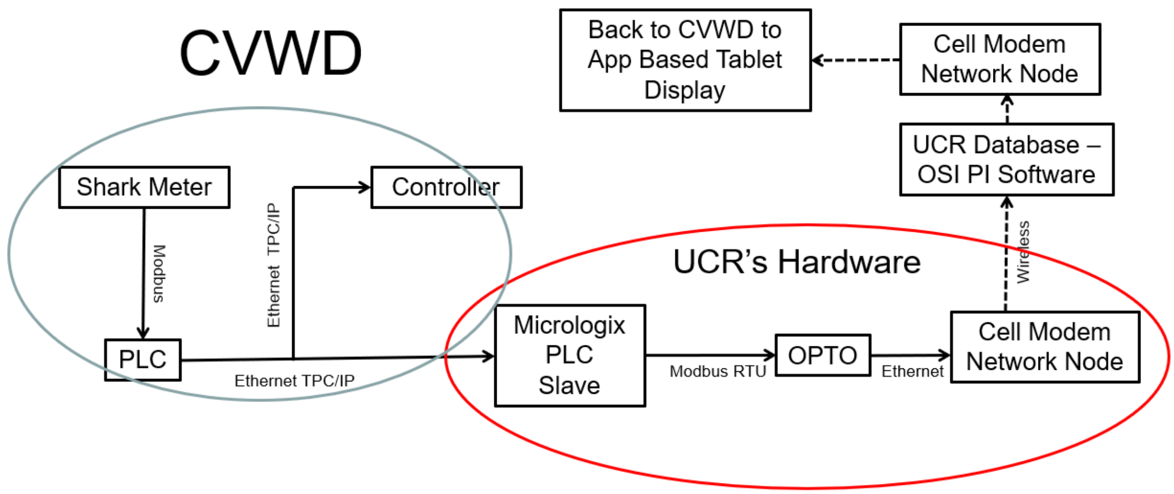
Source: University of California, Riverside

Figure 15: Olivenhain Municipal Water District System Showing Integration with University of California Riverside Proposed Hardware Solution



Source: University of California, Riverside

Figure 16: Cucamonga Valley Water District System Showing Integration with University of California Riverside Proposed Hardware Solution



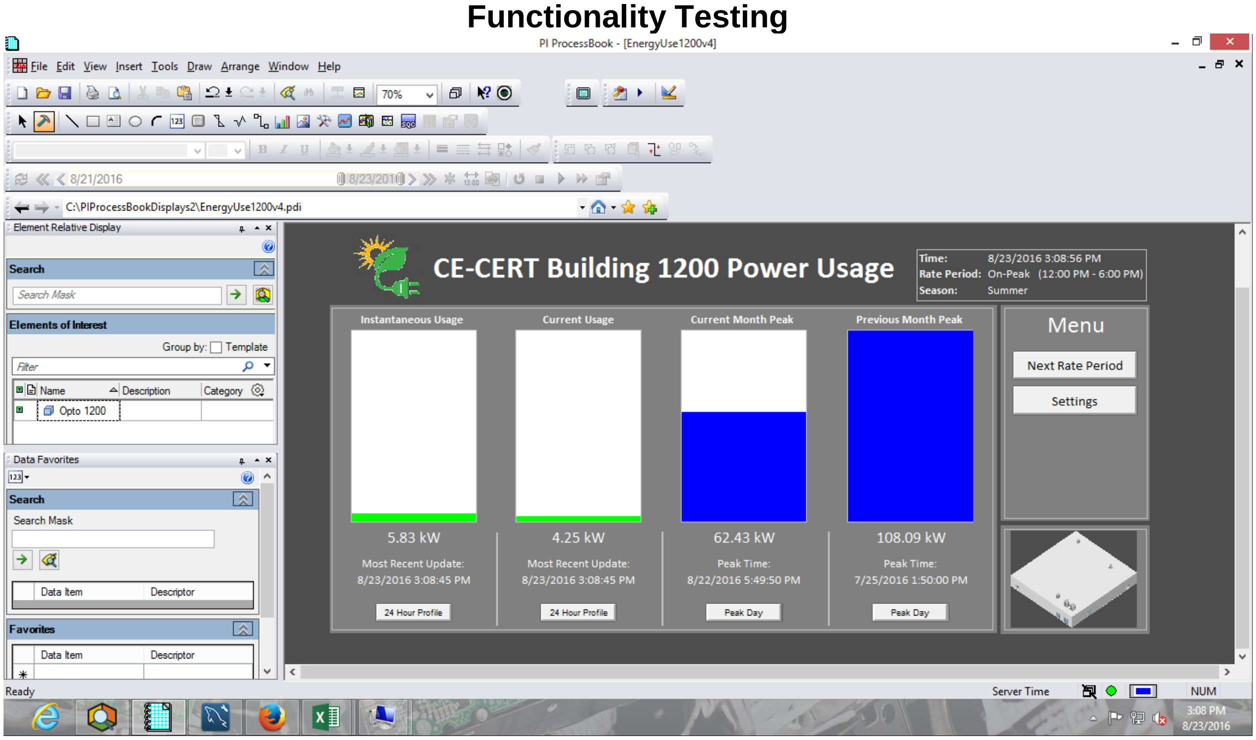
Source: University of California, Riverside

UCR has extensive knowledge and experience working with Opto 22 controllers and SoftPACK suite. An Allen Bradley MicroLogix 1100 PLC was the originally proposed hardware setup as the communications between the OMWD and CVWD existing PLCs, and the Opto 22 controller. This architecture was also designed to provide an additional layer of security to both water districts, by allowing the operational and energy data to be send to UCR's database without providing direct access into their network.

2.1.1 Analysis of System Component Integration Within Integrated Demand Side Management and Energy Management System Architecture

The proposed system components and EMS architecture were used within UCR's existing microgrid to optimize system characteristics and evaluate functionality. The original design was created by using the existing energy monitoring hardware to measure energy use. The facility that was used as a test site was a UCR research building.. This building is in a commercial setting with total energy consumption being monitored, recorded, evaluated, and displayed. Real-time energy use and peak energy demand was continuously evaluated. Figure 17 shows the display for the system prototype design and energy usage analysis. This system deployment served as the basis for evaluating integrated demand side management (IDSM) and EMS architecture for future deployment at any of the three water districts.

Figure 17: Dashboard Implemented at University of California, Riverside for Functionality Testing



Source: University of California, Riverside

2.1.2 Customized Integrated Demand Side Management and Energy Management System Design

Each individual site in IEUA, CVWD, and OMWD is managed by an on-site SCADA system with operated assisted strategies for demand response (DR) and uncontrolled events. Two energy management strategies are being proposed and coordinated for each of the water districts. The first strategy is to minimize the occurrences, frequency, and duration when the maximum energy demand set point is reached on the power usage dashboard. The second strategy is to provide an integrated notification system of current energy demand and prior energy usage history.

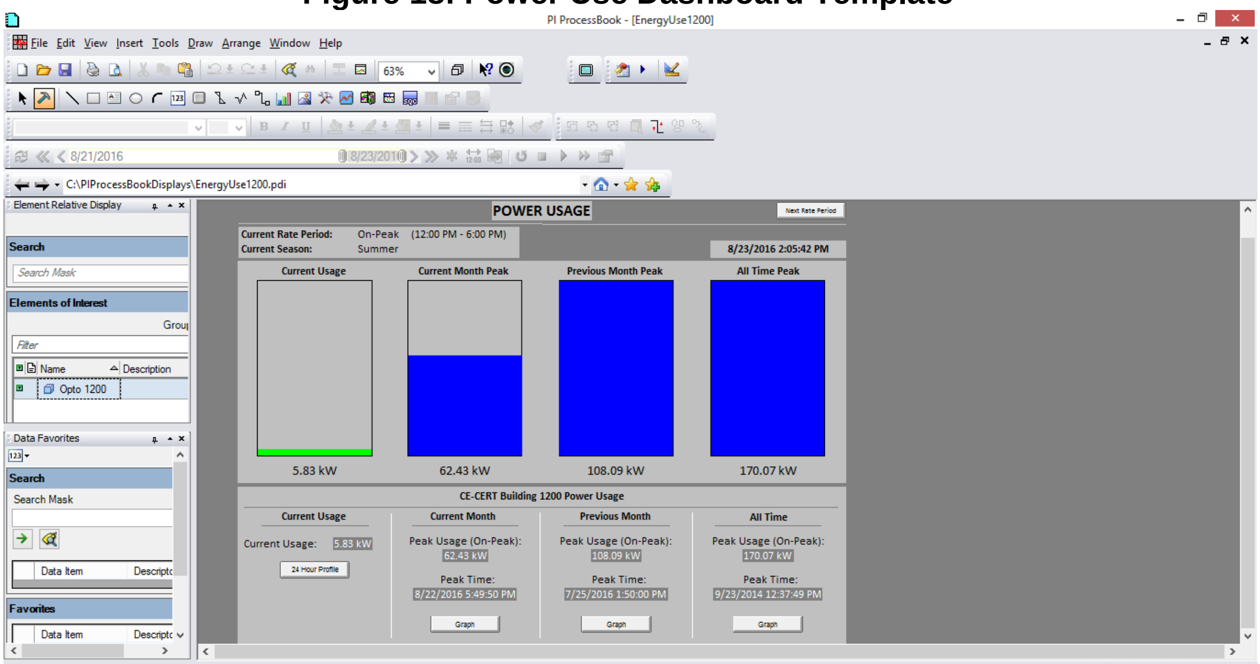
To minimize the occurrence, frequency, and duration of high energy activity for each district, an operational history of energy meter data and corresponding SCADA data was reviewed and evaluated. The review has identified specific operational events leading to brief periods of elevated energy use that could be mitigated through moderated pumping activity. To assist in alleviating high pump activity events, the system operational mode in conjunction with energy consumption was evaluated. The proposed control method is to reduce pump activity when recovering from DR and similar uncontrolled events. Situations leading to unusually low reservoir levels initiate maximum pumping response atypical for daily operation. These occasional events produce unusually high short-term energy consumption levels and correspondingly high energy costs. A proposed control strategy was coordinated to moderate pumping activity when compensating for atypical events. The control strategy does not compromise the overall system operation or recycled water supply.

The second management strategy was the integration of an energy advisory notification display to alert SCADA operators of real-time and historical energy use. The plant operators use the energy notification to aid in reducing real-time facility energy demand. The advisory notification provides alerts and feedback associated with peak operation energy demand for the specific meter rate schedule. The advisory notification displays the following:

- Real-time power demand (kW)
- Current and prior billing cycle maximum demand (kW)
- Current All Time Maximum demand (kW)
- Time of use billing period (peak, off-peak, mid-peak)
- Previous billing cycle maximum demand

The energy advisory notification provides direct and immediate feedback on energy utilization associated with facility operations. Plant operators are responsible for complex plant operations of numerous processes performing simultaneous functions. The plant operators are equipped to integrate energy demand as an operational consideration when energy demand would otherwise reach elevated levels. In addition, the integration of TOU utility rates schedule into their SCADA and EMS system is of high value. On project completion, the EMS now captures instantaneous data allowing for a migration from the existing demand base control scheme to a scheme capable of both demand and efficiency based controls. With these controls in place OMWD, IEUA, and CVWD are now able to operate at more efficient level to minimize electrical use and optimize operational efficiency. Figure 18 shows the dashboard displaying real-time energy, prior billing cycle, all-time maximum demand, TOU, and previous bill cycle maximum demand.

Figure 18: Power Use Dashboard Template



Source: University of California, Riverside

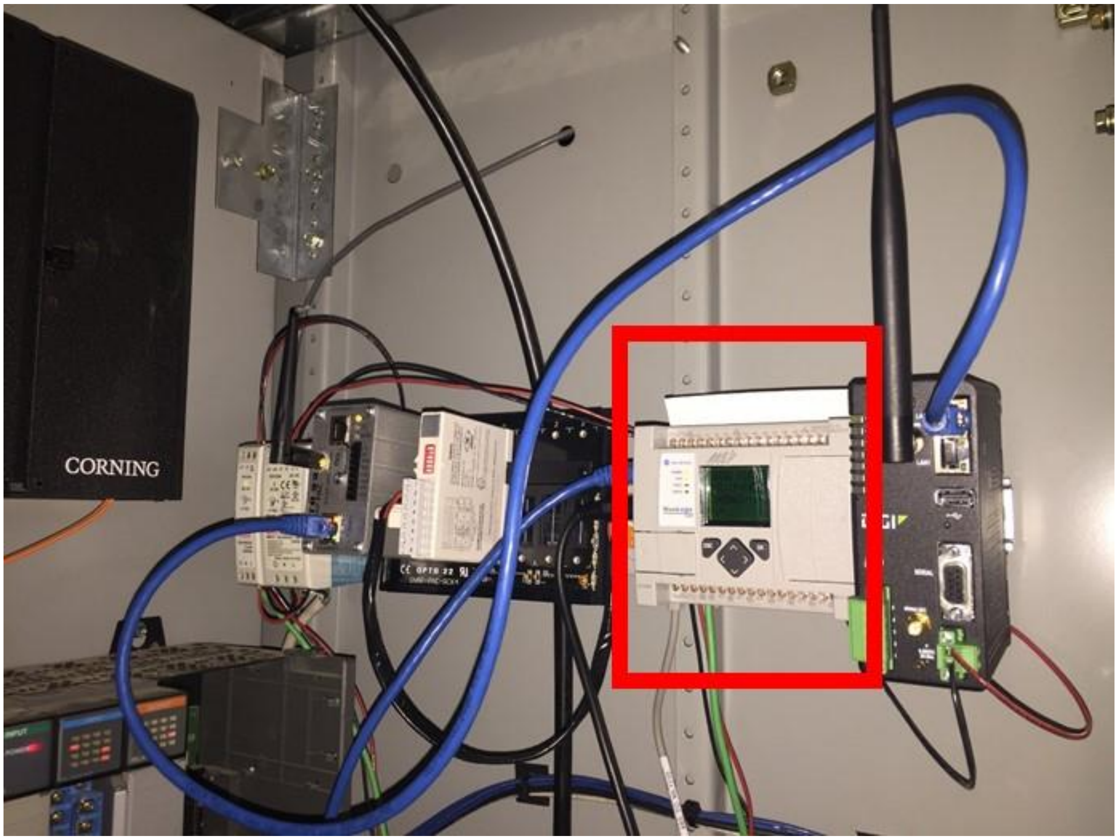
2.1.3 Integrated Demand Side Management and Energy Management System Components, Functions, and Operations

UCR and district partners collaboratively implemented an integration path for hardware, software, and control engineering into their existing system. The original hardware requirements included the installation of PLC's, OPTO 22, and Cellular Modem to produce real-time efficiency data to each water district. The cell modem is capable of transmitting communications to UCR servers and communicating back to the water district to ultimately reside alongside their existing SCADA network. Software requirements includes an EMS compatible that is used for energy monitoring and management strategies with the existing HMI. The system component installation at each site consisted of energy measurement, Modbus communication, data management, SCADA communication, and EMS display. Water districts had the option to utilize their existing SCADA networks or integrate project provided components.

2.1.4 MicroLogix Programmable Logic Controller Systems

The MicroLogix PLC Systems shown in Figure 19 includes embedded Ethernet/IP, on-line editing, and an LCD panel and was originally proposed to be integrated with existing hardware at each water district. The MicroLogix PLC was chosen because of its many features such as the built-in liquid crystal display (LCD) panel shows controller status, in/out (I/O) status, and simple operator messages. The MicroLogix controller can handle a wide variety of tasks using two analog inputs, 10 digital inputs and six digital outputs. The specific PLC tasks include transmission of Modbus electrical measurements from the meter location to the SCADA network.

Figure 19: MicroLogix Programmable Logic Controller Devices for SCADA Communication



Source: University of California, Riverside

2.1.5 DIGI Cell Modem

The Digi TransPort WR31 is a router designed for commercial or industrial applications. It provides a secure, connection and has the multicarrier capability such as global LTE and HSPA+. The modem is used a way to transfer data without connecting to the water district local internet. Using the Digi Cell modem allowed the team to transfer the data from the site to the servers at UCR, which is then stored into the SQL and OSIsoft PI data base. The features of the cell modem allowed the team to easily mount and connect to the modem since it had a wide range of features build into the modem:

- Ethernet, serial and I/O for connecting diverse field assets

- Extremely resilient cellular connection through Digi's patented SureLink, VRRP+ protocol, and dual SIM slots
- Enterprise Routing features for security, logging, and redundancy (stateful firewall, VPN, SNMP); no annual enterprise software license required
- Digi Remote Manager provides mass configuration, device management, and troubleshooting tools
- Rugged aluminum enclosure, optimized for Deutsche Institut fur Normung (DIN) rail or shelf mounting

2.1.6 Opto 22 SNAP Programmable Automation Controller System

The Opto 22 system consists of a combination of hardware and software that can be used to do industrial control, remote monitoring, and data acquisition. The SNAP PAC System used in this project consists of four integrated components:

1. PAC Project Software Suite—easy-to-use flowchart-based control programming, HMI development and runtime, plus optional OPC server, database connectivity software, and software-based controller for PC-based control
2. SNAP PAC controllers—standalone or rack-mounted industrial controllers with networking options and a RESTful API, or a software-based controller
3. SNAP PAC brains—intelligent I/O processors for distributed control on Ethernet (wired and wireless) and serial networks
4. SNAP I/O—analog, digital, and serial I/O modules for connecting to field devices, machines, and sensors

These four simple but flexible components form a system capable of handling any application from basic equipment monitoring to complete factory automation. Figure 20 displays the standard Opto22 SNAP PAC components.

Figure 20: Opto 22 SNAP Programmable Automation Controller Components

Source: OPTO 22

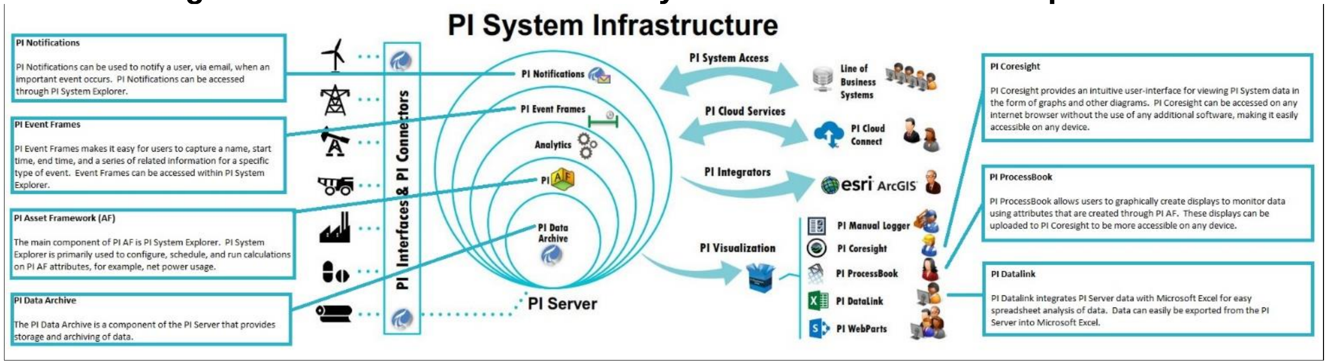
2.1.7 OSIsoft Process Information Software

The process information (PI) system is a suite of software products shown in Figure 21 that are used for data collection, historicizing, finding, analyzing, delivering, and visualizing. The basic PI system architecture is built upon the PI server, where PI tags are stored. These tags hold time series data for various processes. The next component in the PI system that is built upon the PI server is the PI Asset Framework, where PI tags are organized into a more understandable and logical asset configuration. The PI Asset Framework is primarily configured and adjusted using PI System Explorer shown in Figure 22, a software provided by OSIsoft. Within the Asset Framework, objects are called elements, and elements can reference PI tags as well as formulas, calendars, and a variety of other data sources shown in Figure 23. Elements can also be used in PI analyses, which are a kind of pseudo programming language built into the Asset Framework with a restricted set of functions. These analyses can check for critical events, such as a data loss or a new peak power measurement, and these events can then trigger PI notifications. PI notifications are built into the PI Asset Framework, and therefore access the PI Data Archive to deliver email notifications when critical events are detected.

Data can be automatically collected from many different sources (Control systems, Lab equipment, Calculations, Manual Entry, and/or Custom software). Most information is gathered using one of the many OSIsoft and third-party PI Interfaces. Users can then access this information using a common set of tools (ex. Excel, web browser, PI ProcessBook) and look for correlations. Some examples include:

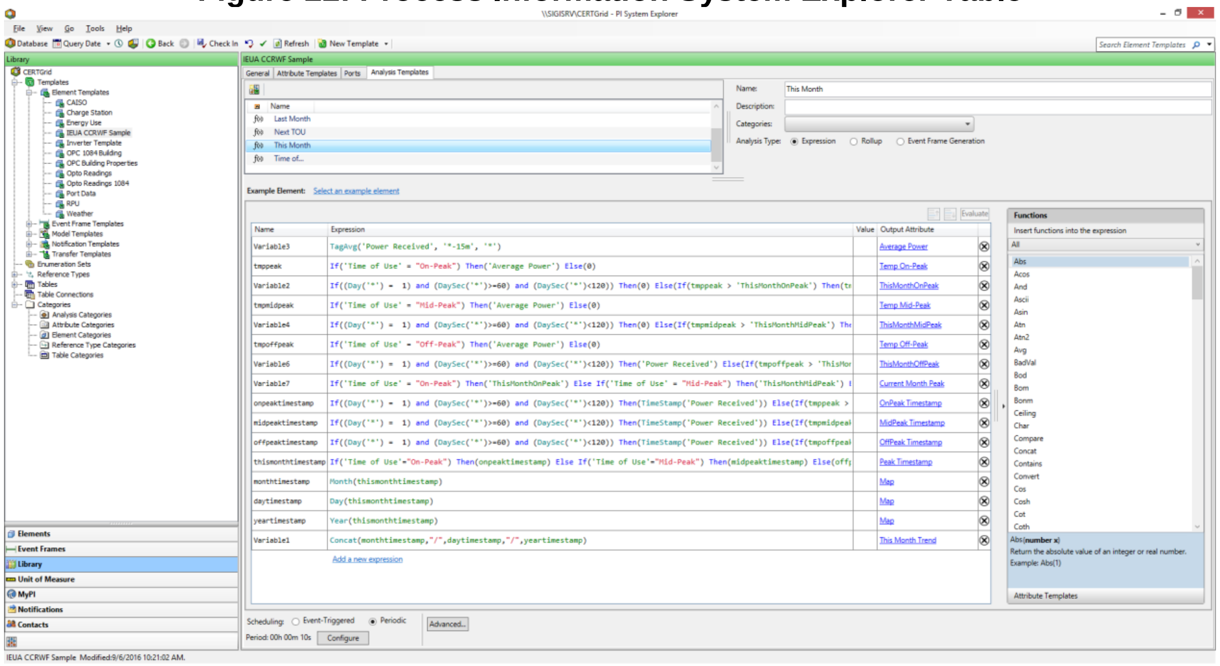
- Analyzing seasonal trends
- Determining if utilities are meeting the demands of production
- Comparing the performance of different lots of raw material;
- Determining when maintenance is required on equipment
- Optimizing the utilization or performance of a production line

Figure 21: Process Information System Infrastructure Components



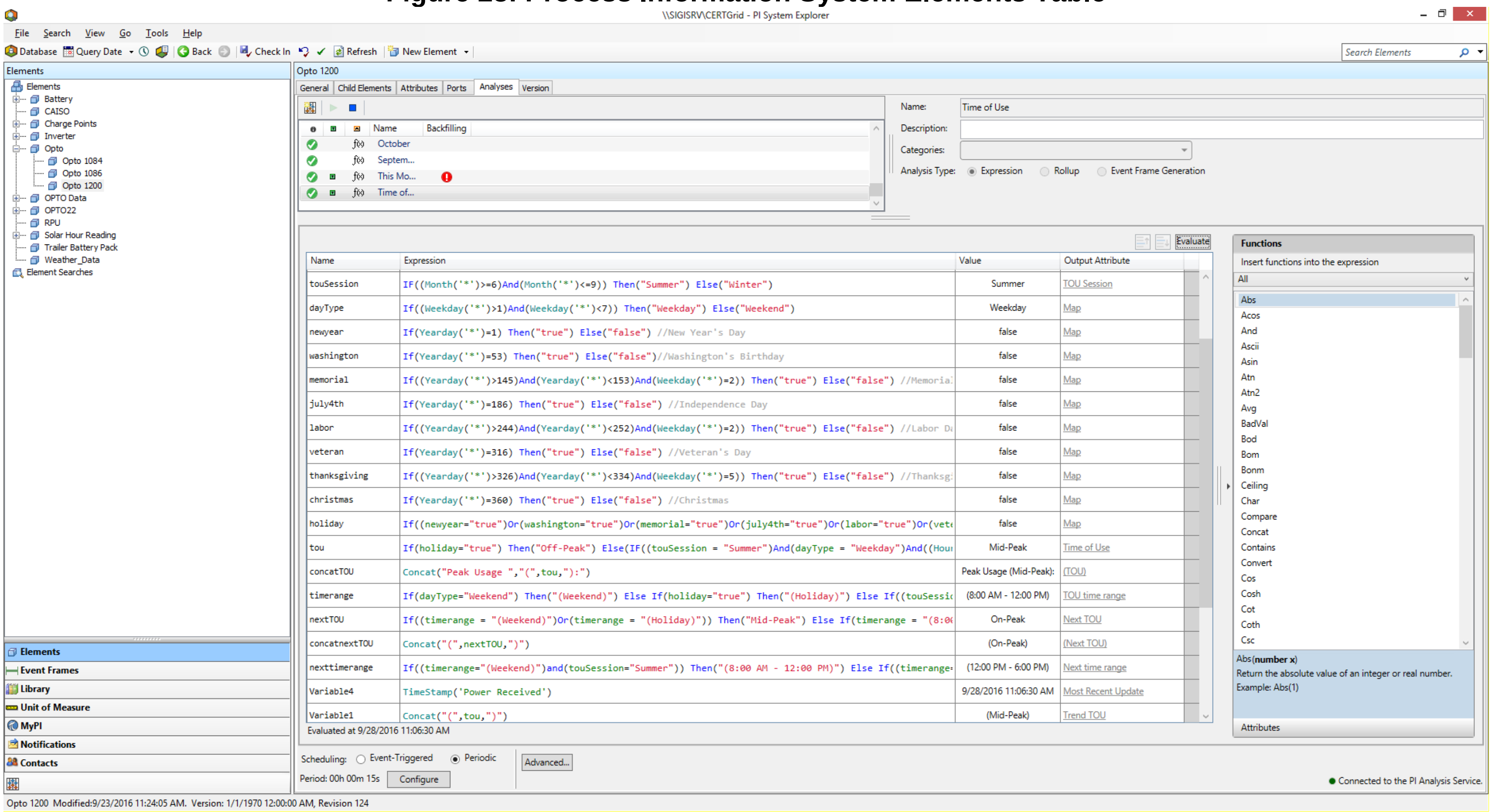
Source: OSIsoft

Figure 22: Process Information System Explorer Table



Source: OSIsoft

Figure 23: Process Information System Elements Table



Source: OSIsoft

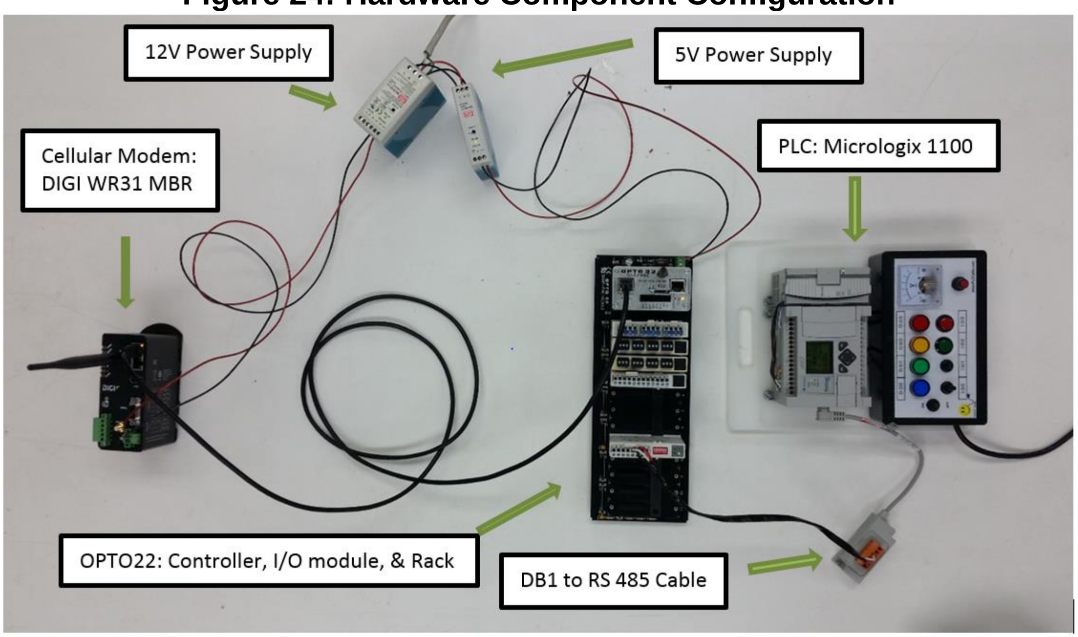
2.2 Component Configuration and Test Plan

The project locations require SCADA hardware integration coupled with EMS strategies to aid the water district in system efficiency and reduction of electricity costs. The project specifically aims to reduce peak demand costs that are determined on time of use and peak energy usage for pumping operations. CE-CERT has experience working with OPTO22 controllers and their Soft Pack suite, and has integrated the components to monitor the energy use at a facility for implementation of IDSM EMS strategies. To keep the water district systems integrated with the existing SCADA architecture an Allen Bradley Micrologix 1100 PLC was used as the communications middle man between the Districts PLC's and the OPTO22 Controller.

The items shown in Figure 24 include:

- Micrologix 1100 Trainer Set
- 12V DIN Rail Power Supply
- 5V DIN Rail Power Supply
- DIGI WR31 Mobile Broadband Router
- RS 485 DB1 Conversion Cable for Micrologix
- SNAP-SCM-485-422
- Opto Rack with Brain

Figure 24: Hardware Component Configuration



Source: University of California, Riverside

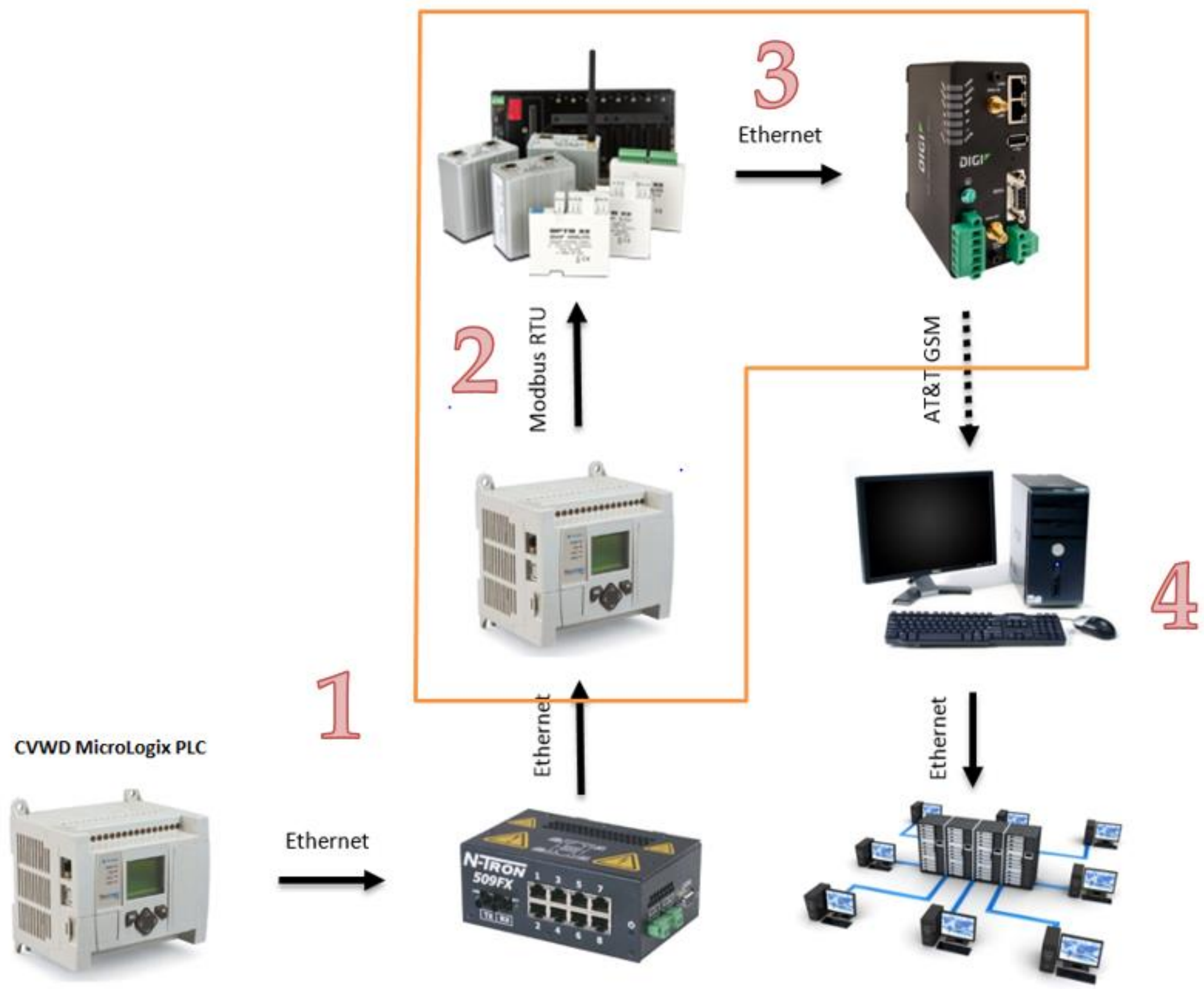
2.2.1 System Explanation

The implemented architecture allows the components to communicate with each other and send data to the Sustainable Integrated Grid Initiative (SIGI) database. The SIGI database is the existing EMS database at the test facility located at CE-CERT. The other project components are already implemented in the system and some have been there since before the project started, this includes everything outside of the orange border.

The following items are detailed in Figure 25:

- Communication from existing SCADA Micrologix to our EMS Micrologix
- Communication Between EMS Micrologix and OPTO SNAP PAC
- Communication Between OPTO and DIGI modem
- Communication Between DIGI modem and EMS Servers

Figure 25: Overview of Hardware Communication Protocols



Source: University of California, Riverside

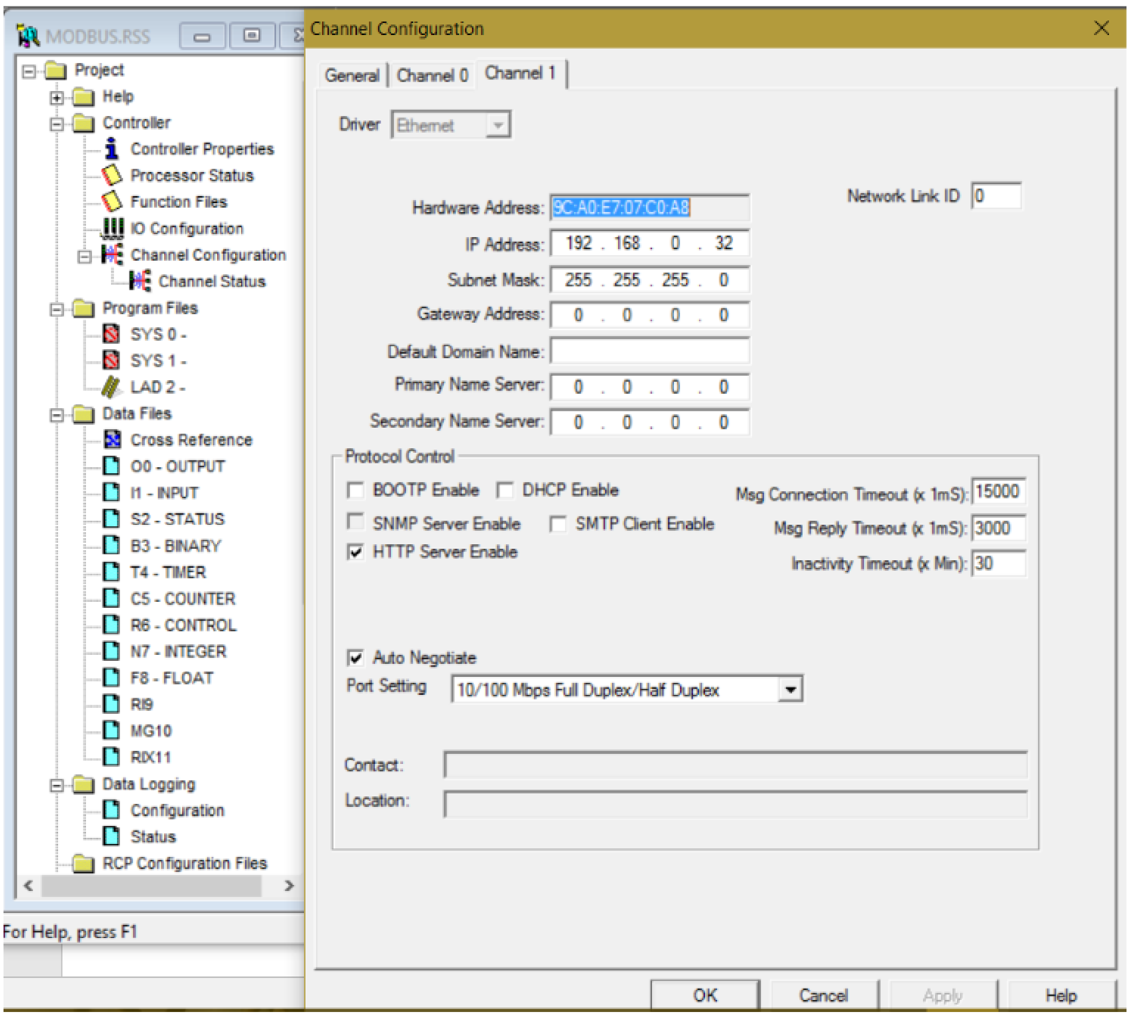
2.2.2 Communication between Cucamonga Valley Water District and Micrologix 1100

Figure 26 shows communication between the SCADA and EMS Micrologix devices utilizes Ethernet protocol. This has already been configured and tested using OPTO to Micrologix. Configuration between Micrologix to Micrologix also utilizes Ethernet protocol.

The final IP address was determined on-site by CVWD and adjusted in the configuration window shown to the right using RSLogix Software.

This is simulated in the test bench by an incremented value that simulates the incoming messages from the water district. When installed, these messages will be energy data that allows the user to easily see the results in these tests.

Figure 26: Configuration Between Micrologix to Micrologix also Uses Ethernet Protocol

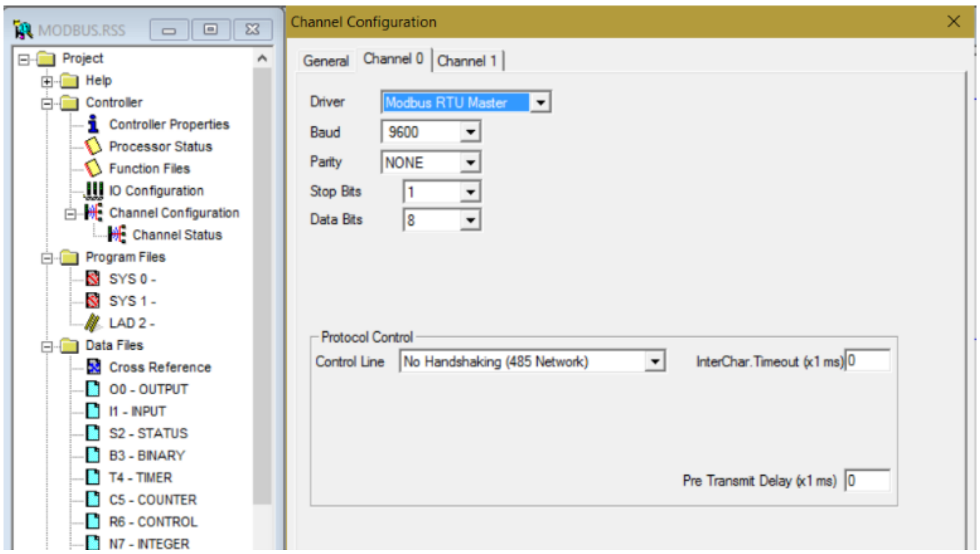


Source: University of California, Riverside

2.2.3 Communication between Micrologix and OPTO SNAP Programmable Automation Controller

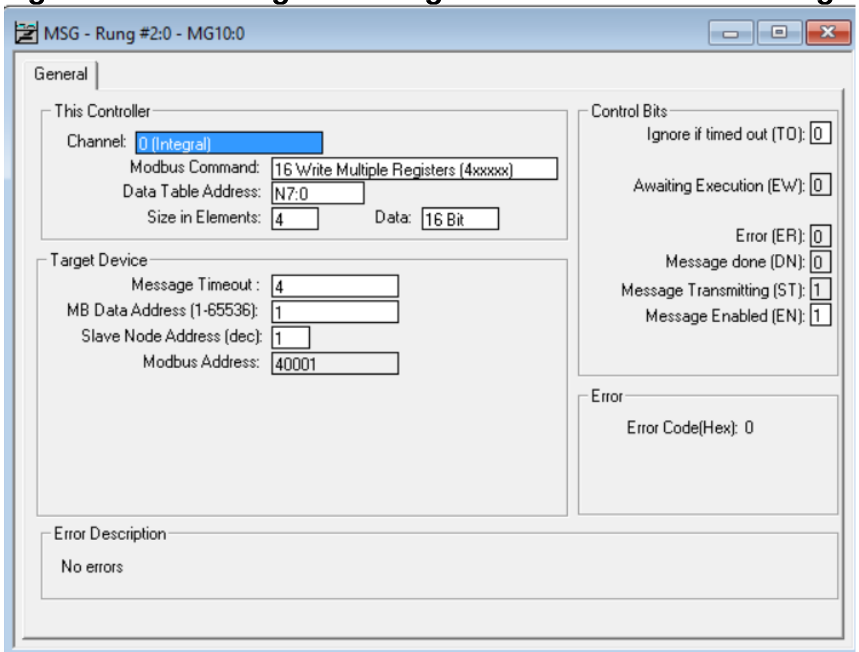
The communication protocol between the Micrologix and Opto components is Modbus RS-485. Just like in the Ethernet communication this is configured using the Channel configuration tool provided in the RSLogix and is set to Modbus Remote Terminal Unit (RTU) at a baud rate of 9600 along with some other necessary configuration settings (Figure 27). Additional configuration is required by creating a message (MSG) block in the ladder logic that tells the controller where to obtain the data from, in this case 4 integers from register N7 as seen in Figure 28.

Figure 27: RSLogix and is Set to Modbus Remote Terminal Unit at Baud Rate of 9600



Source: University of California, Riverside

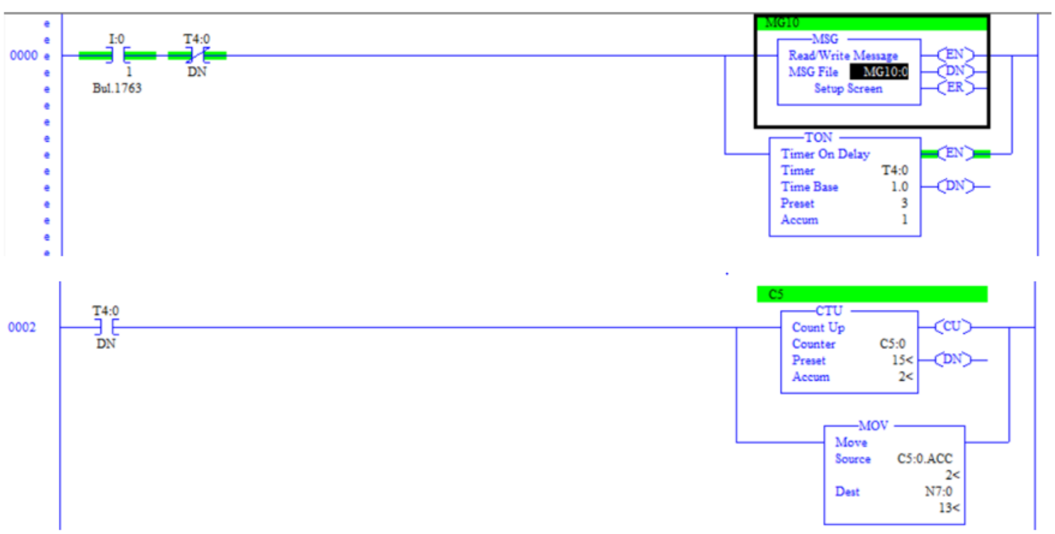
Figure 28: Creating a Message Block in the Ladder Logic



Source: University of California, Riverside

Testing this communication was completed by creating an auto incremented value that would simulate the data coming from the water district SCADA. Figure 29 shows how ladder logic is implemented by creating a timer (within Timer on Delay (TON) block) that ticks every 3 seconds and activates the Count up timer (within Count Up (CTU) block). This value is then moved to the designated register N7:0 where the data was packaged and transmitted via Modbus.

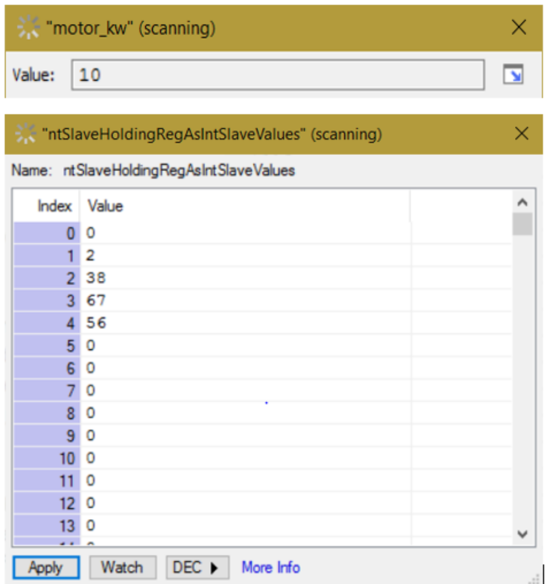
Figure 29: Ladder Logic



Source: University of California, Riverside

Relative to OPTO22 components the integration and evaluation ensures that the variable receives the data from the Micrologix is auto incremented as expected. As can be seen to the right variables 1 through 4 contain values, and only value 1 is auto incremented during testing as expected. This variable is then moved to a "secure" location which is verified by checking out the variable during runtime in Figure 30.

Figure 30: "Secure" Location Verification

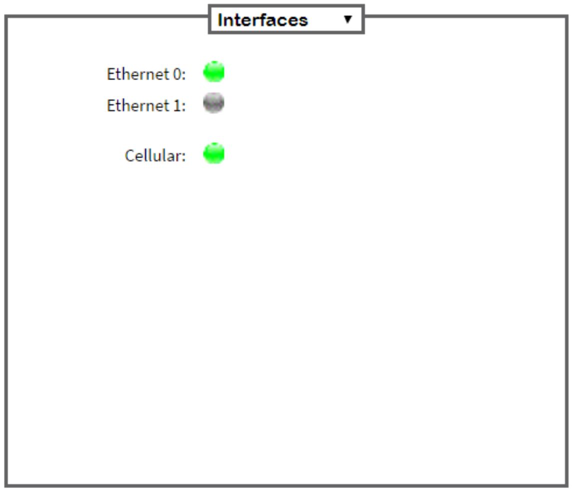


Source: University of California, Riverside

2.2.4 Communication Between OPTO and DIGI

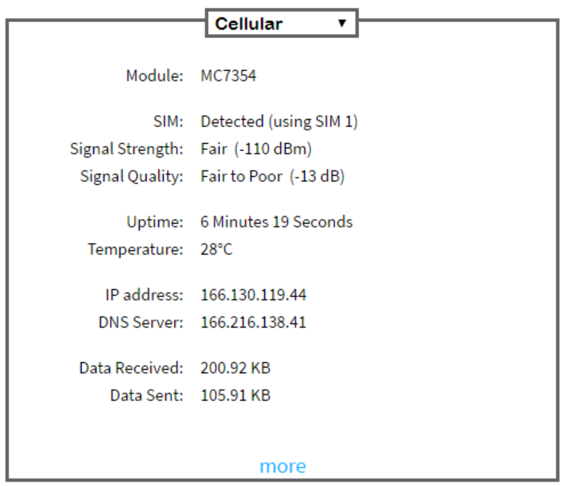
Configuration and communication from OPTO22 components to the DIGI modem allows data to be transmitted to the EMS Server. Communications into the network created by the DIGI port. Forwarding must be configured and transmitted according to IP networking requirements.

Figure 31: Interfaces



Source: University of California, Riverside

Figure 32: Cellular Status



Source: University of California, Riverside

Standard IP address "location" (IP Address) of the DIGI device could change based on AT&T network configuration at the time, so the research team procured an account with a static IP address. This IP address is administered by the cellular provider (AT&T). To test the cellular connection using the DIGI device and login required the gateway IP address of 192.168.1.1. The main window displayed the status of the device.

The configuration settings allowing for port forwarding are shown in Figure 33. These options are then saved to the device's flash memory using the "Save Configurations" option which ensures the data is not lost during a power cycle of the device.

Figure 33: Configuration of Port Forwarding

Forward connections from external networks to the following internal devices.
In order to forward to an internal port, an interface must have its NAT configuration set to "IP address and Port".

(you may configure up to 30 forwarding rules):

External Min Port	External Max Port	Forward to Internal IP Address	Forward to Internal Port	
22001	22001	192.168.1.65	22001	Delete
				Add

Source: University of California, Riverside

2.2.5 Communication between DIGI and Servers

OPTO uses the OptoDataLink software which pulls data from the OPTO device. The database is newly established and still requires specific site configuration. Initial testing confirms the communication of data originating from the OPTO22-connected SCADA through the DIGI modem to the EMS server database. Once the setting and options are set in OptoDataLink, the data is recorded in the server. This data is then used to create the user interface using OSIsoft software.

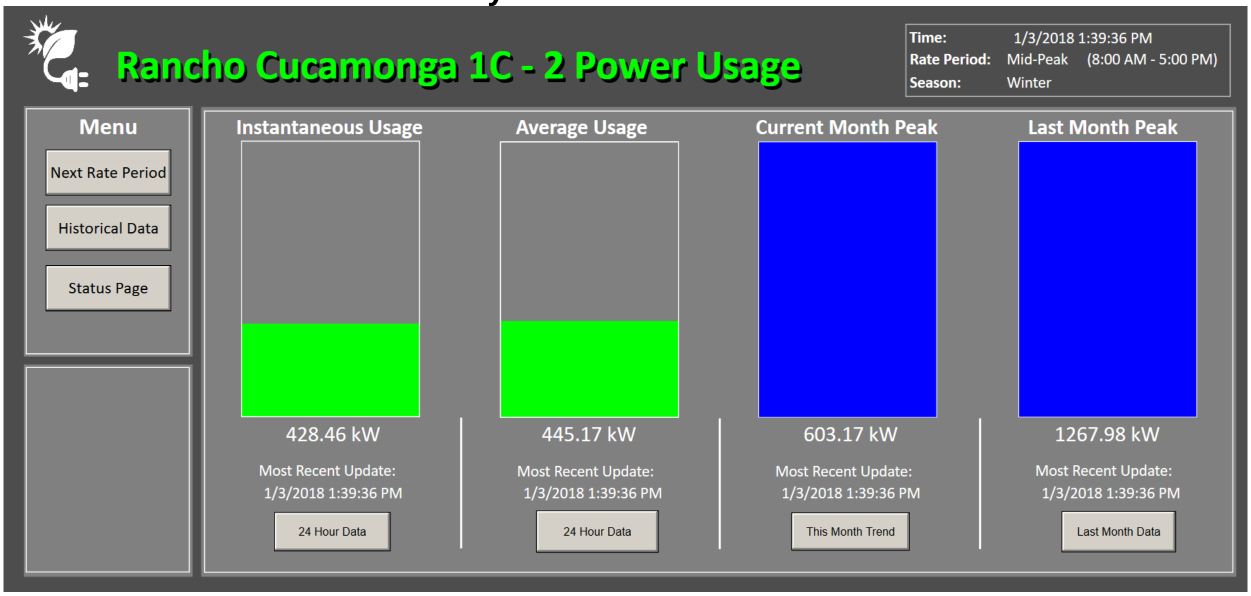
2.3 Energy Management System Outline

The Energy Management System utilizes a display within the OSIsoft environment. The display allows users to easily view various power use figures, including:

- Instantaneous power usage
- 15-minute average power usage
- Current month peak power usage
- Previous month peak usage

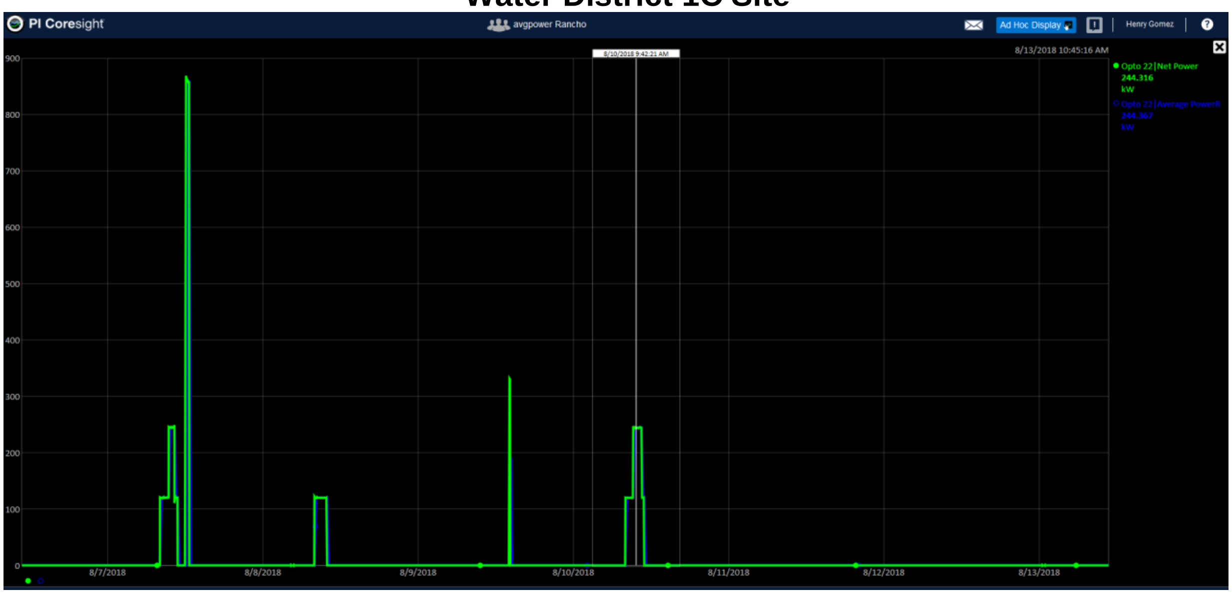
Instantaneous and actual use change color based on how close they are to the current month peak, and provide a visual warning when power usage is excessive. Current month and previous month peak values are dependent on the rate period shown in Figure 34, meaning they change based on the current rate period. There are also graphs available for the current month, previous month, and the past 7 hours for instantaneous and actual power use, shown in Figure 35. The menu on the left allows users to navigate to different pages to view peaks for the next rate period, view historical data for the past year, or view data for other buildings. In the bottom left of the display, there is a window to view solar generation and battery information. Lastly, there are email notifications for when power usage gets too high.

Figure 34: Main Display of the Energy Management System for the Cucamonga Valley Water District 1C Site



Source: University of California, Riverside

Figure 35: Graph of the Seven Hours of Actual Power Use at Cucamonga Valley Water District 1C Site



Source: University of California, Riverside

2.3.1 Collecting Data

As described in section 2.1, the real-time power use data must be collected from the existing SCADA components. Opto 22 is used to collect data for power received from the grid and power delivered to the grid. The data can then be saved in a relational database management system (RDBMS), such as MySQL. The PI Interface is configured in PI Interface Configuration Utility to transfer data to the PI Server. This data is saved as PI Tags, one for power received, and one for power delivered.

2.3.2 Calculations

All energy calculations occur within PI System Explorer. Results of the calculations are stored in new PI Tags. For example, net power usage can be calculated by taking the difference between power received from the grid and power delivered to the grid, and the output could be saved as a tag named Net Power.

Since the display changes based on the rate period, one of the first things that must be calculated is the rate period, also known as TOU. TOU, next time of use, time of use time range, and next time of use time range are all used within the display, and have relatively similar calculations. To determine TOU, calculations have to be performed to check for the season, holidays, day of the week, and time. Appendix A shows the structure for these calculations. The next two sections of calculations are used to determine the current month peak power use, and the previous month's peak power usage for each rate period. These parameters are calculated in real-time by comparing the current power usage with the peak power use for the current rate period.

The PI System also displays the energy information in bar graphs color-coded to represent increasing energy levels. The graphs are percentage-based rather than value-based because some months have much lower power use, which would result in bars with minimal fill.

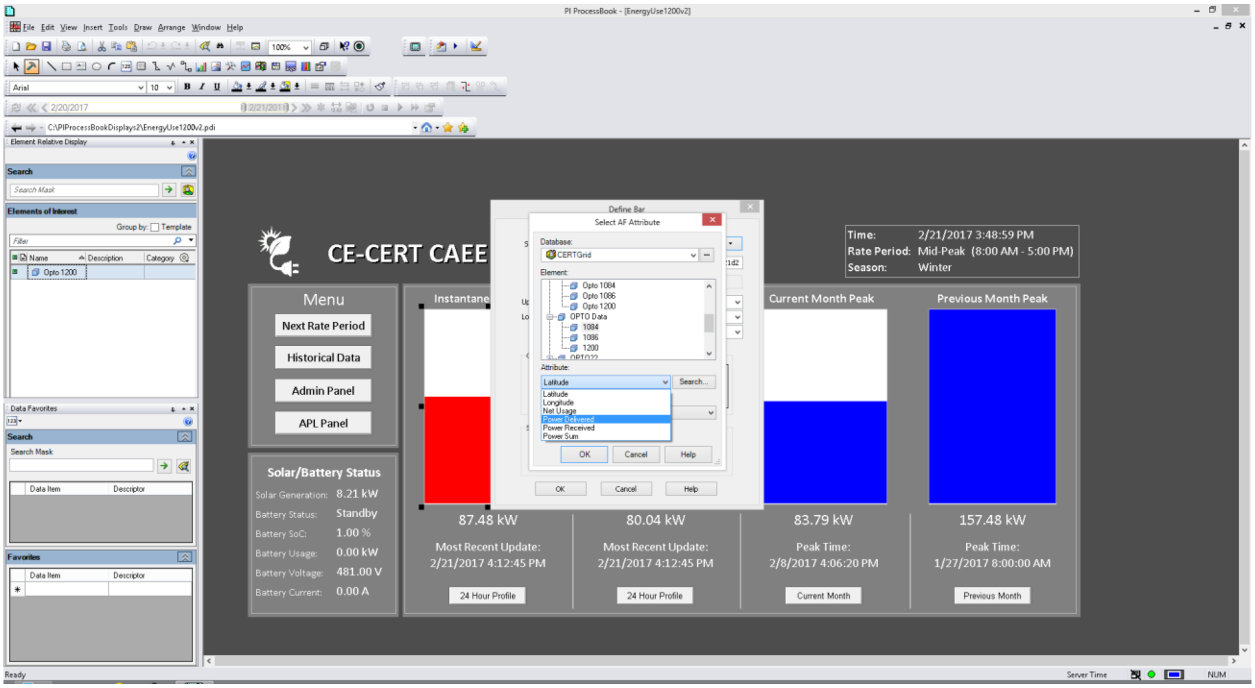
Lastly, there are historical data calculations for each month, to store the peak power usage for each rate period at the end of each month. These values are only kept for one year, and then they are overwritten when the month repeats.

2.3.3 PI ProcessBook Display

PI ProcessBook provides an intuitive interface that allows attributes, which can range from current energy delivered to current time, that have already been calculated in PI System Explorer to be visually displayed. Calculations themselves are not completed in ProcessBook.

Creating a display is achieved in Build Mode (hammer icon) and with the various tools on the taskbar. Graphics such as bar graphs and line graphs are created, which should then be linked to an attribute to display its corresponding value on the graph (Figure 36). Simpler graphics such as rectangles and lines are created to shape the look of the display. In addition, buttons are created for navigating throughout the multiple "pages" of the display. Displays are run and tested by clicking Run Mode (cursor icon).

Figure 36: Selecting an Attribute to be Displayed on a Bar Graph in Process Information ProcessBook



Source: University of California, Riverside

2.3.4 PI Coresight Display

PI Coresight serves as an alternative to view displays done in PI ProcessBook without having to use the Run Mode function on PI ProcessBook. All displays created on PI ProcessBook are automatically uploaded to PI Coresight. To use Coresight, the user connects to UCR's network either directly or through UCR's proxy.

2.3.5 PI Notifications

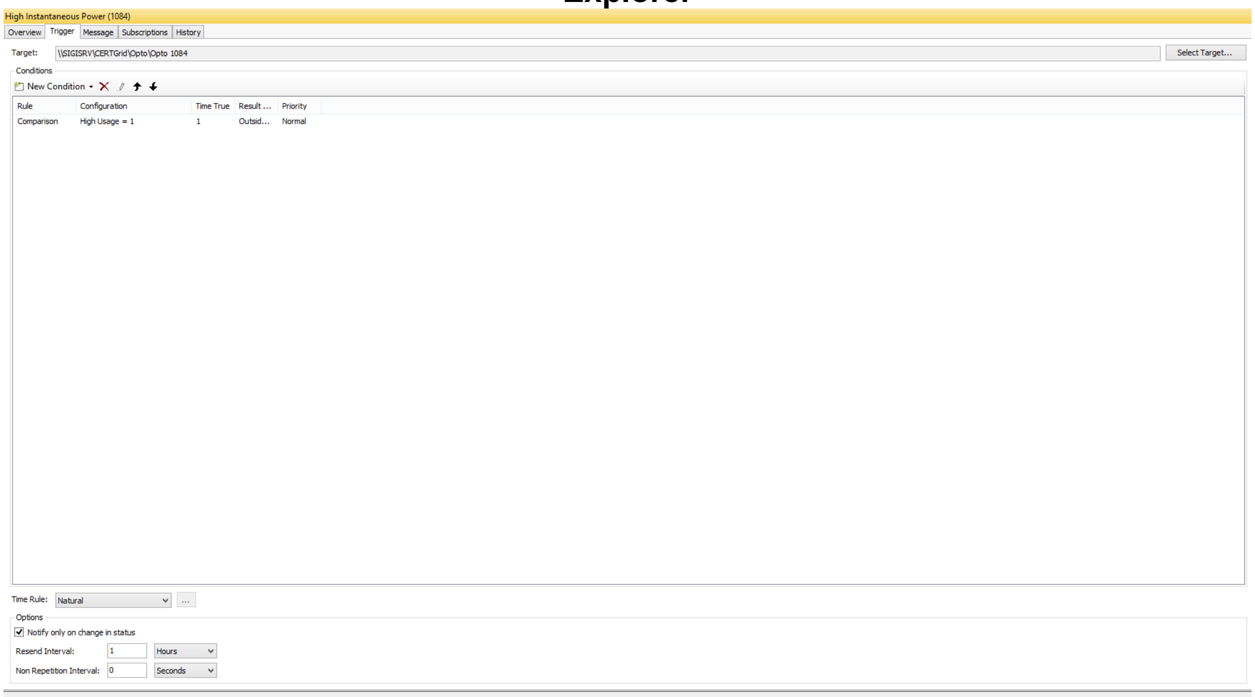
The PI Asset Framework (PI AF) manages the email notifications that are triggered when certain EMS thresholds had been met. Notifications can be accessed and edited by the PI System Explorer. These notifications can be setup to send email notifications based on thresholds defined in the PI System Explorer. For example, the high-power notification uses the variables defined in Figure 37 to determine if the email notification should be sent. By declaring a condition, such as the one in Figure 38, it is possible to control the rate in which email notifications are sent.

Figure 37: Variables Used for Email Notifications in Process Information System Explorer

Name	Expression	Value	Output Attribute	
MinPeak	`Min('JanPeak','FebPeak','MarPeak','AprPeak','MayPeak','JunPeak','JulPeak','AugPeak','SepPeak','OctPeak','NovPeak','DecPeak')`		Map	⊗
Variable1	`If(('Power Sum'>='Current Month Peak')and('Power Sum'>(MinPeak))and('Average Power'<'Current Month Peak')) Then(1) Else(0)`		High Instantaneous Power	⊗
Variable2	`If('Power Sum'='Average Power') Then(1) Else(0)`		No Data	⊗
Variable3	`If(('Battery Usage' <> 0)and(HasChanged('Battery SoC','*-10m')="False")) Then(1) Else(0)`		Inverter Down	⊗
Variable4	`If(('Average Power'>='Current Month Peak')and('Average Power'>(MinPeak))) Then(1) Else(0)`		High Average Power	⊗

Source: University of California, Riverside

Figure 38: Conditions Used for Email Notifications in Process Information System Explorer



Source: University of California, Riverside

PI System Explorer is also used to edit the content of notifications. The notifications are used to display the time and value at which the condition was met. Additionally, email notifications can be forwarded as text message by setting up email forwarding through the email provider. Figure 39 illustrates the forwarded email notification.

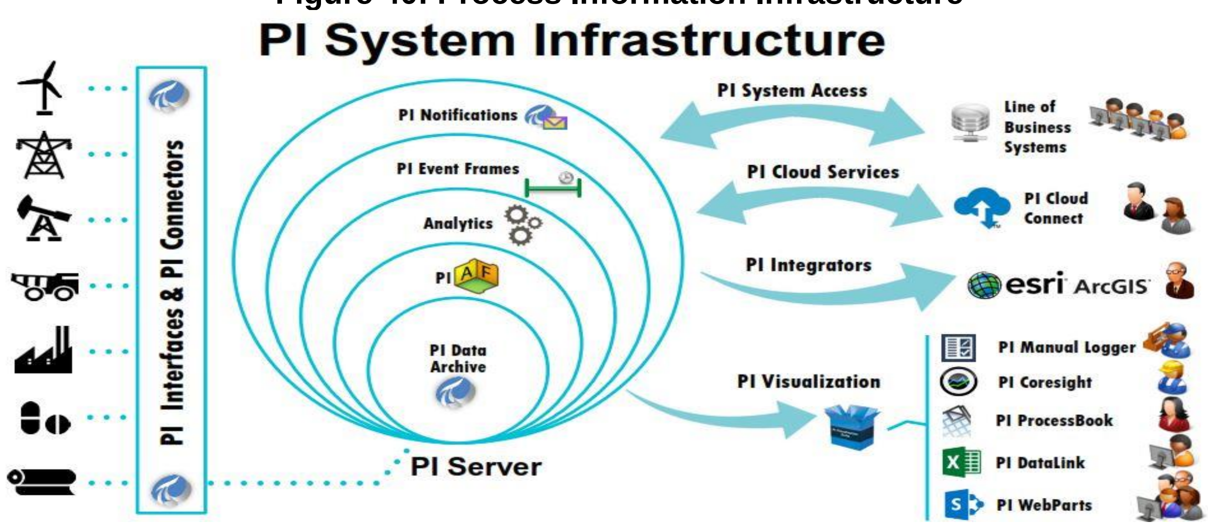
Figure 39: Email Notification Forwarded as a Text Message

Source: University of California, Riverside

2.4 Process Information Infrastructure

The PI System consists of three main components: PI Interfaces and Connectors, a PI Server, and PI Clients. Each of these components are shown in Figure 40, from left to right. PI Interfaces and Connectors format data from data sources to be uploaded to the PI Server. The PI Server stores all of the data and provides a user interface to manage the data, do calculations, and send notifications. PI Clients are programs that allow users to visualize data in the form of graphs and spreadsheets.

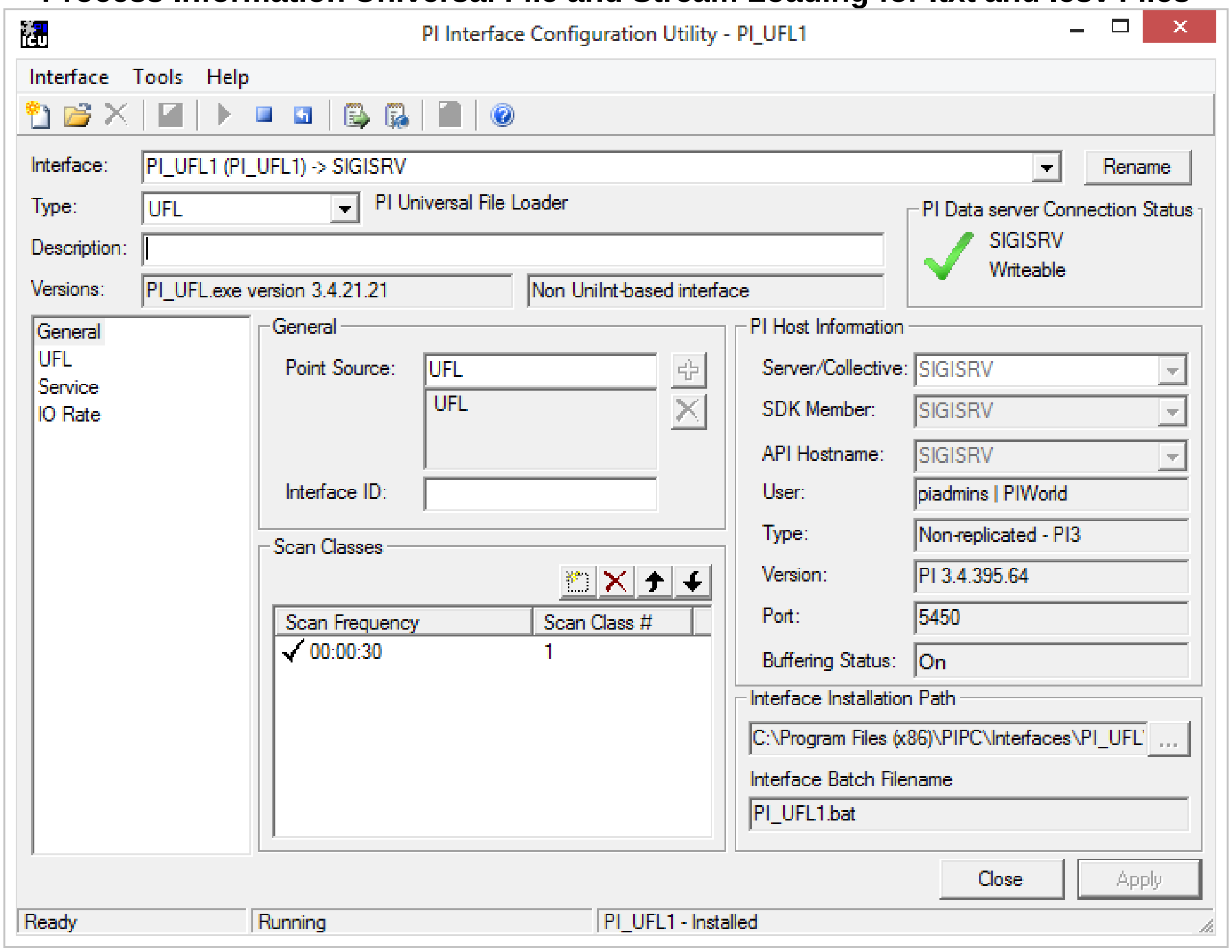
Figure 40: Process Information Infrastructure



Source: OSIsoft

SCADA data is initially retrieved from a data source, like a pump, motor, tank, etc. However, data from data sources are in their own proprietary language, which is not necessarily compatible with the PI Server. The role of PI Interfaces and Connectors is to translate the data into something that can be forwarded to the PI Server. PI Interfaces are configured using PI Interface Configuration Utility (PI ICU). Interfaces are configured to receive data directly from data sources, from a relational database management system (RDBMS) like MySQL, or from simple txt or csv files. Figure 41 shows a PI ICU Interface that was created to import txt and csv files using Universal File and Stream Loading (UFL).

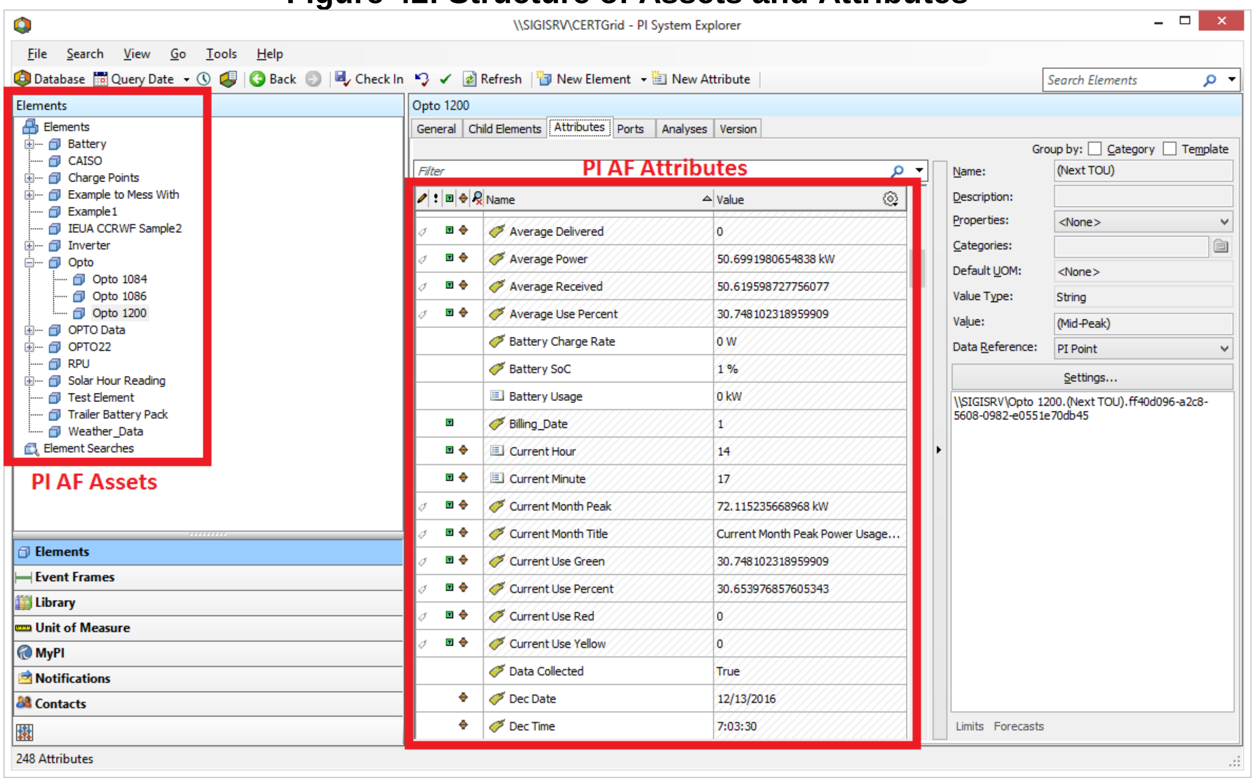
Figure 41: Process Information Interface Configuration Utility Used to Configure Process Information Universal File and Stream Loading for .txt and .csv Files



Source: University of California, Riverside

After data is configured properly using PI ICU, it is sent to the PI Server. The PI Server consists of PI Data Archive, to store data, and PI Asset Framework (PI AF), which provides a user-friendly interface for managing data. The main component of PI AF is the program PI System Explorer. Within PI System Explorer there are PI AF Assets and PI AF Attributes. PI AF Assets are organized in a hierarchical system and are used to represent physical items, like buildings, pumps, or tanks. PI AF Attributes describe the Asset associated with them. For example, power use is an attribute that can be associated with a building or an asset. Other examples could be temperature in the building or the height of water in a tank. This structure of assets and attributes is detailed in Figure 42, with assets on the left side and attributes in the middle. Attributes can also be the result of a calculation. For example, an attribute representing the volume of water in a tank might be obtained from the height of the water and the cross-sectional area of the tank. All of these attributes are stored in the form of a PI Tag. PI Tags store real-time data that can easily be graphed against time using a PI Client.

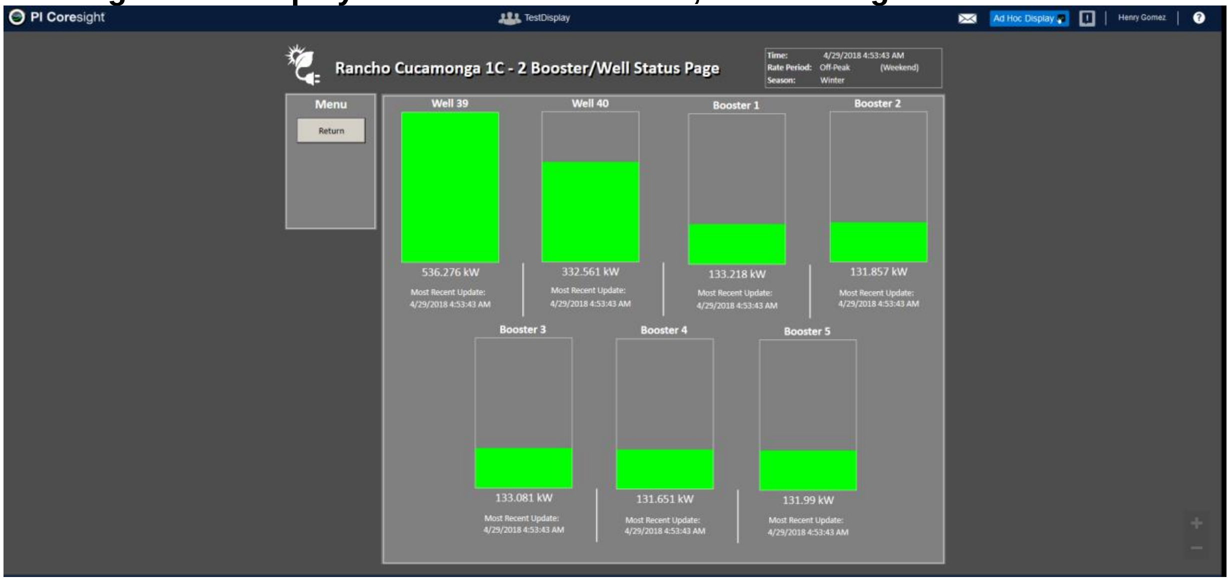
Figure 42: Structure of Assets and Attributes



Source: University of California, Riverside

PI Clients are programs that allow users to easily access and view data that is stored on the PI Server. This can be in the form of various graphs and charts within PI ProcessBook and PI Coresight, or in the form of spreadsheets, using PI Datalink. PI ProcessBook is a program that allows users to create dynamic, interactive graphics and trends featuring real-time PI data. PI Coresight is very similar to PI ProcessBook, but it is a web-based program that can be accessed on any browser, making it more accessible. All displays that are created with PI ProcessBook are automatically uploaded to PI Coresight. Figure 43 shows an example of a PI ProcessBook CVWD booster/Well activity display being viewed on PI Coresight. Lastly, PI Datalink is a plug-in for Microsoft Excel that integrates PI Server data with Excel, allowing for analysis in the form of spreadsheets.

Figure 43: Display to Monitor Power Use, Made Using PI ProcessBook



Source: University of California, Riverside

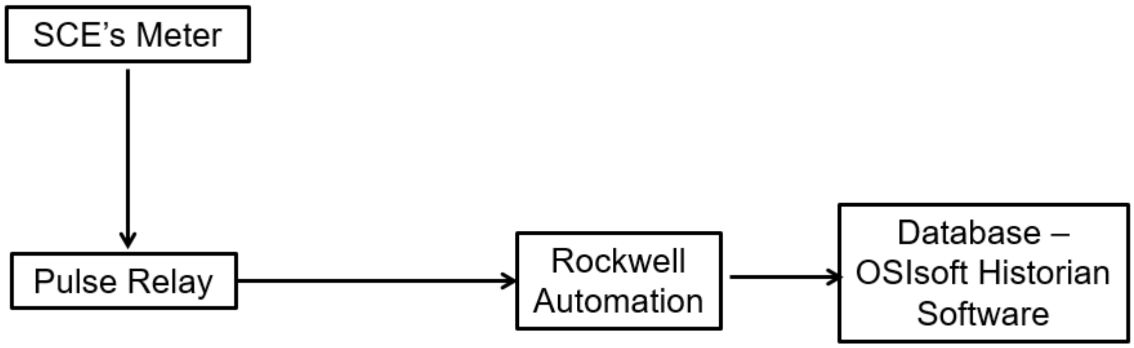
2.5 Final Site Design for Each Water District

UCR's energy management system is designed to integrate with a variety of industry-standard systems and equipment, regardless of equipment manufacturer, including:

- Building automation and management systems
- SCADA and other industrial monitoring systems
- Bill management systems
- New and existing metering equipment

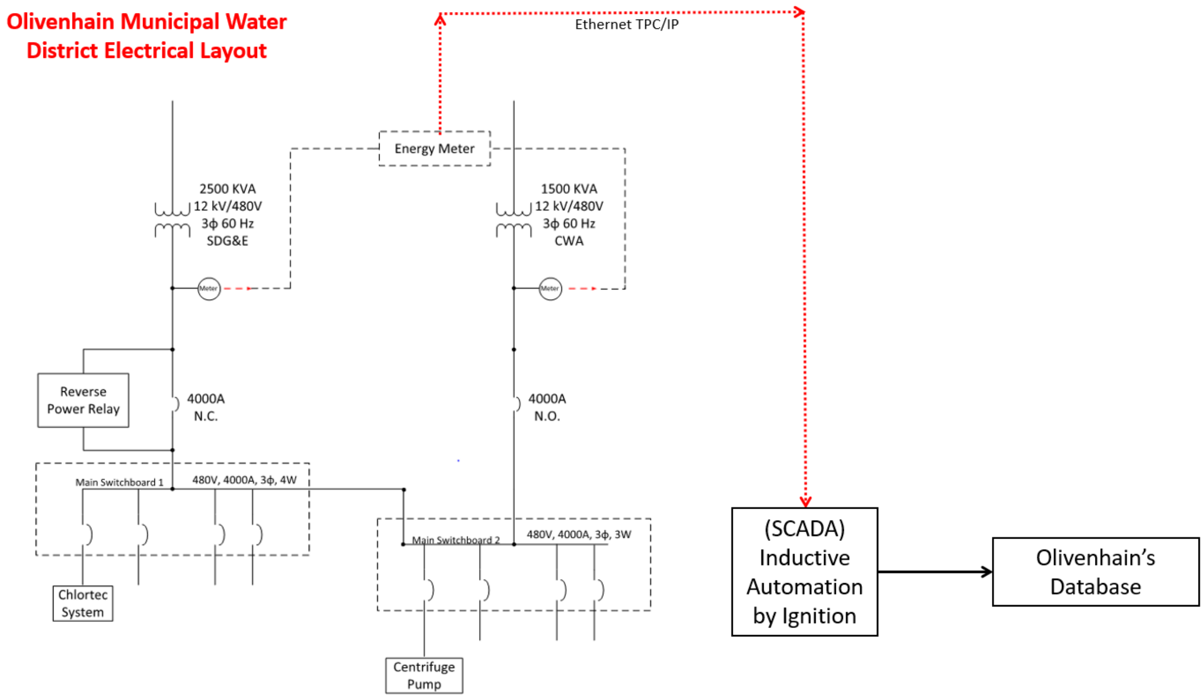
Figure 44, Figure 45, and Figure 46 demonstrate the final design and layout for integrating the EMS system design into each water district. The EMS installations include systems fully integrated on-site at IEUA and OMWD. At CVWD, the integration went through two iterations with the final iteration installing OSIsoft software at the water district. Each system installation and configuration requires a system integrated energy measurement located on the customer side of the meter for the location of interest.

Figure 44: Inland Empire Utilities Agency System Showing Integration with Pulse Relay



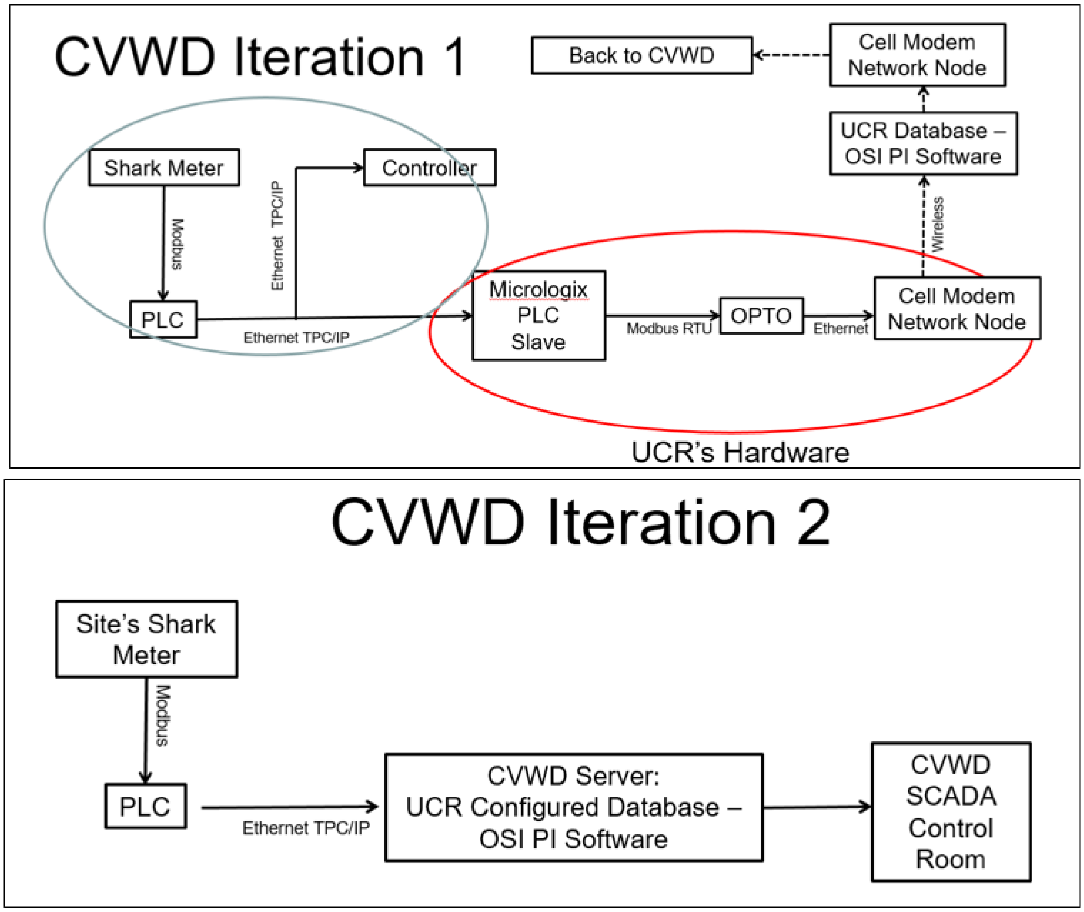
Source: University of California, Riverside

Figure 45: Olivenhain Water Treatment Plant SCADA System Design



Source: University of California, Riverside

Figure 46: Cucamonga Valley Water District SCADA System Design Iterations



Source: University of California, Riverside

2.6 Final Customized Integrated Demand Side Management and Energy Management System Design

For IEUA, CVWD, and OMWD districts, each individual site is managed by an on-site SCADA system with operated assisted strategies for DR and uncontrolled events. Two energy management strategies are being proposed and coordinated for each of the water districts. The first strategy is to minimize the occurrences, frequency, and duration when the maximum energy demand set point is reached on the Power Usage Dashboard (PUD). The second strategy is to provide an integrated notification system of current energy demand and prior energy histories.

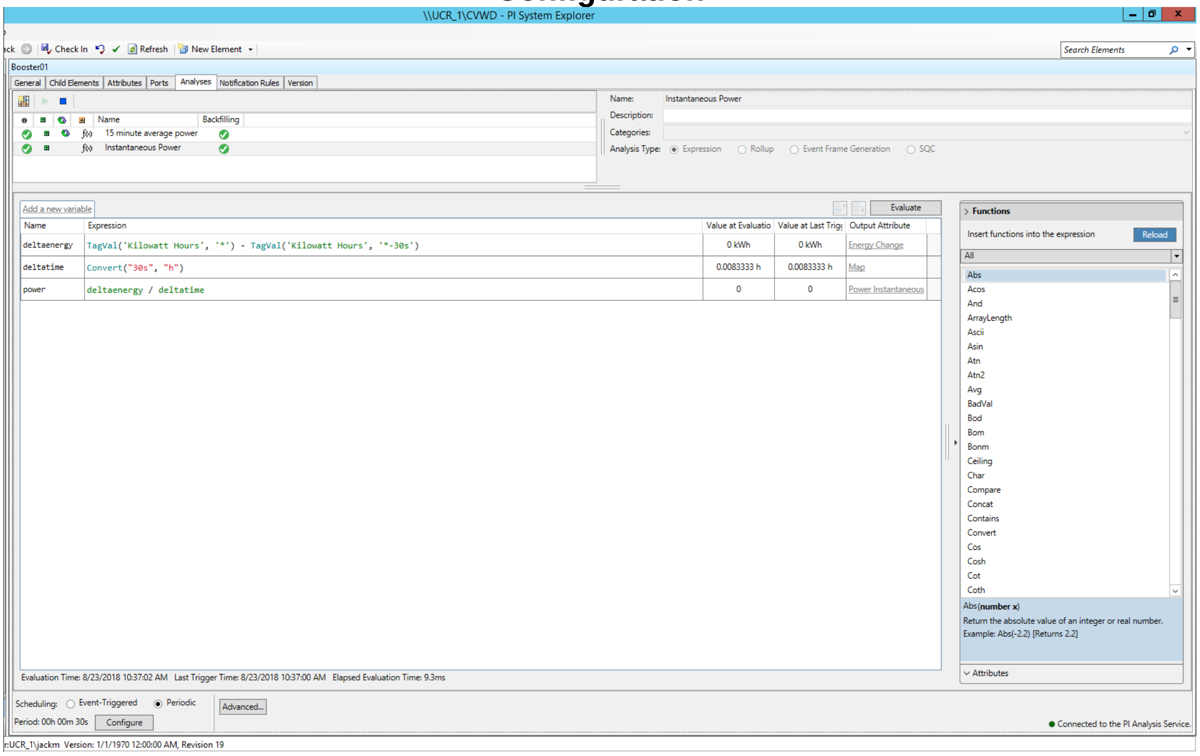
To minimize the occurrence and frequency, and duration of high energy activity for each district an operational history of energy meter data and corresponding SCADA data was reviewed and evaluated. The review has identified specific operational events leading to brief periods of elevated energy use which may be mitigated through moderated pumping activity. To assist in alleviating high pump activity events the system operational mode in conjunction with energy consumption was evaluated. The proposed control method was to reduce pump activity when recovering from DR and similar uncontrolled events. Situations leading to unusually low reservoir levels initiated maximum pumping response atypical for daily operation. These occasional events produced unusually high short-term energy consumption levels and correspondingly high energy costs. A proposed control strategy was coordinated to moderate pumping activity when compensating for atypical events. The control strategy does not compromise the overall system operation or recycled water supply.

The second management strategy is to integrate an energy advisory notification display to alert SCADA operators of real-time and historical energy use. The plant operators used the energy notification to aid in reducing real-time facility energy demand. The advisory notification provided alerts and feedback associated with peak operation energy demand for the specific meter rate schedule. The advisory notification displays the following:

- Real-time energy demand (kW)
- Current and prior billing cycle maximum demand (kW)
- Current All Time Maximum demand (kW)
- Time of use billing period (peak, off-peak, mid-peak)
- Previous billing cycle maximum demand

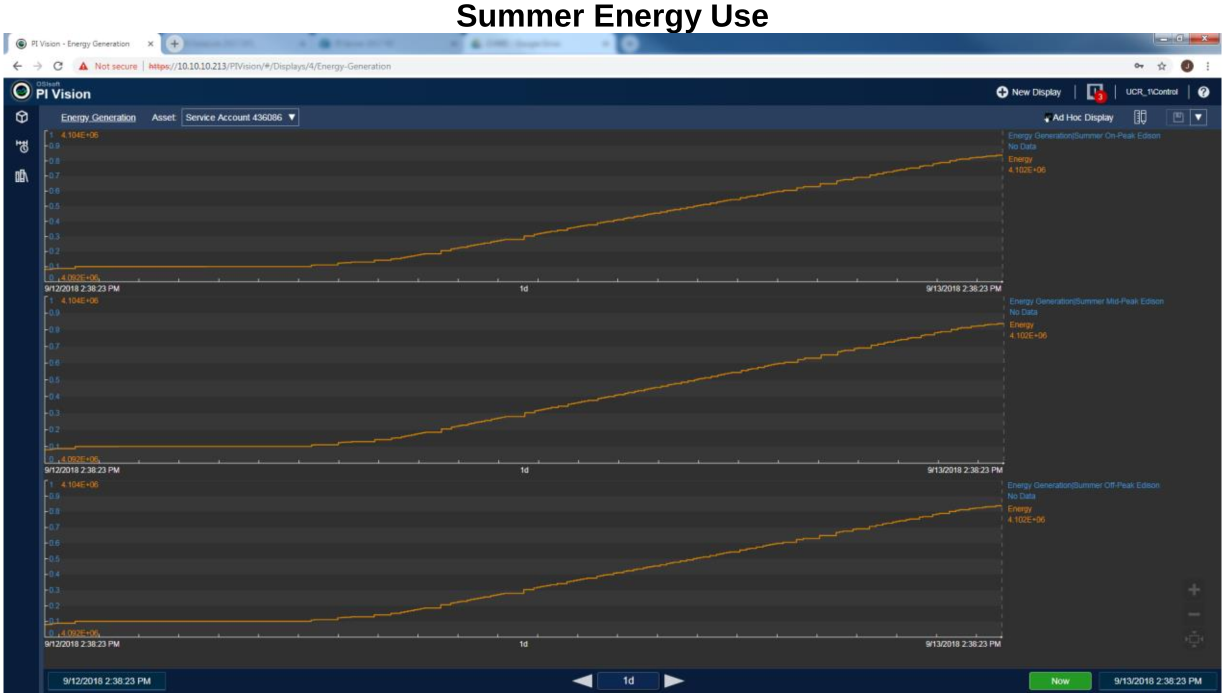
The energy advisory notification provides direct and immediate feedback on energy use associated with facility operations. Plant operators are responsible for complex plant operations of numerous processes performing simultaneous functions. The plant operators are equipped to integrate energy demand as an operational consideration when energy demand would otherwise reach elevated levels. Also, with the integration of TOU utility rate schedule into their SCADA and EMS system is of high value. On project completion, the EMS records instantaneous data allowing for a migration from the existing demand-based control scheme to a scheme capable of demand-and efficiency-based controls. With these controls in place the team was able to operate at more efficient level to minimize electrical use and optimize operational efficiency. The OMWD and IEUA districts used an internal SCADA programmer add an EMS screen and expand their existing SCADA program using the architecture UCR provided. CVWD's initial design and setup integrated hardware purchased from an outside vendor into their existing scheme, but this was later found to have security limitations. CVWD then chose to design an internal system housed within CVWD's secure servers. This eliminated the need for external hardware and transferring data to UCR.This alternate system did not allow for the integration of OSIsoft PI tags into their existing SCADA system for real-time monitoring. Figure 47 shows the programming within OSIsoft PI Explorer on calculating instantaneous power. Figure 48 shows the display at CVWD Displaying On, Mid, and Off peak energy usage.

Figure 47: Process Information System Explorer Instantaneous Power Configuration



Source: University of California, Riverside

Figure 48: Cucamonga Valley Water District Displaying On, Mid, and Off peak Summer Energy Use



Source: University of California, Riverside

2.7 Project Approach Conclusion

The goal of this project is to reduce peak loads and electricity costs in the delivery and treatment of water in California. The strategy involves overlaying and incorporating the existing EMS and/or SCADA system without disrupting current operations at the demonstration sites. The planned deployment includes three water agencies located in California's investor-owned utility territories that manage ground water, surface water, and reclaimed water, in large, medium, and small quantities.

The overall approach details a planned design and deployment efforts for three water agencies: Inland Empire Utilities Agency, Olivenhain Municipal Water District, and Cucamonga Valley Water District. The goal when designing the energy integration strategies is to create a migration path to move from a water demand-based control scheme to a scheme capable of both demand and efficiency-based controls. This migration path required hardware installation at CVWD, software installation/integration at IEUA and OMWD, and engineering. A primary energy integration strategy was to minimize the occurrences, frequency, and duration when the maximum number of motors are operating for pumping operations. A second strategy was to provide an integrated notification system of current energy demand and prior energy historical usage for the water treatment facilities. This demonstration project highlights a pathway for water agencies in California to reduce their peak energy consumption substantially without detriment to service or reliability. The project also identifies "real world" implementation issues that have not emerged in previous proof-of-concept research.

CHAPTER 3: Project Results

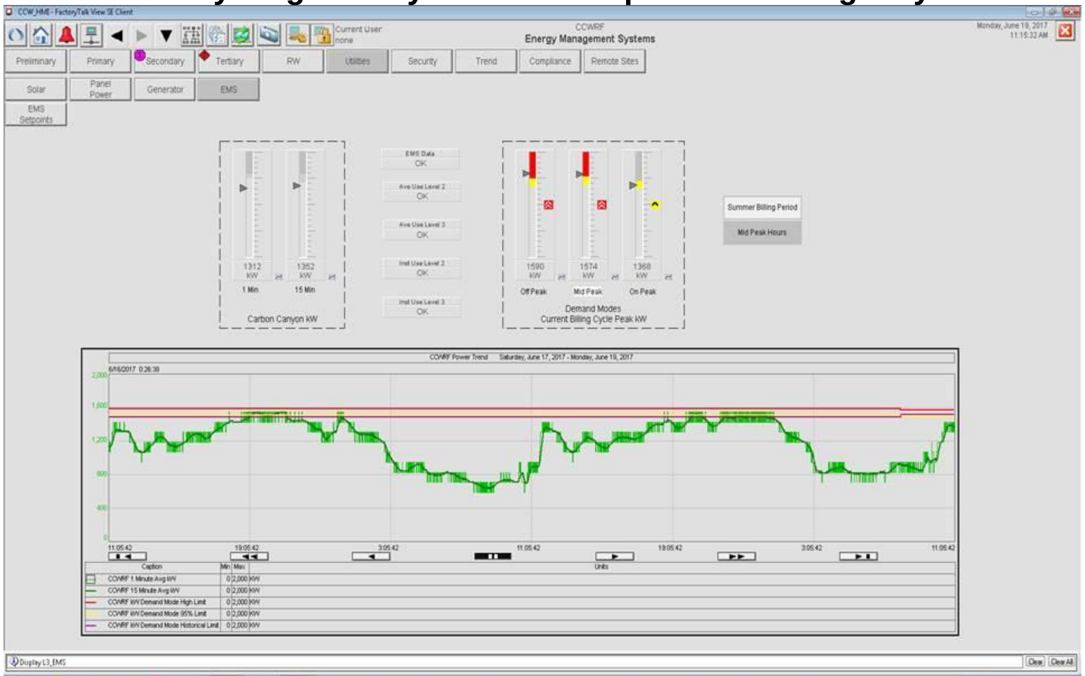
The CE-CERT and Olivenhain Municipal Water District, Cucamonga Valley Water District, and Inland Empire Utilities Agency are linked by common electrical energy management system improvement interests and seek to continue collaborations and exchanges in fields of shared interest and expertise. Collaboration between CE-CERT and the partner water districts demonstrate a set of general electrical energy demand improvement objectives resulting in field implementation EMS integrating with water district existing SCADA leading towards sustainable energy use.

3.1 Inland Empire Utilities Agency

IEUA's CCWRF facility is located within SCE's service territory. The electrical rate schedule incorporates a TOU demand charge within the monthly billing cycle. To ensure the deployed EMS is monitoring, displaying, and managing the facilities energy consumption correctly the EMS data was compared with SCE billing data. This comparison ensured the IDSM strategies would be reflected in the resulting SCE electrical demand and corresponding billing data. Figure 49 shows the real-time EMS display for the CCWRF within IEUA. This display provides real-time energy consumption for the facility and identifies when energy management strategies should be enacted. Figure 50 shows the EMS interface for setting holidays and billing cycles, which impacts monthly charges, associated with electrical demand TOU charges.

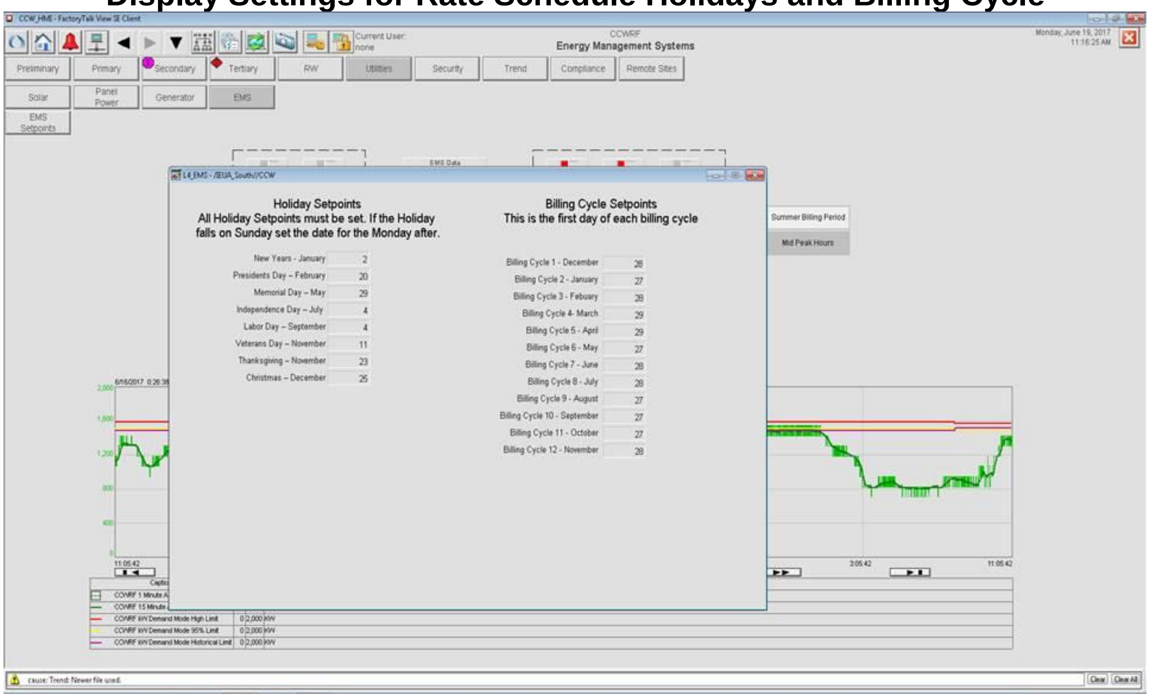
The data analysis and validation of IEUA EMS required a compilation and comparison of SCE 15 minute interval data and site-collected EMS data. The EMS-based data was independently collected and stored through the facility's SCADA and data historian. The EMS-derived data is monitored and captured approximately every 20 seconds and requires time alignment with the separately measured SCE meter data. Figure 51 shows the two separate and independent data sets used for analysis and validation. Figure 52 provides the 15 minute calculated value from the EMS used for direct comparison and validation with SCE data. The EMS calculated 15-minute average and SCE interval data were found to agree unless data loss occurred.

Figure 49: Energy Management System SCADA Display for Carbon Canyon Water Recycling Facility at Inland Empire Utilities Agency



Source: University of California, Riverside

Figure 50: Inland Empire Utilities Agency Energy Management System SCADA Display Settings for Rate Schedule Holidays and Billing Cycle

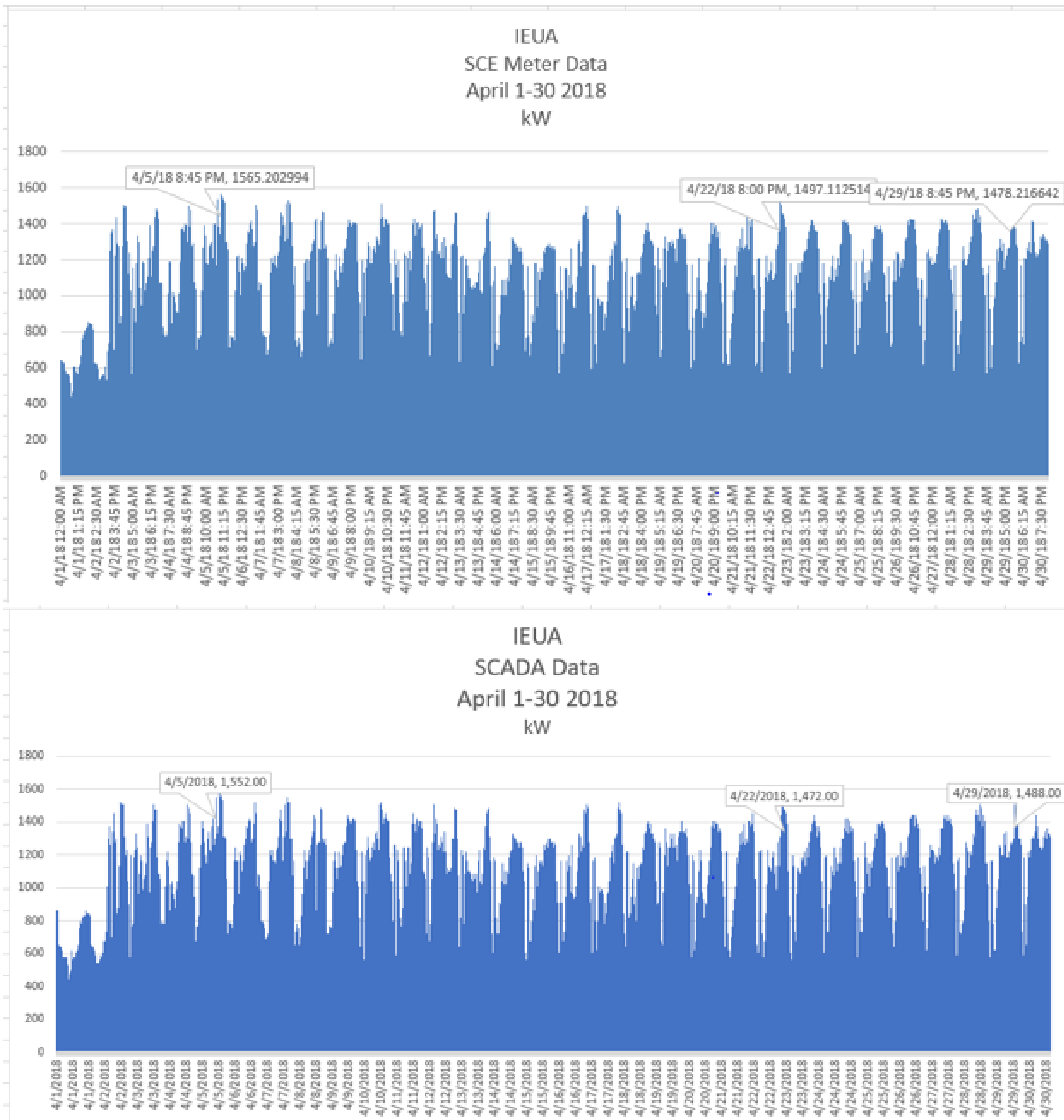


Source: University of California, Riverside

Figure 51: Inland Empire Utilities Agency Data Analysis and Comparison between Southern California Edison 15 Minute Interval Data and SCADA Data Logged Graphs

Source: University of California, Riverside

Figure 52: Inland Empire Utilities Agency Data Analysis and Comparison between Southern California Edison 15 Minute Interval Data and SCADA Historical Graphs



Source: University of California, Riverside

3.2 Olivenhain Municipal Water District

3.2.1 Objectives, Scope, and Major Activities

UCR's CE-CERT and OMWD have demonstrated, used, and validated energy management, data acquisition, and supervisory control strategies that can reduce peak loads and electricity costs in the delivery and treatment of water in California. This new system has been designed to overlay and incorporate EMS with existing SCADA system without disrupting existing operations at the demonstration site. The approach is also compatible with existing equipment of any age from any manufacturer.

The objectives for the overall project was to design an EMS for the purpose of providing additional knowledge and opportunities in mutual advances for the ongoing efforts for both parties, OMWD and CE-CERT. The goals of the EMS were as follows:

- To monitor systems in real-time
- Display the energy use data and store historical data in SCADA allowing the operators to monitor and reduce energy demand

The major project components were:

- Assessment and inventory of existing SCADA infrastructure at the facility
- Design of site-specific configuration
- System integration and site deployment
- Operation and validation

Any new SCADA and EMS system component designed at CE-CERT is designed to function together with the existing systems and complement each other.

The overall result of the EMS system is to reduce the amount of energy used during specific peak times as delineated in the summer and winter TOU rate schedules. The kW peak demand reductions were achieved by shifting energy use from on-peak times to off-peak times based on OMWD's demand and guidelines for water delivery and treatment. The EMS integrated within the SCADA allowed operators to monitor peak loads and shift loads to minimize 15-minute peak demand.

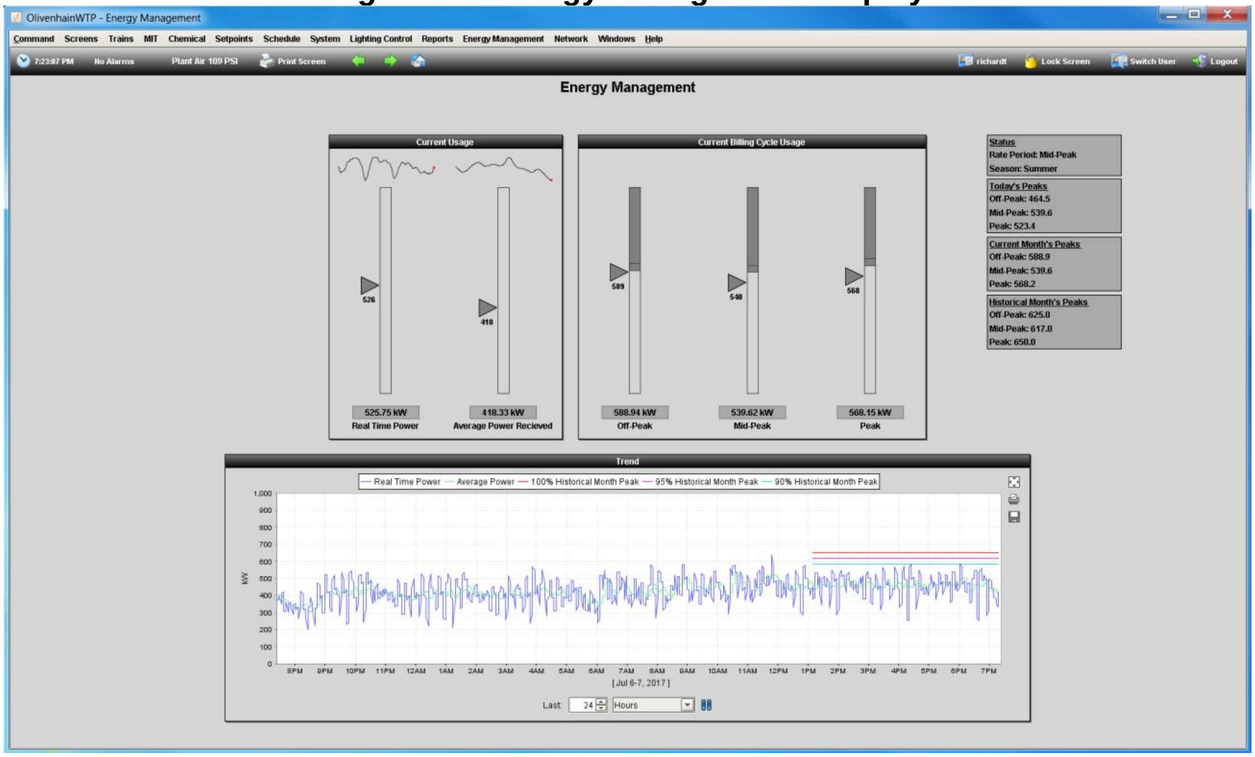
3.2.2 EMS Architecture Design

The EMS design created an energy efficient solution with the use of customized energy management system and supervisory control and data acquisition system at the OMWD's DCM Water Treatment Plant. The EMS tasks and functions implemented at OMWD are indicated in the figures and tables below:

- Screens showing instantaneous usage, actual usage, current month peak, previous month peak and other available values as indicated on Figure 53
- Add alarm notifications as indicated in Table 3
- Add EMS control I/O as available indicated in Table 4

- Add calculated variables as explained on Figure 54
- Have alarms auto adjust with rate schedule as shown on Figure 55

Figure 53: Energy Management Display



Source: University of California, Riverside

Table 3: Alarm Notifications

Failures	Response
High instantaneous power usage	Alarm/alert generated
High 15-minute power usage	Alarm/alerted generated
No energy data	Alarm/alert generated

Source: University of California, Riverside

Table 4: Energy Management System Control I/O

I/O Tag	Description	SCADA Function Monitor	SCADA Function Trend/ Historical	SCADA Function Priority
Real-time Power	Instantaneous Power (One minute average kW calculation from pulse signal)	✓	T/H	N/A
Average Power Received	15-minute running average power received from grid (15-minute average kW calculation from pulse signal)	✓	T/H	N/A
Average Use Level 1	Makes bar gray if 15-minute average usage < 100% of 15-minute average peak	✓	N/A	1*
Average Use Level 2	Makes bar yellow if instantaneous usage > 100% of 15-minute average peak and average usage > 85% of billing month in historical table	✓	H	1*
Average Use Level 3	Makes bar red if instantaneous usage > 100% of 15-minute average peak and average usage > 90% of billing month in historical table	✓	H	1*
Instantaneous Use Level 1	Makes bar gray if real-time usage < 100% of current real-time month peak	✓	N/A	1*
Instantaneous Use Level 2	Makes bar yellow if real-time usage is > 100% of current month peak and > 95% of billing month in historical table	✓	H	1*

I/O Tag	Description	SCADA Function Monitor	SCADA Function Trend/ Historical	SCADA Function Priority
Instantaneous Use Level 3	Makes bar red if instantaneous use > 15-minute average peak and if 15-minute average usage is > 100% of current month peak and if > 95% of billing month in historical table	✓	H	1*
Last Month Peak Usage	Previous month peak usage during the current TOU	✓	T/H	N/A
This Month Mid Peak	Peak usage for the current month and mid-peak TOU	✓	T/H	N/A
This Month Off Peak	Peak usage for the current month and off-peak TOU	✓	T/H	N/A
This Month On Peak	Peak usage for the current month and on-peak TOU	✓	T/H	N/A
Time of Use	Peak, Mid-Peak, Off-Peak	✓	N/A	N/A
TOU Season	Summer/Winter	✓	N/A	N/A
Return to Normal	Sent RTN when 15-minute average < current month peak	✓	H	N/A

***The alarm priority is to apply during daytime shift operating hours only. Alarms not sent during weekends or evening/night hours.**

Source: University of California, Riverside

Figure 54: Calculated Variables

The EMS shall calculate peak energy values for each time of use energy period (peak, mid-peak, off-peak). The monthly peak 15 minute average should be saved for each month for use in the historical table.

Instantaneous kW = one minute running average of kW from Energy Meter

15 minute kW = 15 minute running average of kW from Energy Meter

Source: University of California, Riverside

Figure 55: Rate Schedule for Olivenhain Municipal Water District

19090 Via Ambiente, Escondido, CA 92067 – DCM Water Treatment Plant (PAT1 -Option F)	
Time Periods	
All time periods listed are applicable to local time. The definition of time will be based upon the date service is rendered.	
Summer – May 1 – October 31 All Other	**Winter** – All Other
On-Peak 11 a.m. - 6 p.m. Weekdays	5 p.m. - 8 p.m. Weekdays
Semi-Peak 6 a.m. - 11 a.m. Weekdays	6 a.m. - 5 p.m. Weekdays
6 p.m. - 10 p.m. Weekdays	8 p.m. - 10 p.m. Weekdays

Source: University of California, Riverside

The real-time energy use through the utility feed energy meter is processed through the SCADA system and stored in the data historian. Figure 56 shows the recorded kW values for 2017 through OMWD's SCADA system as well as the values recorded by SDG&E. From validation process, the research group was able to determine that the values difference between OMWD's SCADA data and SDG&E 15-minute was on average less than 5 percent difference.

Figure 56: Olivenhain Municipal Water District Water Treatment Plant Data Analysis and Comparison between San Diego Gas & Electric 15 Minute Interval Data and SCADA Historized

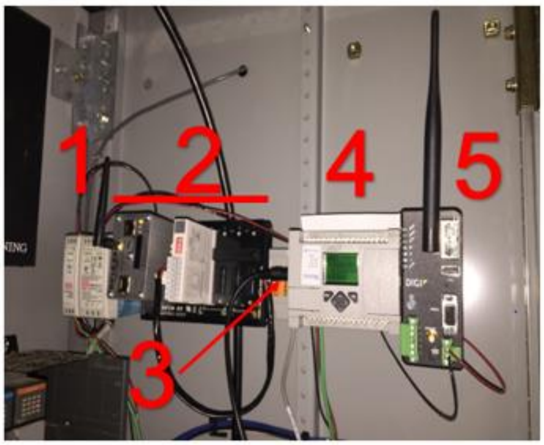
		Aug-17		
Day	15 min int	WTP SCADA recorded values		% difference
1	598.8	605.9		1.17181053
2	538.8	548.3		1.732628123
3	556.8	568.6		2.075272599
4	553.2	596.7		7.290095525
5	546	558.4		2.220630372
6	530.4	543.3		2.374378796
7	589.2	602.3		2.174995849
8	508.8	545.5		6.727772686
9	484.8	529.3		8.407330436
10	544.8	565.5		3.660477454
11	568.8	579.3		1.812532367
12	531.6	556.2		4.422869471
13	526.8	546.5		3.604757548
14	600	600.4		0.066622252
15	584.4	587.6		0.544588155

Source: University of California, Riverside

3.3 Cucamonga Valley Water District

CVWD's 1C facility is located within SCE's service territory. The electrical rate schedule incorporates a TOU demand charge within the monthly billing cycle. The 1C site EMS data comparison was done between the SCE billing data to ensure the EMS is monitoring, displaying, and managing the facilities energy consumption correctly. This comparison ensures the IDSM strategies will be reflected in the resulting SCE electrical consumption and corresponding bill. Figure 57 displays the installed energy monitoring equipment at CVWD 1C location. Figure 58 shows the real-time EMS display for the 1C within CVWD, as well as kW demand for each individual component within 1C such as boosters and wells. The energy use captured comes directly from CVWD PLC registers and sent to the PLC. Once the PLC obtains the register values, OPTO 22 then sends the data wirelessly to servers located at UCR. Figure 59 shows instantaneous peak demand as well as 15 minute average energy use as each individual booster is turned on. This EMS display provides real-time energy consumption for the facility and identifies when energy management strategies should be activated.

Figure 57: Energy Monitoring Hardware Installed at Cucamonga Valley Water District 1C Location

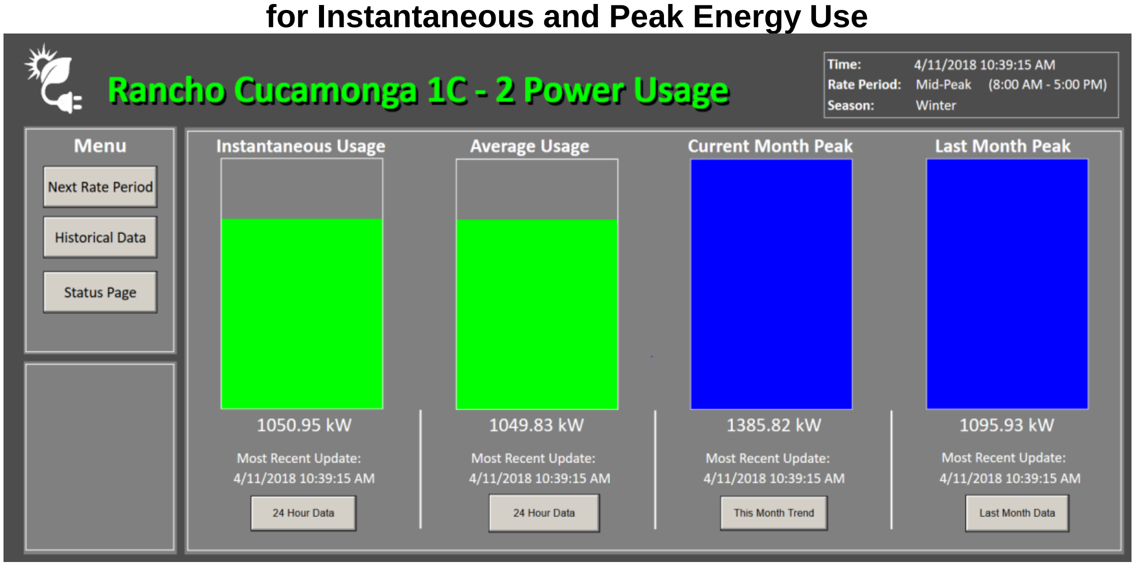


The following items shown in the image include the following.

1. 12V and 5V DIN Rail Power Supply
2. SNAP-SCM-485-422 with Opto Rack and Controller "Brain"
3. RS 485 DB1 Conversion Cable for Micrologix
4. PLC Micrologix 1100
5. DIGI WR32 Mobile Broadband Router

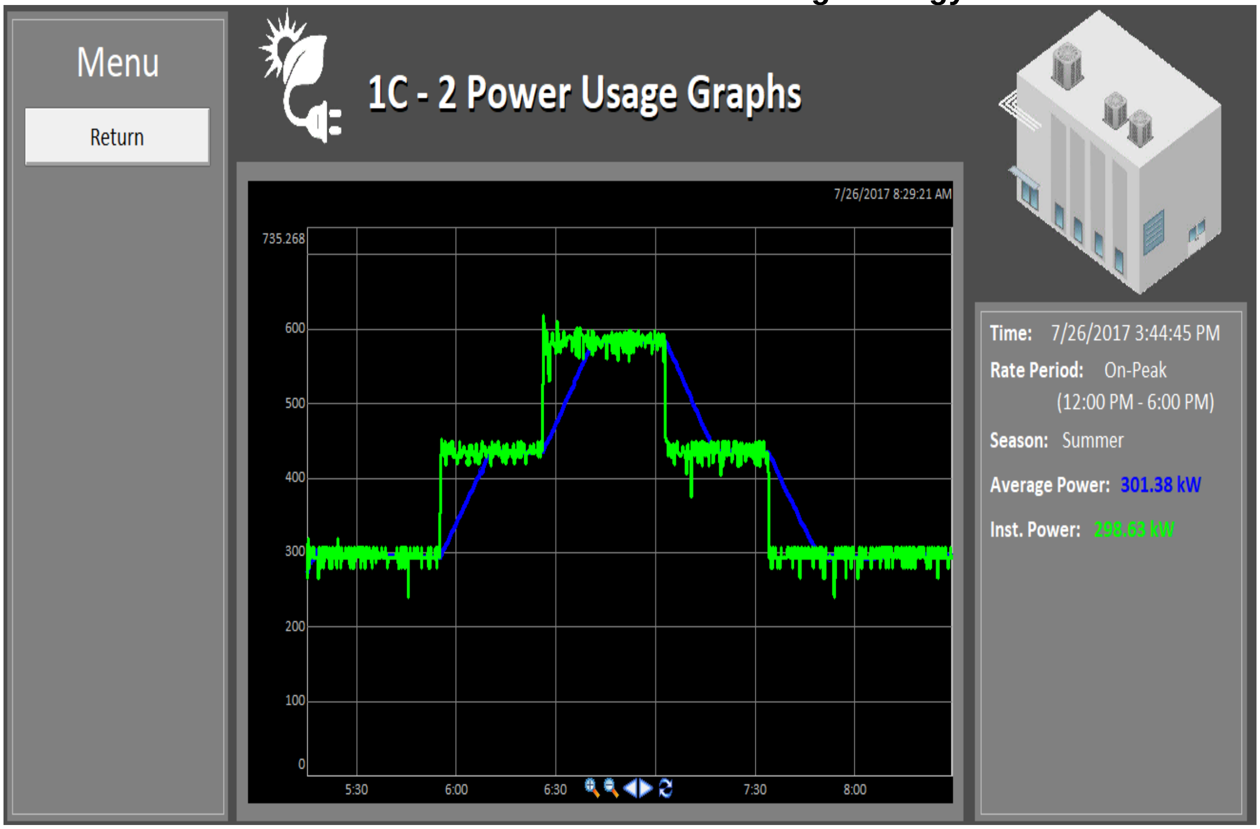
Source: University of California, Riverside

Figure 58: Cucamonga Valley Water District Energy Management System Display for Instantaneous and Peak Energy Use



Source: University of California, Riverside

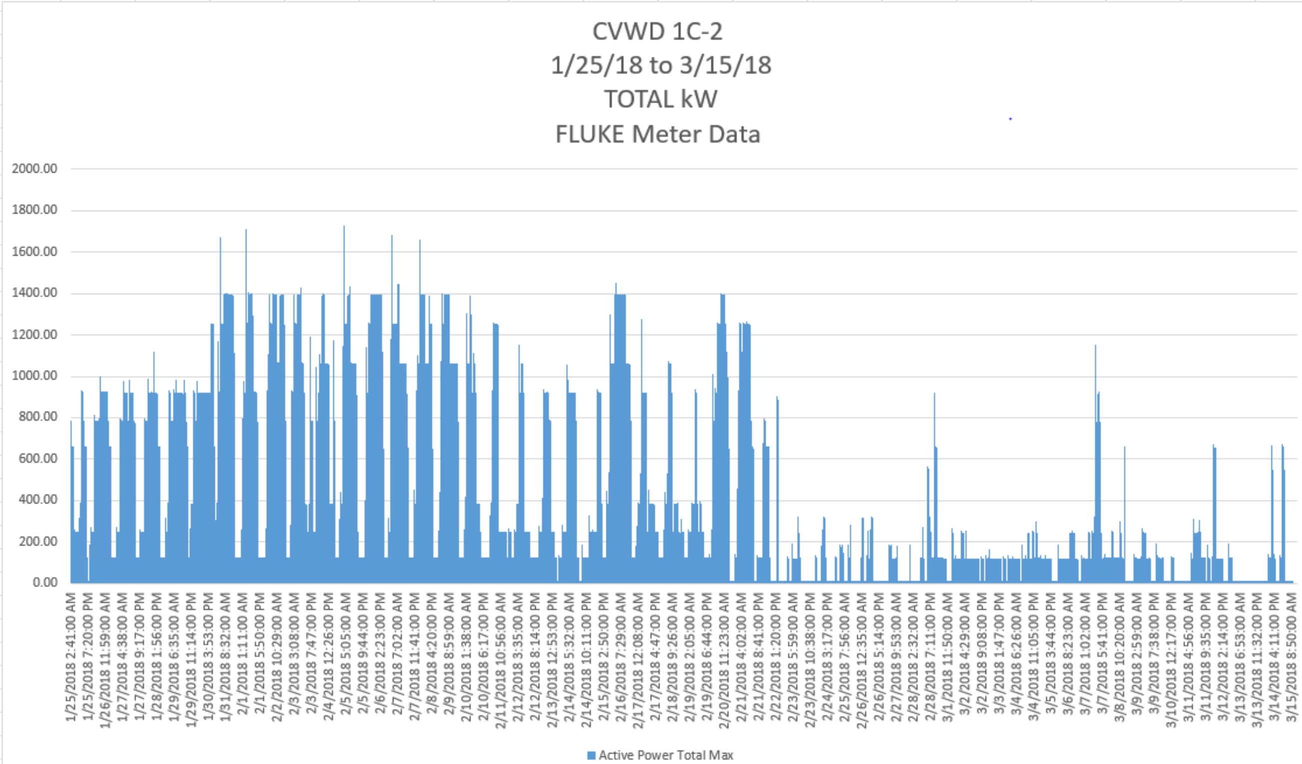
Figure 59: Cucamonga Valley Water District Energy Management System Display for Instantaneous and 15 Minute Average Energy Use



Source: University of California, Riverside

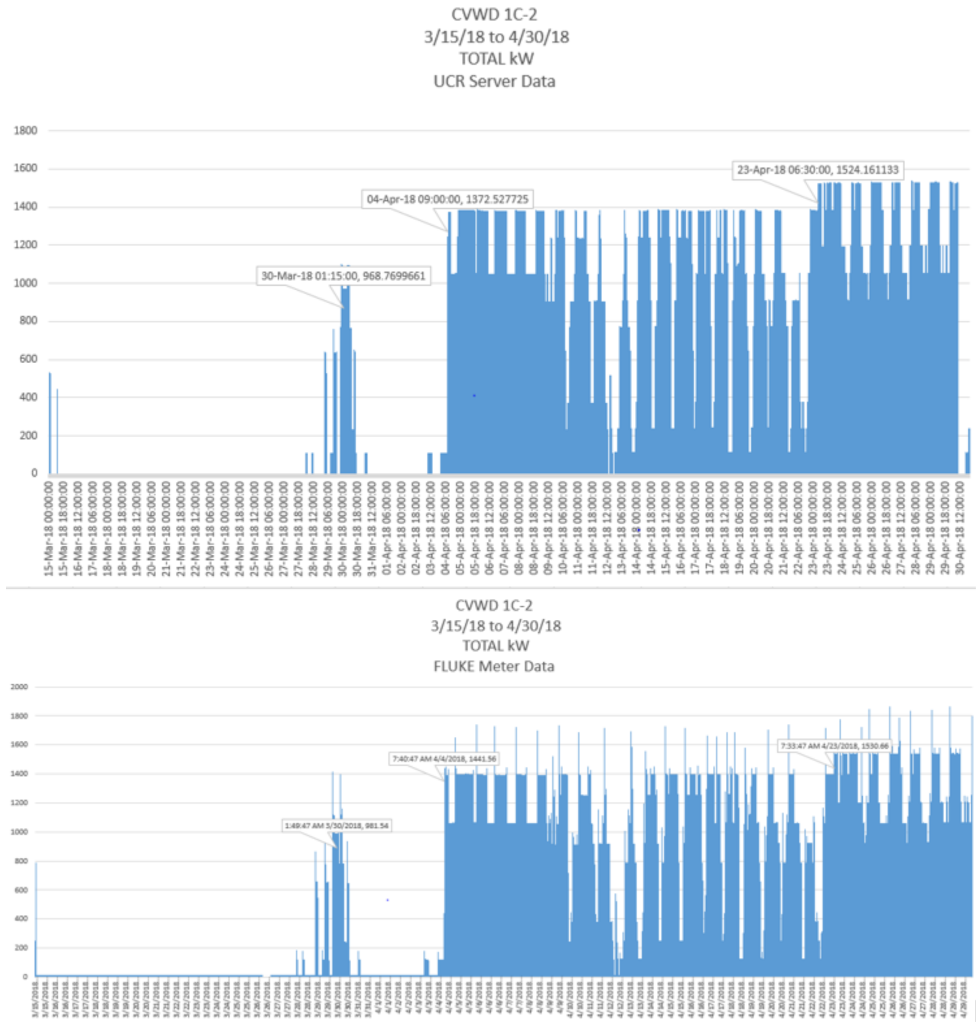
The data analysis and validation required a compilation and comparison of independently measured facility energy and site collected EMS data. The EMS-derived data is monitored and captured approximately every 20 seconds and requires time alignment with the separately measured Fluke meter data located at the 1C site. Comparisons were completed between an independent Fluke meter installed at the 1C site and what is being recorded through UCR's energy monitoring hardware. UCR engineers compared each data source by analyzing Fluke-recorded data and what is being captured through the collected EMS data that is stored in OSIsoft's server. Figure 60 shows the Fluke- recorded data used for analysis and validation. Figure 61 shows the comparison of the 15-minute measured value from the EMS data and comparing it to the recorded Fluke meter data.

Figure 60: Validation of Independently Recorded Energy Data at Cucamonga Valley Water District 1C Location with Fluke Meter



Source: University of California, Riverside

Figure 61: Cucamonga Valley Water District Data Analysis and Comparison between OPTO (Hardware Setup at Site) and University of California Riverside Fluke Recorded Graphs at 1C Location



Source: University of California, Riverside

3.4 System Operation

CE-CERT has used and commissioned IDSM strategies at three water district locations. The three installations use existing on-site SCADA architecture to integrate an EMS within the existing architecture. The three locations: O MWD, CVWD, and IEUA have collaborated in the use, testing, and validation of IDSM strategies within the EMS architecture. CE-CERT and the water districts have targeted energy improvement objectives and field implementation of IDSM and EMS to help minimize peak energy demand at selected locations.

3.5 Cucamonga Valley Water District System Operation

CVWD's 1C facility is located within SCE's service territory. The electrical rate schedule incorporates a TOU demand charge within the monthly billing cycle. At 1C site, the EMS data comparison was done between the SCE billing data to ensure the deployed EMS is monitoring, displaying, and managing the facilities energy consumption correctly. This comparison ensures the IDSM strategies will be reflected in the resulting SCE electrical consumption and corresponding bill. Overall operation from deployment to twelve-month observation to the use of the energy management system for CVWD is described in detail in the subsections.

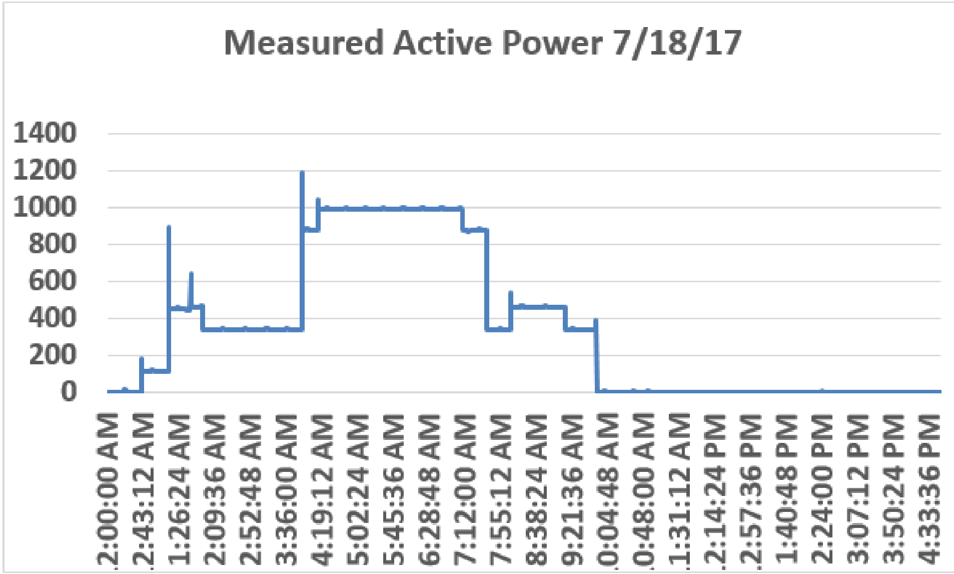
3.5.1 Energy Management System Use

The Cucamonga Valley Water District EMS was designed to record valuable real-time data from the 1C Pumping Site and provide this data to the operators. The original EMS was designed by CE-CERT engineers to provide real-time EMS display for the 1C site within CVWD, as well as kW demand data for each individual component within 1C such as boosters and wells. The information gathered from the newly designed EMS is currently being recorded and processed at CE-CERT via OPTO 22 controller and OSIsoft software. It was designed so that CVWD could visually see energy usage at the site and provide the water district a way to optimize energy use at the site based on these observations.

Hardware installation at the site started April 4, 2017. Full hardware installation has been in functional running operation since July 5, 2017. The hardware has been continually collecting data since it was operational with the exception of a few instances of signal or data loss due to CVWD updating or upgrading code on the PLC. The energy use captured comes directly from CVWD PLC registers and is sent to the PLC. Once the PLC receives the register values OPTO 22 it takes that data and sends it wirelessly to the servers located at UCR. From there it is stored in an SQL database at CE-CERT. Data from the controller is also collected in real-time to the PI Interface to be displayed for the users, which is designed to provide real-time energy consumption for the facility and allows the operator to identify when energy management strategies should be enacted.

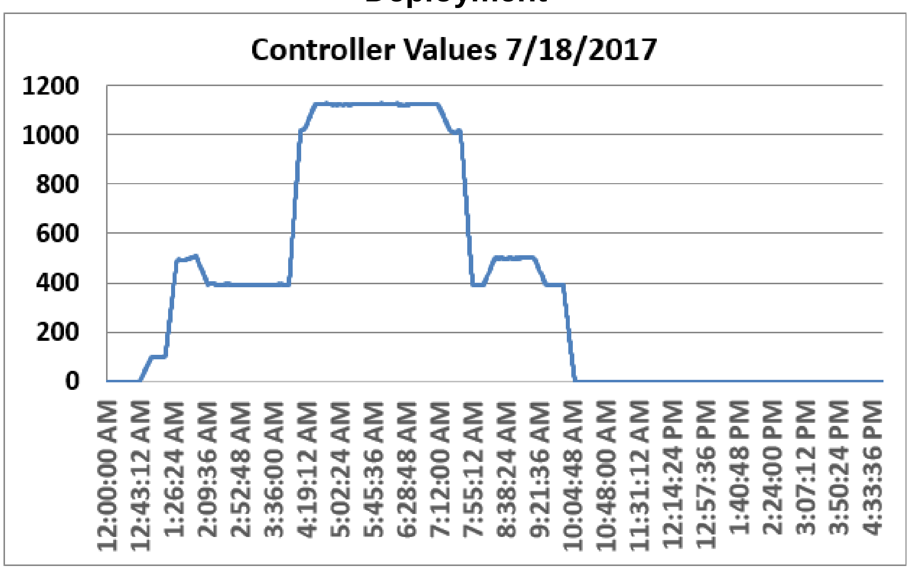
Efforts after using EMS have focused on verification of the data with actual measurements. The measurements methods used at CVWD 1C site were to setup a Fluke power meter and capture energy usage at the site as seen in Figure 62. The Fluke meter is capable of logging the data and is used to verify the data being captured by comparing it to the data being recorded and logged at CE-CERT; the live measurements are compared against the logged values saved in the SQL database shown in Figure 63. Originally, the hardware was only capturing kWh since the only tags CVWD was recording at the time was kWh. In order to provide valuable and meaningful energy data to the operator the researcher had to calculate the scaling values needed for the site data in OPTO as seen in Figure 64.

Figure 62: Measured Active Power (kW) from Fluke Meter



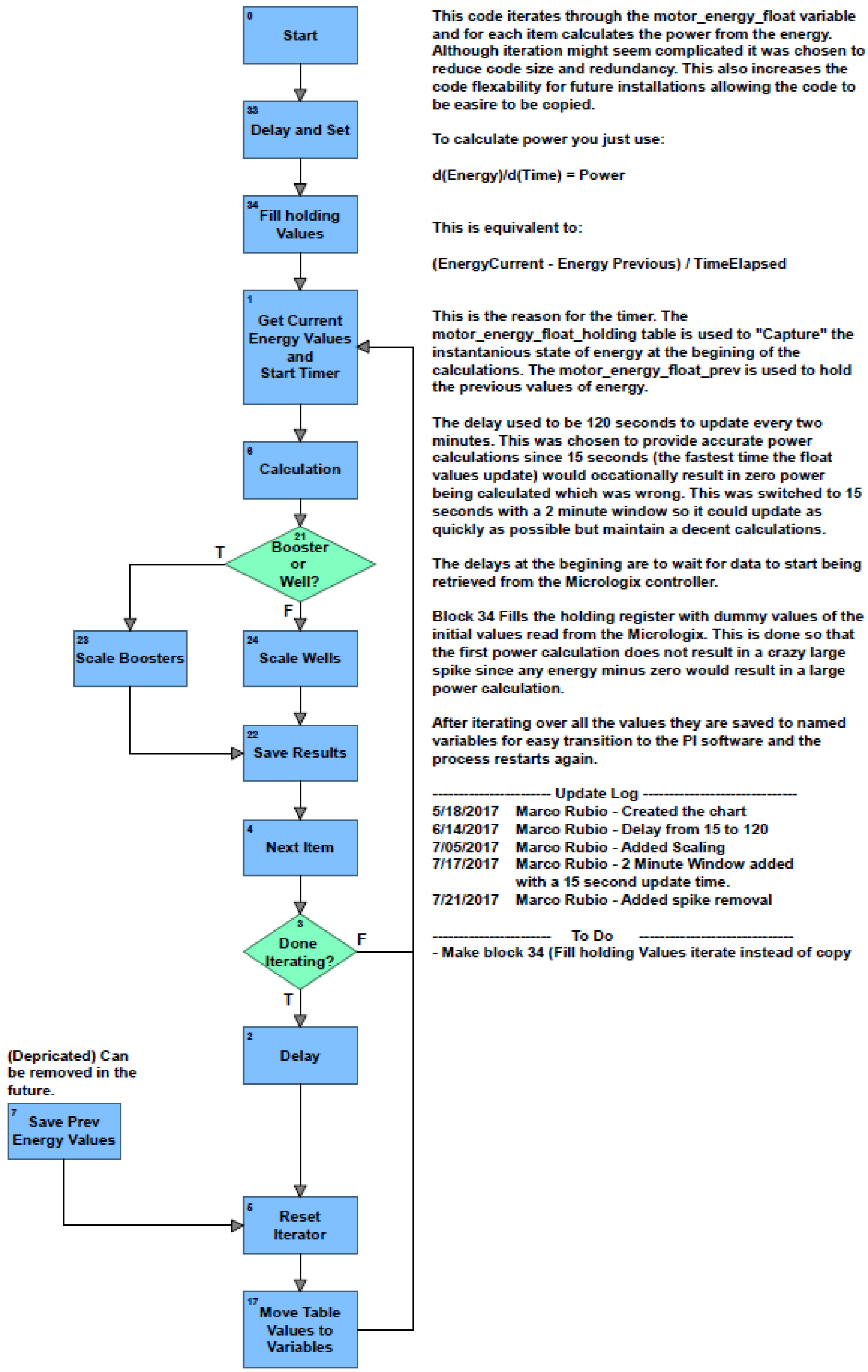
Source: University of California, Riverside

Figure 63: Measured Active Power (kW) from OPTO/Process Information after Deployment



Source: University of California, Riverside

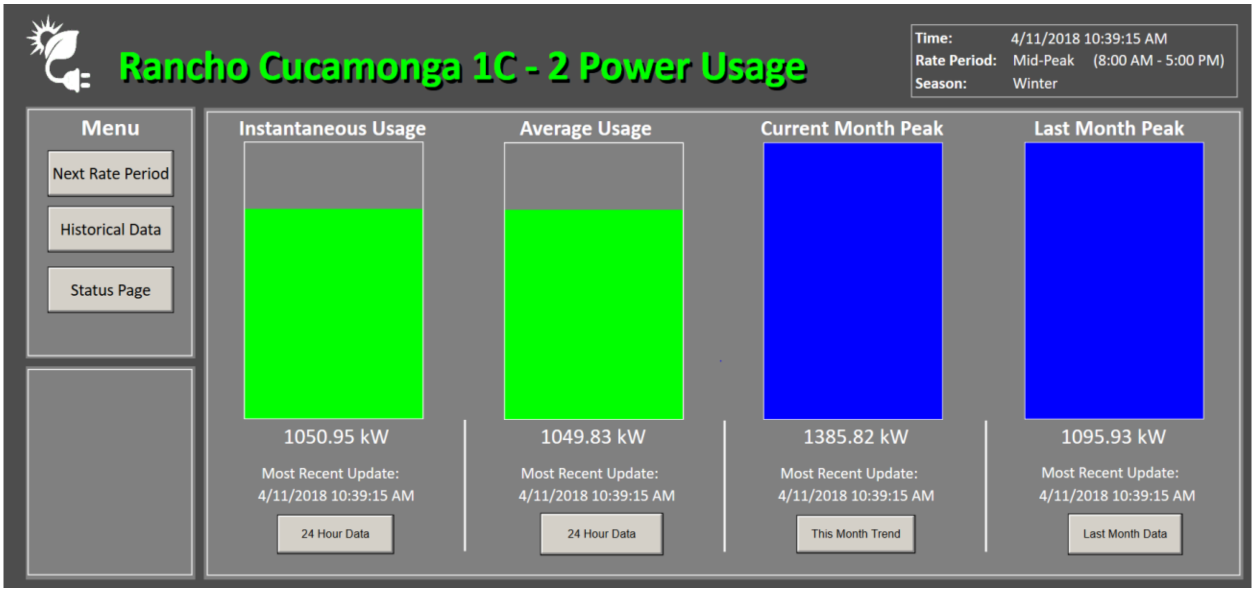
Figure 64: Controller Algorithm to Convert Cucamonga Valley Water District kWh to kW



Source: University of California, Riverside

The proposed system components and EMS architecture had been used within UCR's existing microgrid to optimize system characteristics and evaluate functionality. The facility monitoring is in a commercial setting with total energy consumption being monitored, recorded, evaluated, and displayed. Real-time energy use and peak energy demand is continuously evaluated. Figure 65 shows the display for system prototype analysis. The dashboard displaying real-time energy, all-time maximum demand, time of use, and previous bill cycle maximum demand. This system deployment served as the basis for evaluating IDSM and EMS architecture.

Figure 65: Energy Management System Display for Cucamonga Valley Water District

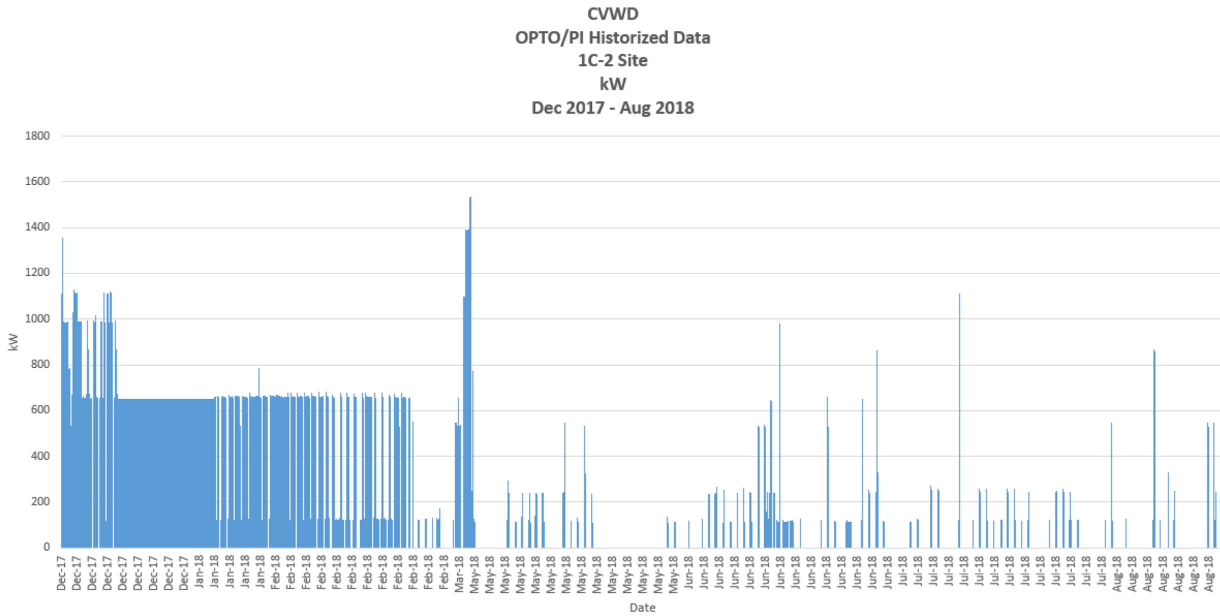


Source: University of California, Riverside

3.5.2 Twelve Month Operation Observations

Data was collected for a month since July 21, 2017 to compare with data gathered from the controller. During that time, the group had developed some communication issues with the OPTO 22 controller and CVWD PLC and did not begin gathering data consistently until December 2017. Between July and December there have been many iterations of software updates to the OPTO 22. During that time, CVWD has also joined in efforts to update their PLC to see the specific kW tags for each pump and wells at the site. CVWD's efforts for the team to switch from kWh to direct kW for each pump and well began in August 2017. Figure 66 shows the beginning of data collection after all the communication errors had been resolved between UCR hardware and CVWD hardware.

Figure 66: Continuous Historized OPTO/Process Information Data 2017-2018

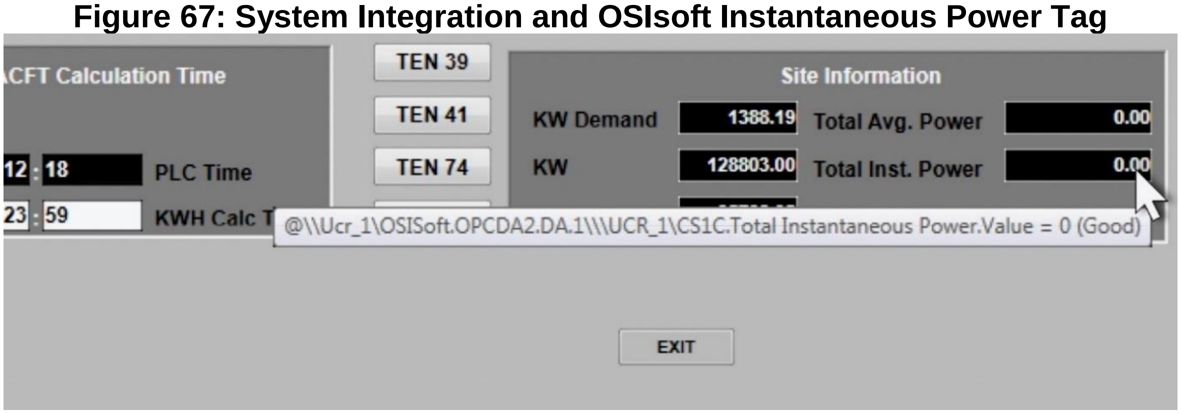


Source: University of California, Riverside

3.5.3 Using Energy Management Systems

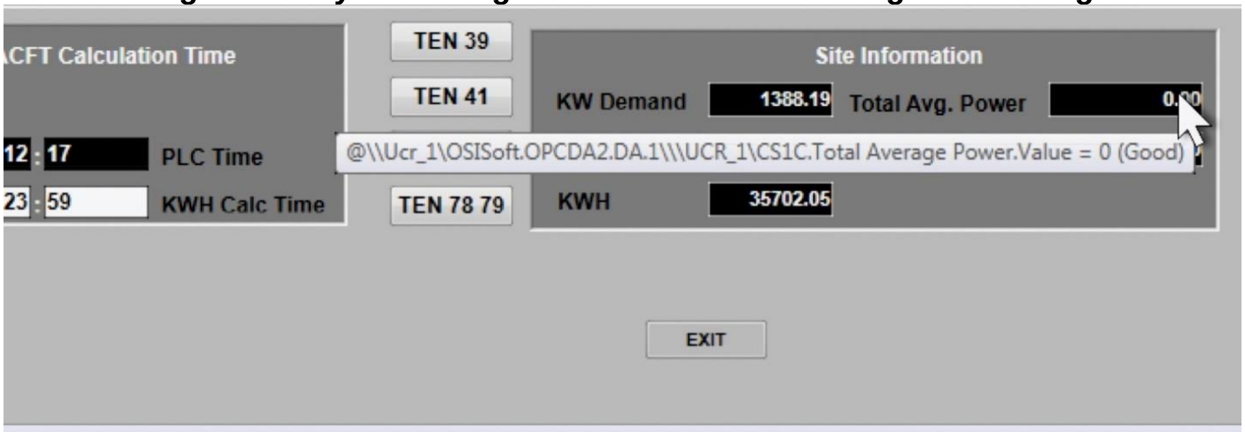
At CVWD for the 1C site, the district originally employed an OSIsoft PI Display that was created by the students and staff at UCR's CE-CERT facility. The water district has since installed and integrated the OSIsoft software into their SCADA system and programmed it into their server as of August 15, 2018. See Appendix B for the installation report. The integration gives the water district the ability to manage and operate the software within their facility without compromising any security at the district. Figure 67 and Figure 68 show the integration with CVWD SCADA system and OSIsoft tags for instantaneous and average power. With the ability to monitor energy use, the water district can now make necessary adjustments to their pumping and reduce energy use.

Figure 67: System Integration and OSIsoft Instantaneous Power Tag



Source: University of California, Riverside

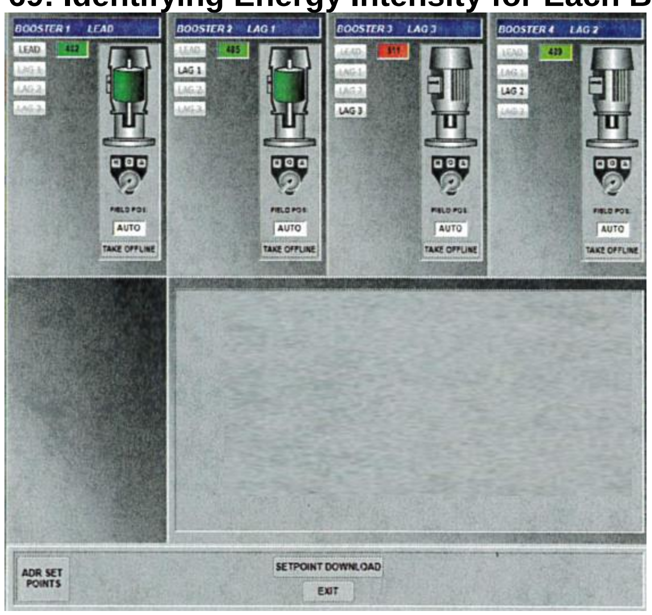
Figure 68: System Integration and OSIsoft Average Power Tag



Source: University of California, Riverside

Staff is now able to determine which pumps to run based on the energy efficiency of the pump instead of relying on previous operational procedures, where up to four pumps were available for pumping with one on standby with each pump being rotated into standby mode on a weekly basis. Figure 69 shows the options an operator has in choosing which pumps to run based on color intensity labels. The intensity label with the lower number operates in lead mode with the pump having the second highest intensity label operating as a booster pump if necessary.

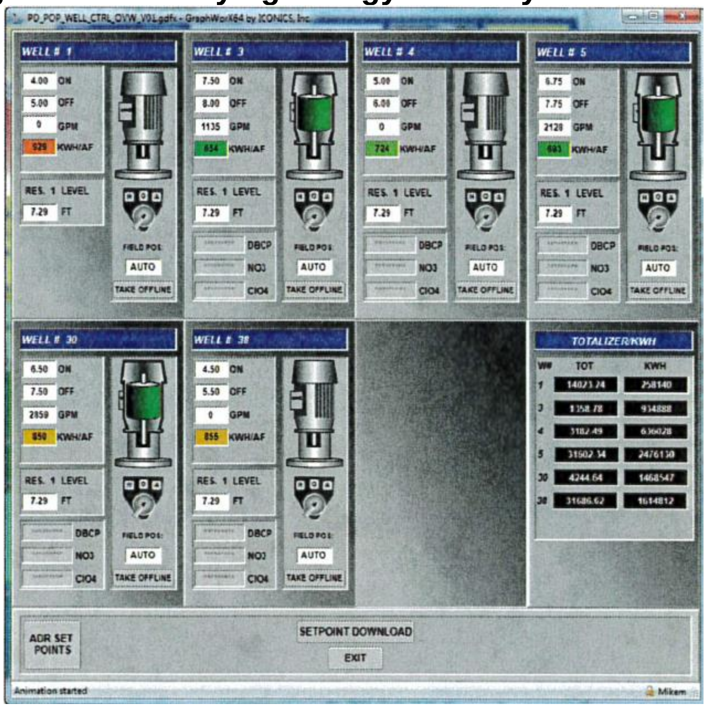
Figure 69: Identifying Energy Intensity for Each Booster



Source: Cucamonga Valley Water District

Figure 70 shows each of the different wells. The well chosen to run is based on which is displaying the lowest energy intensity and will meet the blending requirements for the water produced.

Figure 70: Identifying Energy Intensity for Each Well



Source: Cucamonga Valley Water District

3.6 Inland Empire Utilities Agency System Operation

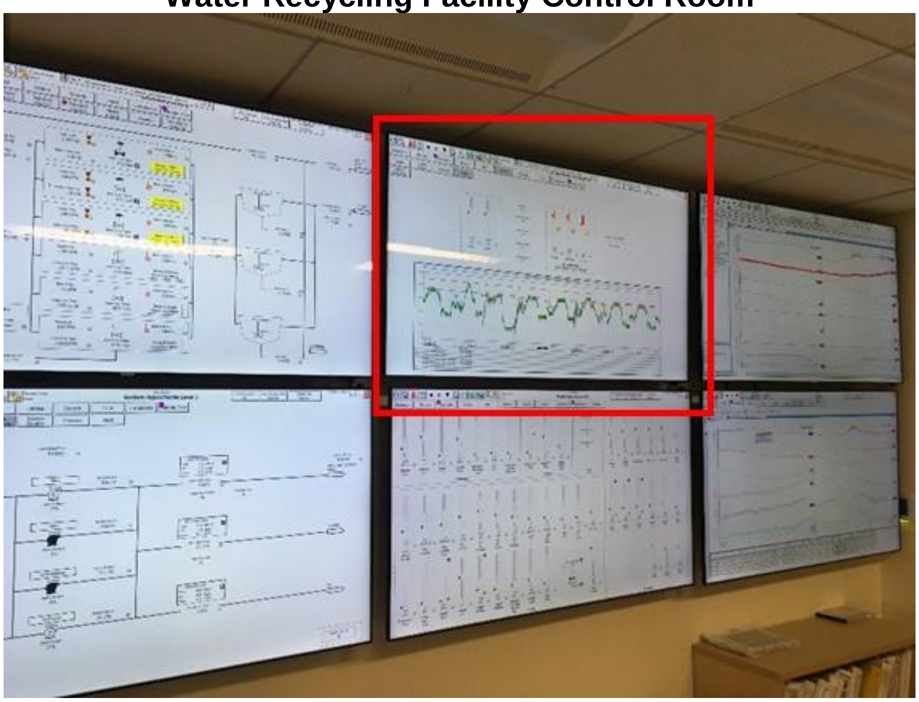
IEUA's CCWRF facility is located within SCE's service territory. The electrical rate schedule incorporates a TOU demand charge within the monthly billing cycle. To ensure the installed EMS is monitoring, displaying, and managing the facilities energy consumption correctly the EMS data is compared with SCE billing data. This comparison ensures the IDSM strategies will be reflected in the resulting SCE electrical consumption and corresponding bill.

3.6.1 Energy Management System Use

The overall use is based on integrating pre-commercial technologies, methods, and approaches for integrating EMS strategies within a SCADA environment at CCWRF. UCR and IEUA staff have demonstrated and used energy management, data acquisition, and supervisory control strategies that monitor and display peak loads to aid in peak demand electricity costs at CCWRF. The project originally began on June 8, 2017 by installing a pulse block in CCWRF's electrical room. It was from the pulse block that the EnerNoc signal was split and routed to the SCADA control room where the pulse signals are calculated and displayed on the SCADA screen as kW demand. The actual programming of the SCADA began the week of June 12, 2017 with continuing improvements made over a few months until it could be verified that SCE's 15-minute interval data was consistent with that being captured by the SCADA program. Currently, CCWRF SCADA display screens and alarm notifications provide operators with real-time comparison of monthly maximum peak electric demand versus instantaneous demand, allowing operators to determine if the current electricity use should be lowered. If feasible, the operators can temporarily reduce pumping to avoid setting a higher maximum demand, savings can be obtained for the billing period by reducing the monthly peak demand charges.

The overall strategy and method overlays and incorporates the existing SCADA system at CCWRF without disrupting current operations. Having the EMS shown in the control room seen in Figure 71, it allows the plant operator to visually see the energy use associated with facility operations. The display provides real-time energy consumption for the facility and identifies when energy management strategies should be activated. Since implementation of the EMS, plant operators are now better equipped to integrate energy demand as an operational consideration to avoid increasing facility peak electric demand.

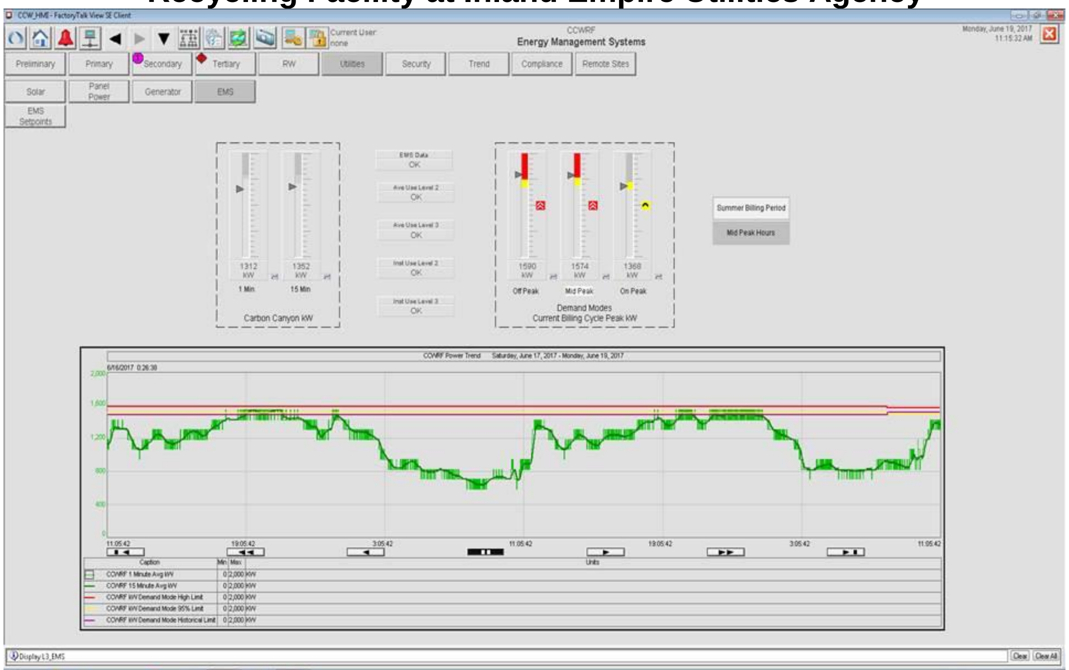
Figure 71: SCADA Energy Management System Integrated Within Carbon Canyon Water Recycling Facility Control Room



Source: Inland Empire Utilities Agency

To ensure that the EMS is monitoring, displaying, and managing the facility energy consumption correctly, EMS data is continually being compared with SCE billing data. This comparison ensures the IDSM strategies will be reflected in the resulting SCE electrical consumption and corresponding bill. Figure 72 shows the real-time EMS display for the CCWRF within IEUA SCADA control room. This display provides real-time energy consumption information for the facility to identify which energy management strategies should be employed. Usage data that enables these decisions to be made are based on instantaneous and real-time energy usage visual screen indicators that were developed to enable an operator to quickly identify an event. The EMS interface also has settings for holidays and billing cycles, which affects monthly charges, associated with electrical demand TOU charges.

Figure 72: Energy Management System SCADA Display for Carbon Canyon Water Recycling Facility at Inland Empire Utilities Agency

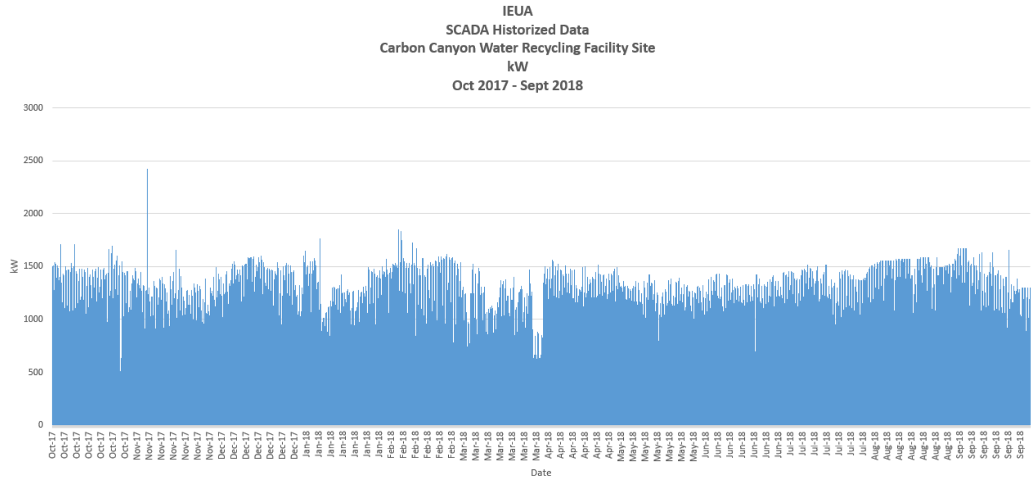


Source: University of California, Riverside

3.6.2 Twelve Month Operation Observations

Evaluation and data collection of SCADA at the CCWRF has been monitored since October 1, 2017. The initial start of programming of the EMS began in July 2017. The EMS was designed from the process control narrative (PCN) created by UCR engineers. The PCN describes algorithms used in the SCADA and how it should be programmed to display energy at IEUA's CCWRF and define alarm notifications. Figure 73 shows the collection of data at the CCWRF.

Figure 73: Continuous Historical SCADA Data 2017-2018



Source: University of California, Riverside

3.6.3 Using Energy Management System

The EMS has been integrated within the CCWRF SCADA since October 2017. Water distribution staff have been receiving alerts and alarms when excessive energy demand is observed during the on-peak time of use rate period. The team learned that excessive alerts become evident if energy thresholds are set too low. IEUA employees and the UCR team have collaborated to determine the ideal threshold setting to provide an appropriate level of alerts and alarms. Currently IEUA gets an alarm that indicates they need to make an adjustment to the system for potential energy demand savings and should reduce non-critical loads. The operator benefits by understanding the magnitude of load reduction required and matching with potential load reduction options. The alarm notification has been optimized to provide operators with real-time energy demand and the current existing peak load that has been recorded to date. Operators use this real-time energy information if needed for energy demand reduction.

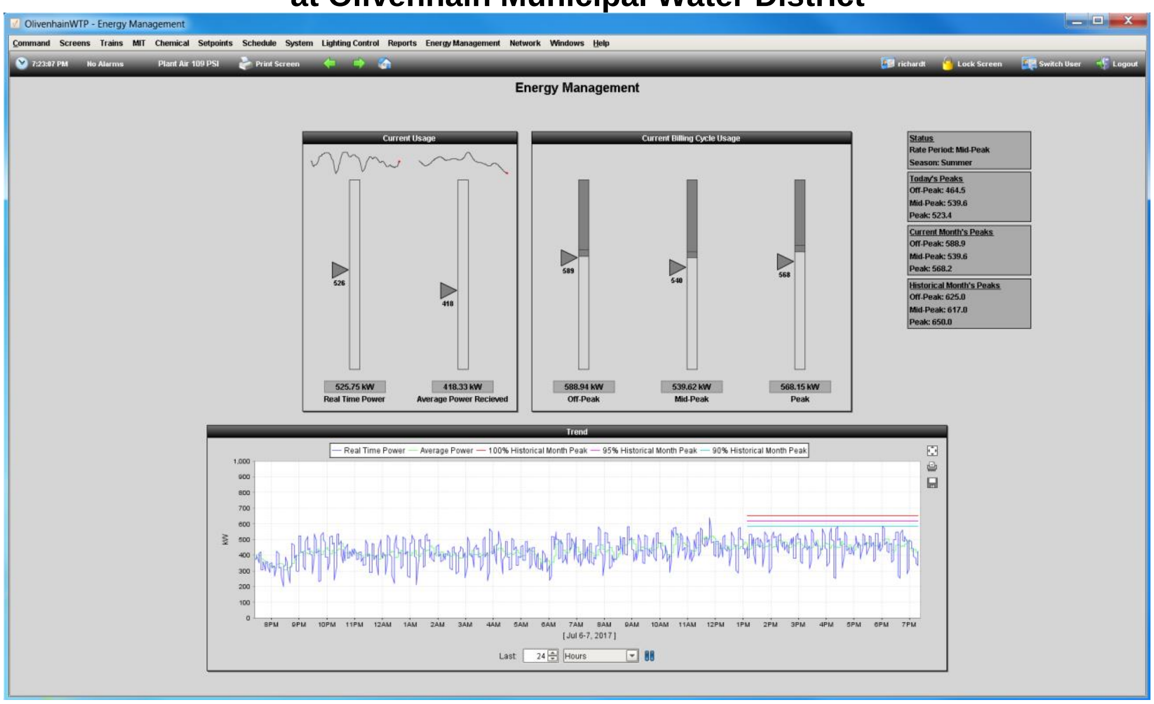
3.7 Olivenhain Municipal Water District System Operation

UCR’s CE-CERT and OMWD have demonstrated, deployed, and validated energy management and data acquisition and supervisory control strategies that can improve efficiency and reduce both peak loads and electricity costs in the delivery and treatment of water in California. This EMS system has been tested and validated to ensure the system data matches SDG&E’s meter data. The objectives for the EMS was to provide additional knowledge by monitoring and displaying real-time energy use and store historical data in SCADA so the operators can identify opportunities to reduce energy use.. The overall result of the EMS system is to reduce the amount of energy used during specific peak-times, relative to the summer and winter season in order to allow for kW demand and kWh energy savings by utilizing demand shifting. Demand shifting involves shifting energy-consuming activities from on-peak times to off-peak times based on OMWD’s demand and guidelines for water delivery and treatment.

3.7.1 Energy Management System Deployment

The EMS monitoring and display method continuously tracks site energy use through the utility meter and provides a real-time status to plant and facility operators. The system was originally created by a contractor using an existing energy meter at the site and creating SCADA tags to develop the SCADA screen used today. The initial design and implementation began June 28, 2017 and was online by July 12, 2017. The energy used for water treatment and pumping operation is continuously variable and dependent upon many factors. The energy provided to water treatment and pumping facilities is usually provided by one utility energy meter at the site location. The capture of energy use at the water treatment plant is by integrating the real-time energy use through the existing energy meter with current transducers (CT) downstream of the utility meter. The CT measures values which are processed through the SCADA system and stored in the data historian. The SCADA at the water treatment plant uses the stored values from the CTs to create advisories based on previous and real-time energy use. The EMS tracks and monitors kW demand and provides HMI feedback of existing energy use relative to 15 minute maximums in the current billing period. The overall objective and intent of integrating an EMS system was to be able to reduce the amount of kW electric power demand used during peak times year-round. This could be accomplished by shifting energy use from on-peak to off-peak times at the water treatment plant, based on water demand and water treatment requirements. Figure 74 shows the real-time EMS display for the OMWD within WTP SCADA control room.

Figure 74: Energy Management System SCADA Display for Water Treatment Plant at Olivenhain Municipal Water District

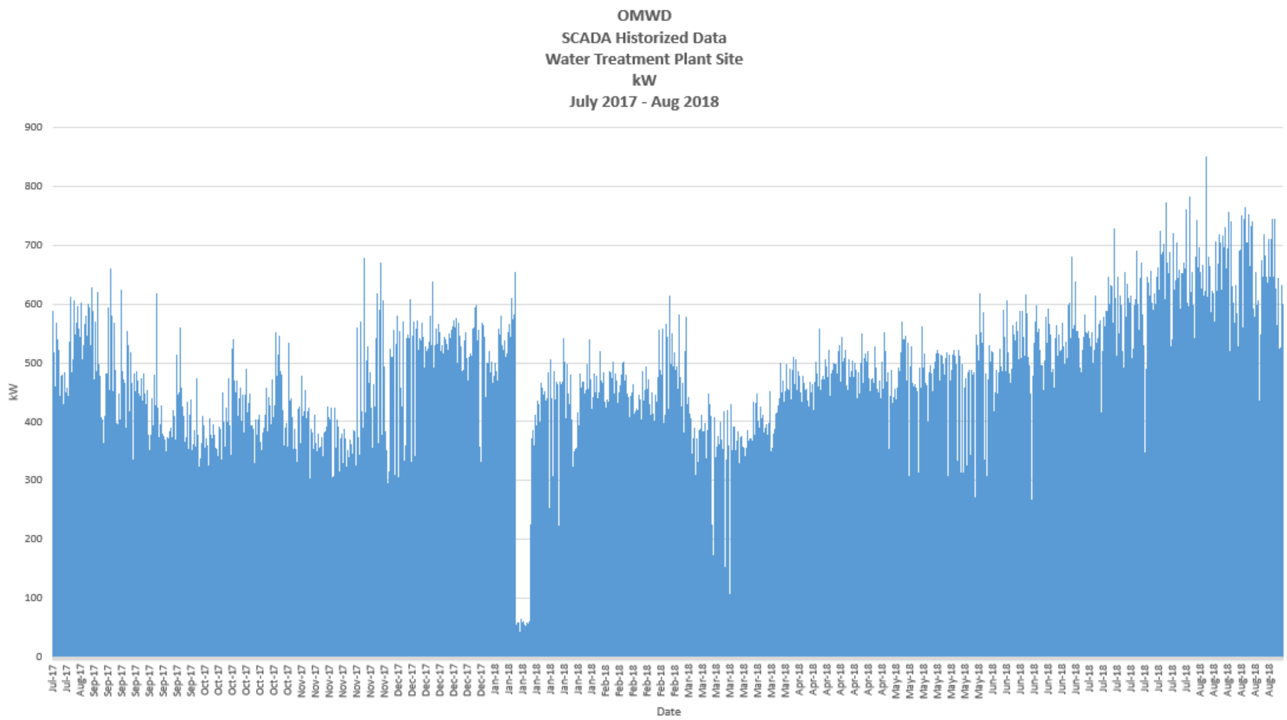


Source: University of California, Riverside

3.7.2 Twelve Month Operation Observations

Evaluation and data collection of SCADA at OMWD's WTP has been continuously monitored since July 1, 2017. The initial start of programming of the EMS began around June 2017 and the EMS was based off the PCN created by UCR engineers, which outlines the algorithm of the SCADA and how to implement and energy display with alerts at the WTP. Figure 75 shows the collection of data at the CCWRF with no loss in data beginning October 2017.

Figure 75: Continuous Historical SCADA Data 2017-2018



Source: University of California, Riverside

3.7.3 Using Energy Management Systems

At OMWD, the EMS has been successfully integrated with the SCADA system since July 1, 2017. Since then, OMWD staff has been using the system whenever possible The team developed and provided to OMWD staff an action item list for options to ensure the facility would not set a new maximum peak demand. This list provides the operator actual options they know they can implement without gaining prior approval from OMWD management.

The list created for OMWD operators is divided into two categories, "Scheduled" or "Daily Average". "Scheduled" is defined when SDG&E notifies OMWD in advance of an event. Table 5 shows a list of options that the operator can choose from, as well if the operator has the ability to implement an action item either remotely or on-site. Since either of these events would normally take place during operating hours, it was discussed that remote ability to shutdown "everything" was not needed.

Table 5: Action Item List When SDG&E Notifies OMWD in Advance of an Event

Scheduled
1. De-rating the Plant (reducing flows). {Remote Ability}
2. Temporarily turn off or reduce flow sales to neighbor agency. {Remote Ability}
3. Postpone maintenance.
4. Temporarily turn off the CL2 Generator. {Remote Ability}

Source: University of California, Riverside

"Daily Average" is defined as an event where the operator would receive an alert from SCADA. Table 6 shows a list of the options the operator can choose from to avoid creating a new peak. The list also shows if this action item can be done remotely or on-site.

Table 6: Action Item List When SCADA Notifies Operator

Daily Average
1. Lights
2. Recirculation Pumps {Remote Ability}
3. CL2 Generator {Remote Ability}
4. HVAC
5. Exhaust Fans
6. Postpone maintenance.

Source: University of California, Riverside

3.8 System Operation Summary

The previous section summarized the testing and validation of IDSM strategies as well as operation at the three water agencies. The goals of the EMS integration have been to create a migration path to move from a water demand-based control scheme to a scheme capable of both demand and efficiency-based controls. This migration path required hardware installation, software installation/integration, and engineering. The primary strategy has been to minimize the occurrences, frequency, and duration when the maximum number of motors are operating for pumping operations. The second strategy has been to provide an integrated notification system of current energy demand and prior energy historical use for the water treatment facilities. The testing and validation confirmed that each location is accurately monitoring real-time energy consumption in agreement with revenue meters installed at the facility location. Additionally, the EMS is properly displaying energy data and presenting operators with various forms of alerts and alarms to help them make decisions on adjusting energy use at their site.

3.9 Measurement and Verification

In December 2018 UCR began working with an independent contractor Alternative Energy Systems Consulting (AESC) to conduct an independent system measurement and verification (M&V) study to verify energy savings from the project. UCR managed the subcontract process and provided AESC with access to site data, background information, and overall system information so that AESC has all the information needed to complete the verification and validation of each water district. This section outlines AESC goals, approach and analysis, which describes their overall process to doing the M&V for UCR.

3.9.1 Background and Measurement and Verification Goal

M&V of the demand savings realized from the demonstration were conducted at the three project sites: CVWD, IEUA and OMWD.

UCR's technology implementation is unique in that it doesn't directly act to control and operate facility equipment to reduce electric demand, but rather provides useful and quickly digestible real-time information that increases the plant operator's awareness of the cost of increased peak demand and supports their decision process to make manual operational changes to avoid the increase. Although customized for each site, the basic approach is to provide real-time electric demand information along with current billing period established peak demand and alarming the operator when the demand begins to encroach on the set peak demand. This approach provides flexibility with respect to each site's operational constraints and configuration and leverages off the shelf technology to augment and support the smartest computer on the planet – the human control operator.

In this project, the goal of the M&V task is to confirm electric demand savings that occurred because of the implementation of UC Riverside's technology. Accomplishing this goal is challenging. At a minimum, these challenges include variation of the electric loads of interest, limited available data, and a significant behavioral factor. Successful M&V requires establishing meaningful independent variables to build reliable data models that can be used to predict electric demand absent UCR's technological intervention (baseline demand) along with a healthy understanding of operator attitudes, information comprehension and resulting actions.

3.9.2 Measurement and Verification Approach

In any M&V project, the ultimate choice of approach must be consistent with the established M&V goal. The approach must also be designed to work within the constraints imposed by data availability, statistical validity, and ease of interpretation. Recent expansions to Option C of the International Performance Measurement and Verification Protocol (IPMVP) have incorporated approaches such as regression analysis that use interval data and independent variables to develop a baseline that accounts for varying conditions like temperature and occupancy. The baseline, representing the conditions at a facility before some intervention, can be applied to post-intervention data to provide an estimate of what would have occurred in the absence of the intervention. The difference between the observed (actual) consumption and the model's estimated consumption forms the basis of the project's savings estimate.

As discussed previously, the goal of the intervention is to reduce monthly peak demand (maximum kW) during on-peak periods such that the corresponding bill costs can be reduced. This goal differs from the more traditional applications of Option C, which have tended to focus on total energy consumption (kWh) – a quantity measured and calculated differently than the peak demand, without regard to specific time periods during individual days. Nonetheless, similar potential approaches, inspired by the success of past efforts relying on interval data, were evaluated at the outset of the project. Despite some modifications, the rationale for such consideration remains consistent with IPMVP Option C, which encompasses a variety of approaches for evaluating "whole building" data to assess energy performance. Ultimately, the behavioral nature of the intervention and the likelihood of observing clear pre-intervention patterns informs a reasonable expectation that a statistical model could provide an acceptable baseline (given ample data availability). Upon initial consideration, these potential approaches included:

- Option C billing analysis (dependent variable: monthly maximum on-peak demand)
- Daily analysis with calculation of monthly maximum demand predictions (dependent variable: daily maximum on-peak demand)
- Tests of statistical significance for differences between pre-intervention and post-intervention monthly maximum demand
- Simple comparison of pre-intervention monthly maximum demand and post-intervention monthly maximum demand

3.9.3 Description of Available Data

Received data was made available via a secure transfer. Generally, each of the files fit one of several key categories: energy interval data, flow data (influent and/or effluent), billing, and project documentation. Two main subfolders were provided. The first main subfolder contained a variety of datasets for each of three sites: OMWD, IEUA, and CVWD. The three project folders included energy interval data (15-minute utility data and SCADA or another alternative source), billing data files, water production data, and site diagrams/profiles. For all three projects, the utility energy interval data was used, rather than the SCADA or another source.[1] Flow data was initially available on a daily

[1] Olivenhain: CEC WTR 15 Min interval WTP 2017 v2.xls; IEUA: 15 min – Aug16 to Aug 18 -CCWRF and RPF.xlsx; CVWD: CEC WTR 1C 2017-01-01 To 2018-08-16 15min interval.xlsx, Cucamonga Valley Water Dist East ave Aug-Oct 2018.xlsx

basis; the daily data was used to assess preliminary models.[2] Flow data at more granular levels, expected to be more valuable in modeling, was requested following this assessment. The included billing data and documentation were referenced to define the on-peak periods for each of the three sites, enabling the maximum on-peak demand to be calculated from the energy interval data. IEUA and CVWD were found to have on-peak periods in summer months, with no equivalent winter period; OMWD, on the other hand, had on-peak periods defined for both summer and winter.

The second main subfolder contained qualitative documentation required by the UCR's contract with the CEC: a Critical Project Review Report (CPR), a Task 5 Interim Report, and a Demonstrations Sites Systems Report. A variety of miscellaneous files are contained in the parent folder, outside the two main subfolders; these included a data glossary (added after the initial transfer to help establish context), a project summary, and a project scope of work.

3.9.4 Description of Analysis

As a first step, the OMWD data was sorted and analyzed to judge the likely appropriateness of a potential daily analysis. Again, flow data was initially received in the form of daily totals; while a more granular level could potentially be more useful, correlations between daily flow and energy variables (daily energy consumption and maximum on-peak demand) were calculated for the three sites to provide a preliminary indicator of the viability of regressions using available data.[3] The correlations are shown in Table 7 for the three sites.

Table 7: Correlation for Preliminary Modeling Assessment

	OMWD Total kWh	OMWD Max On-Peak kW	IEUA[1] Total kWh	IEUA[1] Max On-Peak kW	CVWD[2] Total kWh	CVWD[2] Max On-Peak kW
Influent	0.94	0.66	N/A	N/A	N/A	N/A
Effluent	0.94	0.66	0.45	0.08	0.66	0.38

1. IEUA flow data was provided for effluent only.

2. It was unclear whether CVWD's flow data was influent or effluent; it was assumed to represent effluent at the time of analysis.

Source: Alternative Energy Systems Consulting

[2] Olivenhain: WTP Production 012015 thru 122018.pdf; IEUA: 930W PS Flow (Dec 2015 – Nov 2018).xlsx, CVWD: CVWD_ProductionData_20181108.xlsx (sum of Well 39, Well 40, and five pumps: PS1C_P1, PS1C_P2, PS1C_P3, PS1C_P4, and PS1C_P5)

[3] Due to the lack of a winter on-peak period, correlations for IEUA and CVWD were calculated for summer weekdays only.

While extensive quantitative analysis is planned, numerous discussions within the project team have led to the expectation that additional qualitative analysis will also be useful. Structured interviews with control operators will be especially valuable. Therefore, the M&V analysis will rely in part on carefully crafted questions and the associated responses from the operators. The operators' input will be factored into the project's ultimate conclusions about the effectiveness of the technology toward peak load reduction.

3.9.5 Measurement and Verification Conclusions and Recommendations

Due to the uncertainties discussed, definitive performance conclusions are not available. However, from the data analysis and site interviews can discern the following.

- All the water agencies valued the UCR system and felt that more can be done with it, including integration with their existing SCADA systems, which was taking place to varying degrees at all sites.
- Although some of the data analysis suggests demand reduction impacts following alarm display, the answers gleaned from the interviews imply that the operators took minimal action when alarms were displayed.
- The water agency operations are highly constrained by regulatory requirements, which, in some cases, resulted in limited scope deployment (the UCR system was applied to a small subset of equipment or that operator action was limited) due to concerns about maintaining compliance.

Based on the M&V effort, M&V group can make the following recommendations.

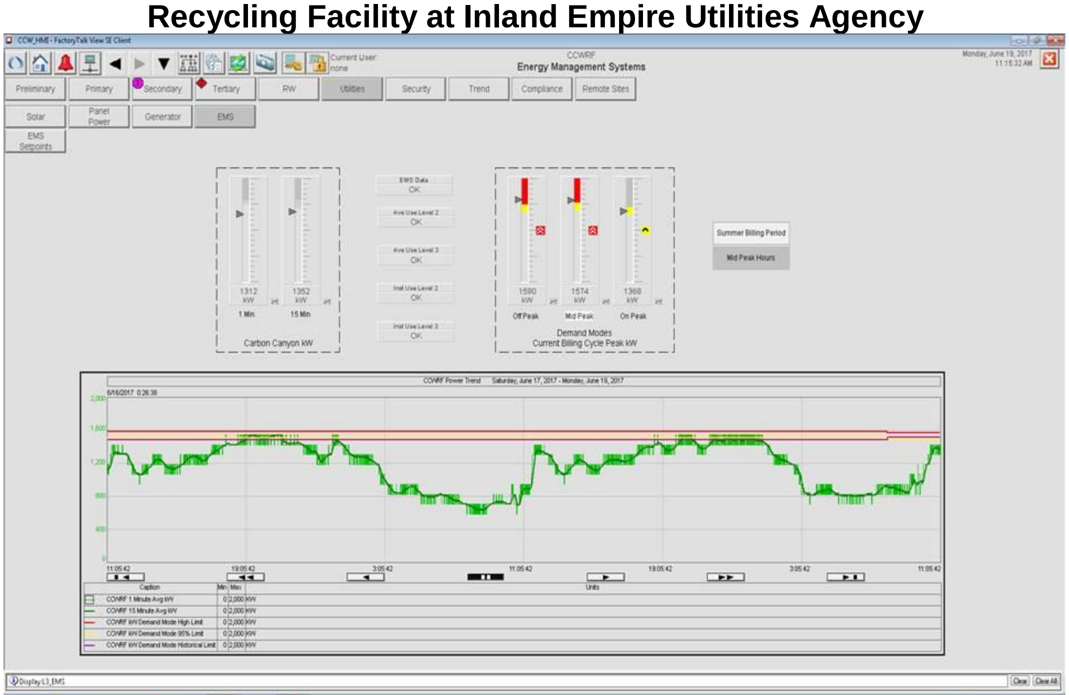
- Complete the integration into the site SCADA to improve site display and response and allow them to customize the information to their needs.
- Develop an operator tool that would provide, in real-time, a list of opportunities for demand reduction and their impact on water quality, supply and demand compliance. It should incorporate plant operating conditions, along with onsite water storage, energy storage and electric generation available capacities and compliance constraints to provide these demand reducing options.
- Develop a planning tool that could be used to evaluate existing and added storage (energy & water) and equipment capacities to expand the opportunities for demand reduction.
- If there is a follow-on development and demonstration of system improvements, and if M&V is required, M&V results would be improved if verification planning took place early in the project execution

CHAPTER 4: Technology/Knowledge/Market Transfer Activities

4.1 Technology/Knowledge Transfer Plan

Water transport and water treatment energy needs account for a large portion of the total related energy use for the state's electricity consumption and includes everything from pumping, treating, collecting, discharging, wastewater, and customer end uses. This project focuses on improving energy demand management for complex water systems managed by SCADA. The technology development focuses on the development of energy management algorithms and methods to be integrated within a water-oriented SCADA facility or distribution network. Traditional water related SCADA systems manage water flows, pump operations, and reservoir levels independent of energy costs. This project has introduced energy costs as an operational factor within the SCADA control methods. The primary integration method has been to create a SCADA operational screen which displays energy and cost related variables and conditions. Figure 76 shows the real-time EMS display for the CCWRF within IEUA. This display provides real-time energy consumption for the facility and identifies when energy management strategies should be enacted.

Figure 76: Energy Management System SCADA Display for Carbon Canyon Water Recycling Facility at Inland Empire Utilities Agency



Source: University of California, Riverside

The Technology/Knowledge Transfer Plan includes the following efforts:

- CEC-sponsored outreach and distribution: These programs have an existing dissemination process which consists of fact sheets, reports, program reviews, conferences, and workshops. The project team completes and participates in all forms of outreach available through CEC-administered transfer activities. The team prepares material, which conveys the technology and applicable market sectors. The team intends to continue these efforts even upon completion of the current deployment program.
- Market sector identification: The project team has selected three water districts, which address different components in the market sector. The three locations represent potable water treatment, wastewater recycling, and water distribution. These three locations have identified the processes and operations suitable for adoption of technology developed and deployed within this project. The team has used efforts to characterize market sectors to be further identified and explored.
- Application identification: Adoption of SCADA integrated energy demand management has proven effective for specific applications within the water treatment and distribution sector. The team has collaborated with water agencies and electric utilities to identify energy use profiles, which would benefit from IDSM technology integration.
- Policy development: Future energy policies and utility rate schedules will greatly impact the financial motivations associated with the adoption of SCADA integrated energy management technology. The team has reviewed and evaluated the policy impacts associated with IDSM technology adoption.
- Development of Presentation Materials: The team has developed presentation, workshop, and pamphlet materials to assist agencies identify which processes or facilities would benefit most from IDSM technology adoption. This information is intended to be shared at an upcoming workshop focusing on the water and energy nexus.

4.2 Water and Energy Nexus Workshop

To aid in the dissemination of IDSM technology associated with this project a workshop has been organized entitled "Water and Energy Nexus" was held on February 27, 2019. The goal of the workshop is to reach out to local, regional, and state water affiliated agencies, which provide water services to the residential, commercial, industrial, and agricultural sectors throughout California. Much of the potable water throughout the state is dependent upon managed distribution systems to acquire, treat, and distribute water while maintaining availability, quality, and reliability. Additionally, the management of wastewater into usable recycled water needed for irrigation, agriculture, industry, and groundwater recharge consists of complex treatment and distribution systems. These water systems consist of processes primarily powered by grid-distributed electricity. The management of these water processes in conjunction with electric power demand management is the focus of the "Water and Energy Nexus" workshop.

Key stakeholders are: water agencies located throughout California, electric utilities, renewable power agencies, energy storage agencies, regulatory agencies, SCADA integrators, and academia. Individual water agencies benefit greatly by understanding operational and financial gains to be realized through improved electrical demand management. Renewable energy generation and energy storage technology is ideal technology for use within water treatment and distribution facilities. Regulatory agencies benefit from a more thorough understanding of the energy use characteristics within the water sector. SCADA integrators and academia are key in demonstrating and deploying integrated energy management systems in a beneficial manner. These stakeholders and sectors are targeted to participate in the workshop.

Key research findings discovered by the UCR team will be shared at the workshop and will be included in future academic publications. The publications include Master's theses, PhD dissertations, IEEE journals, and potentially water industry publications.

The demonstration sites include specific SCADA-controlled operations within three water districts. These operations consist of water treatment facilities and pumping stations. The water districts plan to expand the energy demand management technology from a single facility location to system wide installations. The initial single site use within each water district has demonstrated the potential benefits of monitoring real-time energy demand. The water districts plan to expand the SCADA energy demand monitoring throughout their district operations.

4.2.1 Water Energy and Policy Conference hosted by UC Riverside at CE-CERT

The CEC has funded technology demonstration and deployment projects that accelerate the commercialization of electricity-related, energy-efficient industrial, agricultural, and water/wastewater treatment processes at multiple sites. UCR's CE-CERT held its first Water Energy and Policy Workshop on February 27, 2019, on the UCR campus in conjunction with the 5th Annual Solar Conference, conference flyer is shown in Appendix C. The water workshop portion of the conference provided an environment for faculty, researchers, community leaders, and project partners from each water district to share with the water industry how energy management has changed and shaped the way each water district operates. Not only was the event made public via CE-CERT's website[4], but several social media platforms such as Twitter[5] and LinkedIn[6] were used to provide information about the event or share visual images of the event as it was happening.

The Solar Conference has historically been a one-day event, but with the addition of the water energy nexus workshop, it opened up opportunities to for city leaders, planners, utility companies to understand not only solar policy, regulation, and environmental benefits but also the connection between water and energy consumption. This is a result of water-related energy use being one of California's largest electrical loads. The workshop focused on how to identify those electrical loads within a water district as well as providing knowledge on what technology is available to capture that load and reduce it. During the two-day Solar Conference 44 speakers made presentations and discussed topics such as current policy, latest technology, microgrids, and sustainability benefits of renewable energy.[7]

The Energy-Water Nexus on day one focused this project and was led by UCR in collaboration with project partners IEUA, CVWD, and OWMW. The workshop featured and described topics such as advanced technologies, methods, and approaches used at each respective water district that helped introduce and improve the level of awareness at each district, and visibility in terms of energy use and power demand reduction. During the workshop, there was a speaker from each water district project partner to speak on their experience of the overall project and project outcome as shown in Figure 77. Since each water district had its own version of implementation it was able to describe how the EMS was specifically designed and implemented at each of the water districts. The water districts also described how each custom EMS was used and how it impacted the overall operation decision-making. Information such as this was a benefit to each of the visiting water districts as well as attendees, because it provided several different approaches to common goal, which is demand saving and/or reduction. The information provided at the workshop had positive reviews by visiting water districts and attendees since each water district throughout California processes water differently.

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[4] UCR CE-CERT's Website, https://www.cert.ucr.edu/events/solar2019.html

[5] UCR CE-CERT's Twitter, https://twitter.com/ucrcecert

[6] UCR CE-CERT's LinkedIn, https://www.linkedin.com/school/college-of-engineering-center-for-environmental-research-and-technology/?trk=d_public_post_follow_view_profile

[7] UCR CE-CERT's Website, https://www.cert.ucr.edu/

Figure 77: Schedule for Each Water District Speaker

10:20 – 11:20 **CEC Sponsored Water & Energy Efficiency Projects - Part I**

Description:

The California Energy Commission (CEC) has funded technology demonstration and deployment projects that accelerate the commercialization of electricity-related, energy-efficient industrial, agricultural, and water/wastewater processes at multiple sites. This session will discuss a project by the University of California, Riverside in collaboration with the Inland Empire Utilities Agency.

Moderated by:

Michael Todd, P.E., Principal Development Engineer, College of Engineering Center for Environmental Research and Technology (CE-CERT)

Presenters:

Pietro Cambiaso, P.E., Deputy Manager, Planning and Environmental Resources, Inland Empire Utilities Agency (IEUA)

Dr. Sadrul Ula, Research Faculty, CE-CERT

11:30 – 12:30 **CEC Sponsored Water & Energy Efficiency Projects - Part II**

Description:

This session will discuss two independent site demonstrations at the Cucamonga Valley Water District and Olivenhain Municipal Water District in collaboration with the University of California, Riverside. This session will feature advanced technologies, methods, and approaches used at each respective water district, which improve the level of awareness and visibility in terms of energy use and power demand.

Moderated by:

Dr. Sadrul Ula, Research Faculty, CE-CERT

Presenters:

Dave Smith, Operations Manager, Olivenhain Municipal Water District (OMWD)

Michael Maestas, Manager, Water Production, Cucamonga Valley Water District (CVWD)

Source: University of California, Riverside

In conclusion, each water district's mode of operations is highly constrained and must meet the primary goals of meeting water consumption demand, meeting wastewater/recycle water processing requirements and maintaining water quality. Even with these constraints, each water districts that presented described the same end result, which was how each water agency benefitted from the project by learning more about what they can do to reduce electric costs such as modifying pump testing procedures, changing overall site operation to a different time of use to reduce peak demand charges, and being able to monitor real-time energy usage using their site-specific EMS. The project generally helped them better understand their overall operation based on the analyses provided by UC Riverside, which resulted in changes of how each district operated and ultimately helped reduce demand whenever possible.

4.3 Technology/Knowledge Transfer Summary

This chapter summarized the technology and knowledge transfer of IDSM strategies used at three water agencies: IEUA, OMWD, and CVWD. The goal of the technology and knowledge transfer is to create a migration path from a water demand-based control scheme to a scheme capable of both demand- and efficiency-based controls. UC Riverside is demonstrating and deploying energy management, data acquisition, and supervisory control strategies that improve efficiency and reduce both peak loads and electricity costs in the delivery and treatment of water in California. This strategy and methodology overlay and incorporates the existing SCADA system without disrupting current operations. This Technology/Knowledge Transfer Activities summary has detailed the technology and knowledge transfer-based energy enhancements with focus on the following:

- Overview of technology detailed in fact sheets prepared for CEC distribution channels
- A detailed Technology/Knowledge Transfer Plan that includes the targeted market sector and potential outreach to end users, utilities, regulatory agencies, and others
- A description of the intended use(s) and applications, which would benefit from adoption of the developed technology
- A discussion of policy development which impacts the adoption of SCADA integrated energy management technology
- Development of Presentation Materials for a CEC- sponsored conference/workshop on the results of the project

CHAPTER 5: Conclusions/Recommendations

The water industry throughout California is extremely diverse with unique challenges influenced by numerous independent factors. The primary focus of water agencies continues to be the acquisition, processing, and delivery of water. Once a water agency is able to successfully fulfill their delivery commitments, improving costs and efficiency often become an operational focus. The goal of this collaborative effort is to integrate energy management strategies without compromising water production needs.

The agencies involved in this study represent both the acquisition, treatment, and distribution of potable water and the collection, treatment, and distribution of recycled wastewater. Each water agency operates and manages unique facilities with distinctive operational characteristics. Therefore, the industry has adopted SCADA systems which allow for distinct control of the specific operations and/or processes. The SCADA systems provide a means to control and monitor activities associated with water processing. Traditionally, the SCADA operation has been programmed to operate independent of energy costs. Additionally, when staff override SCADA-defined activities the cost of energy is frequently unknown. The traditional SCADA based operational methods employed by water agencies allows for potential IDSM energy cost reductions if energy consumption is added an operational parameter.

The focus of the project has been to introduce beneficial IDSM strategies at individual water agencies without compromising their operational performance. The partner agencies have all benefited by developing a more detailed understanding of their energy profiles while incorporating IDSM technology. Each water agency operates a diverse system comprised of many facilities with numerous electric revenue meters. The rate plan assigned to the revenue meter combined with the facilities operational activities determines the potential for IDSM cost reductions associated with peak demand charges. This project has demonstrated IDSM peak demand reduction strategies deployed for a specific facility within each water agency. The technology employed during this project can be migrated to additional sites (revenue meters) within each water agency.

Staff associated with the operation of water facilities have often been segregated from the energy being measured at the revenue meter and the associated costs. The evolution of billing within the energy sector has created energy management strategies which are often reactionary. Electric bills arrive a month after the energy has been utilized and therefore any energy strategy used is only realized in delayed billing benefits. This project has demonstrated the benefits of coupling real-time energy use in tandem with SCADA operations. Therefore, real-time energy use is available immediately as an operational parameter to be considered as a SCADA variable.

It is recommended that SCADA operations include a real-time energy consumption value to identify the real-time energy cost of operation. This allows for EMS and IDSM peak demand tracking and alert systems to trigger when excessive energy costs are being incurred. Additionally, energy costs can be directly correlated with the process at hand and identify when abnormal operations occur. Further benefits can be obtained if forecasting evolves to allow preplanning of energy needs and avoiding conditions which create excessive energy demand peaks. These EMS and IDSM strategies can benefit the ratepayer with reduced peak demand charges and benefit the utility with reduced peak demand loads on power plants, transmission facilities, and distribution systems.

CHAPTER 6: Benefits to Ratepayers

6.1 Introduction

A 2005 CEC study revealed that water-related electric energy consumption in California amounted to nearly 19 percent of the state's total energy use.[8] If the electricity consumption for water end uses is excluded from that figure, the energy used for water supply, water conveyance, water treatment, water distribution, and wastewater treatment amounts to 5.1 percent of the total statewide electricity needs. The same study stated that the water and wastewater treatment in California required 3,000 MW peak electricity demand. The discoveries of this study have motivated a number of initiatives to gain better understanding of the relationship between water and energy, and exploring the potential of energy efficiency and demand reduction programs in water production and delivery.

The main objective of this project was to demonstrate an automated system at water treatment facilities, for monitoring instantaneous power and alerting operators to reduce electric load by turning off or rescheduling non-essential processes. These actions can result in reducing electricity demand during peak hours, which in turn can result in lower electricity costs due to lower demand charges and energy charges. In addition, the reduction of peak demand reduces peak generation capacity needs and improves the reliability of the electric grid system.

6.2 Quantitative Benefits

6.2.1 Electricity Demand Reduction

Integrated energy management systems and SCADA systems has helped to reduce peak electric demand and electric energy use during peak periods. Electricity generation, transmission and distribution systems in California face maximum stress during the peak demand period. During the September 2014 heat wave, many areas of Southern California established new peak demands surpassing previous records of 2006-2007. By reducing peak demand from a major electricity-using sector, the project was able to alleviate the need for expensive and inefficient peaking power plant generation units. The demand reduction technology implemented through this project has helped reduce the need for new plants, increasing reliability with very little additional cost.

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[8] *California's Water-Energy Relationship*, California Energy Commission, Final Staff Report CEC-700-2005-011-SF, November 2005.

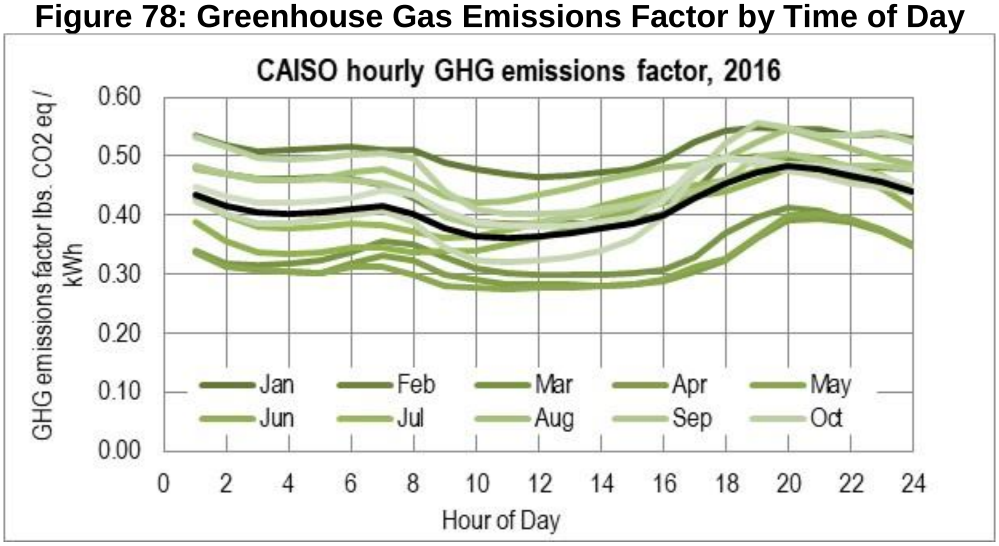
6.2.2 Deferred Generation Capacity

Peak electricity demand requires utility companies to acquire additional generation capacity to meet these demands. Normally, the generation source to meet peak demand is natural gas. The cost for the additional generation capacity is passed on to the ratepayers. Reduction in peak demand not only improves the reliability of the electric grid system, by preventing overloading and blackouts, but also eliminates the need for additional generation capacity. A conservative figure for the annual cost of generation capacity of $25.70/ kW-year is used here. The demand reduction of 41 percent at CVWD 1-C site would result in annual savings of $12,434 (41 percent x 1,180 kW x $25.70/ kW-year). A potential statewide reduction of 41 percent of demand peak by water production facilities would result in $31,611,000 annual savings.

6.2.3 Greenhouse Gas Emissions Reduction

According to data from California Air Resource Board (CARB) greenhouse gas (GHG) emissions originating from in-state electricity generation and imported electricity account for 16 percent of the state's total GHG emissions.[9] Although the electricity generation-related GHG emissions in California have been decreasing in the last several years, partly due to renewable energy resources such as solar, for the same reason, there has been an increasing difference between emissions from energy generated during mid-day versus energy generated in the evening during peak hours. Figure 6.1 shows analysis performed by Beyond Efficiency consulting, based on CAISO generation data by generation source type. The data indicates that the average difference between the maximum emissions during on-peak and minimum emissions during mid-day is 27 percent for 2016.

Figure 78: Greenhouse Gas Emissions Factor by Time of Day



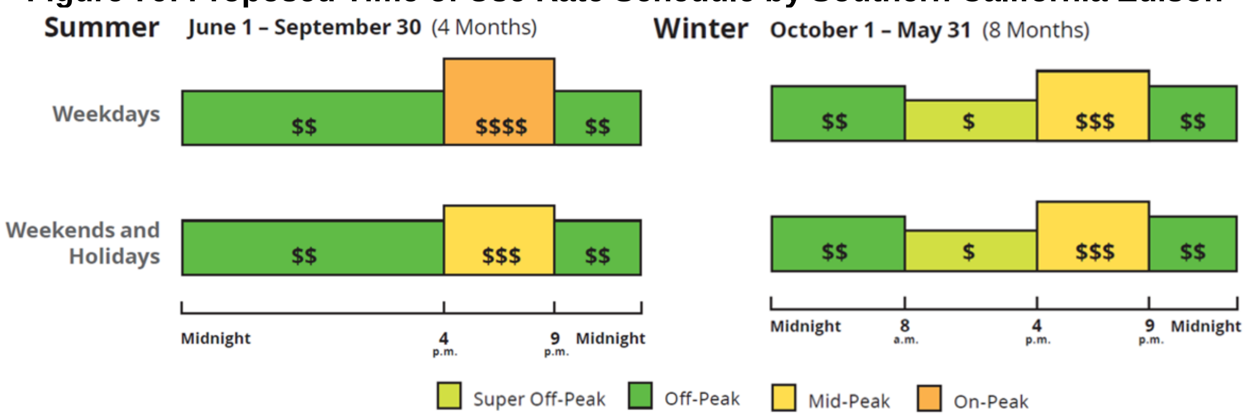
Source: http://beyondefficiency.us/blog/whats-dirtiest-time-day-use-electricity

[9] California Air Resource Board website, https://www.arb.ca.gov/cc/inventory/data/data.htm

While this daily trend of GHG emissions per kWh does not align with the current time-of-use rate schedule for commercial customers by utility companies, SCE has announced its plan for updating the current TOU schedule in March 2019. Figure 79 summarizes the proposed new SCE TOU schedule, which indicates shifting the on-peak period in summer to 4 PM-9 PM and mid-peak in winter to 4 PM-9 PM. This aligns better with GHG emissions per kWh by time of day shown in Figure 78. Therefore, shifting energy use from on-peak time to off-peak time during the day in summer, and from mid-peak to super off-peak in winter can lead to significant GHG emissions reduction.

If the reduction of 41 percent in demand is applied over an average of one hour per day during peak hours. This would amount to 27 percent reduction in GHG emissions in the annual generation of 448,950 MWh (41 percent x 3,000 MW x 1h/day x 365 days). At 0.25 $mTCO_2/MWh$, this reduction in GHG emissions translates to reduction of 30,304 $mTCO_2$ (metric tons of CO_2).

Figure 79: Proposed Time of Use Rate Schedule by Southern California Edison



Source: https://pages.email.sce.com/TOU/en/

6.3 Qualitative Benefits

6.3.1 Increased Power Grid Reliability

Since water-related energy use as whole is a considerable portion of the total energy use in California, decreasing peak demand for water and wastewater treatment during peak hours could have a tremendous positive impact on the electric grid system. During peak periods, the electricity generation, transmission, and distribution systems in California face maximum stress. Therefore, reduction on peak demand could lead to increased grid reliability without the need for additional generation capacity.

6.3.2 Awareness of Energy and Demand Use

Through participation in this project the various staff members from management and operations from the participating water districts, have gained an increased awareness of their energy and demand use and better understanding of the electricity tariffs. With increased awareness the priority of energy and demand conservation has increased, following compliance with water quality standards, meeting customer demands, and safety.

6.3.3 Power Quality and Fault Monitoring

Implementing a dynamic signaling system to alert operators to periodically adjust power use during peak periods required installation of power meters to provide real-time power readings. The data from those meters was compared and verified against the utility revenue meters. In addition, these meters have the capability of providing power quality metrics, which can be used in detecting power issues earlier and troubleshooting power-related problems. Some of the measured parameters include voltage sag, voltage swell, current unbalance, real power, reactive power, power factor, crest factor, inrush current, harmonics, and others. Power quality meters can provide additional savings to water districts in identifying power losses and degraded efficiency.

6.3.4 Integration of Energy and Demand Data with SCADA

Installation of power meters at the participating project sites, and integration of the power data with the existing SCADA and historian systems, has given water districts an additional valuable metric for their water operation. For example, the data can be used to evaluate the energy efficiency of the water production at a specific site in real-time or trends over specific time periods. In addition, energy and power data for specific equipment can be used for monitoring the efficiency of that particular equipment.

6.3.5 Electricity Bill Estimation

As part of this project, a software application tool was developed to estimate the electricity bill for the current billing cycle, based on the power meter data and rate schedule parameter inputs. The tool is useful to water production managers in gauging the energy use and energy cost of operation. The tool provides a breakdown of the electricity bill charges.

6.3.6 Technology De-risking

One of the objectives of this project is establishing the economic and practical feasibility of the approach, proving the reliability of components from companies in California, and reducing risk for future investment. Proven and widely adopted technologies result in lower costs for later installations. Thus, a benefit from this project to ratepayers will be a reduction in electricity bills with the wider adoption of this technology. The technology and approach demonstrated through this project for reduction of peak demand at water districts, are not limited to the water production process only, they could be applied to wide range of industrial processes in the state of California. Therefore, de-risking of this technology and approach could have a greater benefit to ratepayers.

ACRONYMS AND GLOSSARY

Term/Acronym	Definition
Acft/yr	Acre-feet per year
ADR	Automated demand response
AF	Asset Framework
AESC	Alternative Energy Systems Consulting
CCWRF	Carbon Canyon Water Recycling Facility
CCRWPS	Carbon Canyon Water Pumping Station
CE-CERT	College of Engineering Center for Environmental Research and Technology
CPR	Critical Project Review
CT	Current Transducer
CTU	Count Up
DCM	David C. McCollom Water Treatment Plant
CVWD	Cucamonga Valley Water District
DR	Demand response
DIGI	Digi International, Inc.
DIN	Deutsche Institut fur Normung
EMS	Energy management system
CEC	California Energy Commission
EPIC	Electric Program Investment Charge
GPD	Gallons per day
GPM	Gallons per minute
GUI	Graphical user interface
HMI	Human machine interface
HP	Horsepower
HSPA	High Speed Package Access
ICU	Interface Configuration Utility

Term/Acronym	Definition
IDSM	Integrated Demand Side Management
IEUA	Inland Empire Utilities Agency
I/O	In/out device
IPMVP	International Performance Measurement and Verification Protocol
kW	Kilowatt
kWh	Kilowatt-hours
kWh/acft	Kilowatt-hours per acre feet
LAFCO	Local Agency Formation Commission
LCD	Liquid Crystal Display
LTE	Long Term Evolution
MGD	Million Gallons per Day
Microgrid	A discrete energy system consisting of distributed energy sources (including demand management, storage, and generation) and loads capable of operating in parallel with, or independently from, the main power grid.
M&V	Measurement & Verification
MSG	Message
MW	Megawatts
NC	Non-coincidental
OMWD	Olivenhain Municipal Water District
OPC	Open Platform Communications
PAC	Programmable Automation Controller
PCN	Process Control Narrative
PI	Process information
PI AF	PI Asset Framework
PI ICU	PI Interface Configuration Utility
PID	Proportional-integral-derivative
PLC	Programmable logic controller

Term/Acronym	Definition
PRV	Pressure reducing valve
psi	Pounds per square inch
PUD	Power usage dashboard
RDBMS	Relational Database Management System
RTU	Remote terminal unit
RWRP	Regional Water Recycling Plant
SCE	Southern California Edison
SDG&E	San Diego Gas and Electric
TOU	Time of use
SCADA	Supervisory control and data acquisition
SIGI	Sustainable Integrated Grid Initiative
Smart Grid	Smart Grid is the thoughtful integration of intelligent technologies and innovative services that produce a more efficient, sustainable, economic, and secure electrical supply for California communities.
SNAP	Software and hardware suite from Opto 22 used for industrial automation, remote monitoring, and data acquisition
SNMP	Simple Network Management Protocol
TON	Timer on Delay
UCR	University of California Riverside
UFL	Universal File and Stream Loading
VFD	Variable frequency drive

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UCR CE-CERT's Website, https://www.cert.ucr.edu/

APPENDIX A:
Calculations Performed in PI System Explorer to Determine the Time of Use

Name	Expression	Value	Output Attribute
touSession	IF((Month('*')>='Summer Start')And(Month('*')<='Summer End')) Then("Summer") Else("	Winter	Map
dayType	If((Weekday('*')>1)And(Weekday('*')<7)) Then("Weekday") Else("Weekend")	Weekday	Map
newyear	If(Yearday('*')=1) Then("true") Else("false") //New Year's Day	false	Map
washington	If(Yearday('*')=53) Then("true") Else("false")//Washington's Birthday	false	Map
memorial	If((Yearday('*')>145)And(Yearday('*')<153)And(Weekday('*')=2)) Then("true") Else("f	false	Map
july4th	If(Yearday('*')=186) Then("true") Else("false") //Independence Day	false	Map
labor	If((Yearday('*')>244)And(Yearday('*')<252)And(Weekday('*')=2)) Then("true") Else("f	false	Map
veteran	If(Yearday('*')=316) Then("true") Else("false") //Veteran's Day	false	Map
thanksgiving	If((Yearday('*')>326)And(Yearday('*')<334)And(Weekday('*')=5)) Then("true") Else("f	false	Map
christmas	If(Yearday('*')=360) Then("true") Else("false") //Christmas	false	Map
holiday	If((newyear="true")Or(washington="true")Or(memorial="true")Or(july4th="true")Or(lab	false	Map
tou	If(holiday="true") Then("Off-Peak") Else(IF((touSession = "Summer")And(dayType = "W	Mid-Peak	Time of Use
concatTOU	Concat("Peak Usage ","(",tou,"):")	Peak Usage (Mid-Peak):	(TOU)
timerange	If(dayType="Weekend") Then("(Weekend)") Else If(holiday="true") Then("(Holiday)") E	(8:00 AM - 5:00 PM)	TOU time range
nextTOU	If((timerange = "(Weekend)")Or(timerange = "(Holiday)")) Then("Mid-Peak") Else If(t	On-Peak	Next TOU

APPENDIX B:
PI System Installation Report

PI System Installation

UC Riverside

Remote

Site ID: – None
Server ID: 2686197

Date(s) of Work: 30-Jul-2018 to 31-Jul-2018 Type of Work: Remote

File Name: UC Riverside – Remote – PI System Installation – 30-Jul-2018 to 31-Jul-2018 – Preeti Srivastav.doc

Version Number: 01

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City, Mexico OSIsoft do Brasil Sistemas Ltda. •

Sao Paulo, Brazil OSIsoft France EURL • Paris,

France

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Revision History

Revision	Date	Responsible Person	Notes
01	31-Jul-2018	Preeti Srivastav	Initial version.

OSIsoft.

Table of Contents

Chapter 1. Work Summary

The following presents the work report regarding the [JOB]

Scope of Work

Date(s) of work: 30-Jul-2018 to 31-

Jul-2018 Type of work: Remote

Percent complete: 100%

From 30-Jul-2018 to 31-Jul-2018, a service activity was performed for a site of UC Riverside in order to install the PI System according to company specific installation instructions. This report presents the work done, the current PI System in place as well as some recommendations.

Representatives Information

OSIsoft Representatives	Product Support Engineer	Preeti Srivastav, psrivastav@osisoft.com
	Deployment Team Coordinator	Aaron Schrage bschrage@osisoft.com
	EPM/CoE	Not Applicable
	Team Lead, Customer Support	Sejal Shah sshah@osisoft.com
	Account Manager	Bob Baer rjbaer@osisoft.com
Customer Representative(s)		Jack Maynard, (951)-529-6862, jmayn001@ucr.edu

Work Done

The following tasks were performed during OSIsoft work:

Installed SQL Server Express 2012 and Installed the latest version of PI AF and PI Analysis Service, PI Data Archive, PI OPC interface, PI Vision on a single server.

Open/Unresolved Issues (Critical > Important > Minor)

Open Issue #1	None	None
Description	None	
Current State	None	
Assigned to	None	

Recommendations (Important > Best Practice > Comment)

Recommendation #1	Use Service Accounts	Best Practice
Description	Default system accounts are used for services	
Recommendation	Use service account for the PI AF Application, PI Analysis, PI Web API, PI Web API Crawler and PI Vision Service	

Brief Daily Log

Day 1: Monday, July 30, 2018

- Installed .NET Framework 3.5
- Installed Microsoft SQL Server 2012 Express edition with SQL Server Management Studio
- Installed and configured
  - PI Server 2018
  - PI AF Server 2018
  - PI Analysis Service 2018
- Enabled WER
- Installed PI Interface for OPC DA 2.6.15.3

Day 2: Tuesday, July 31, 2018

- Uninstalled Read-Write version of PI Interface for OPC DA 2.6.15.3 as per customer request
- Installed and configured PI Interface for OPC DA (Read-Only) 2.6.15.3
  - Tested interface using tag OPCTestPoint
- Installed PI DataLink 2017 SP2 5.4.2.0
- Installed and configured PI Vision 2017 R2 SP1 3.3.1.0
  - Used Basic Authentication
- Configured/scheduled PI Vision backup

Chapter 2. PI System Architecture

This section presents the current PI System architecture following OSIsoft work. Versions of the software installed are also specified

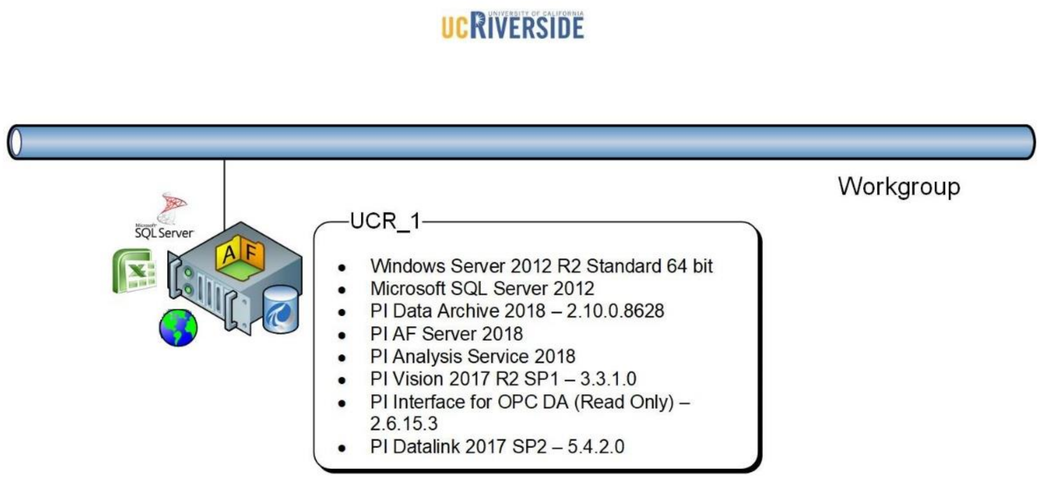


Figure 1 – Current PI System Architecture

Appendix A. Installation Details

Installation Details

UCR_1	
.Net Versions	
.NET 2 Version	2.0.50727.4927
.NET 3 Version	3.0.30729.4926
.NET 3.5 Version	3.5.30729.4926
.NET 4.x Version	4.7.02558
Disk Information	
Drive Letter File System File Type	C:\
Total Available Space Total Size	NTFS
Volume Label	Fixed
	227.01
	278.53
	N/A
General Information	
Data Usage Approval Data Usage Approval	True
Time Data Execution Prevention Available	07/31/2018 13:13:22
Data Execution Prevention Level Last Reboot Time Model	TRUE
PI Server Number Time Zone Vendor	3
	07/31/2018 10:15:46
	PowerEdge R610
	2686197
	Pacific Standard Time
	Dell Inc.
Memory	
Installed Physical Memory Available Physical	16
Memory Total Physical Memory Available Virtual	11.2045745849609
Memory	15.9873847961426
Total Virtual Memory	13.1104164123535
	18.3623847961426
Network Information	
Network Cards and Speeds	Name Speed Broadcom BCM5709C NetXtreme II GigE (NDIS VBD Client) #36 100000000
Workgroup	WORKGROUP
Operating System	
Architecture	64-bit
Version	Microsoft Windows Server 2012 R2 Standard
OSI FSE	
OSI FSE 64-bit shortcut Folder Location	Does not exist or is non-default
Exists	

(31-Jul-18)

Processor Information		
CPU Name	Intel(R) Xeon(R) CPU E5620 @ 2.40GHz	Intel(R) Xeon(R) CPU E5620 @ 2.40GHz
Number Of Cores	4.00	4.00
Number Of Logical Processors	8.00	8.00

Report Generation	
Admin User Used	True
Logs Extracted	False
File Uploader	OSI\psrivastav
Online FSTS Confirmation	Yes
FSTSs Followed at site	False
Run Time	07/31/2018 13:13:53
RunTime(UTC Offset)	07/31/2018 20:13:53
User Account Used	UCR_1\Control
Uploaded to OSIsoft on	7/31/2018 3:10:02 PM

AF Client

Default Database	
Name	Test
Element Count	1
Default Server	
Name	UCR_1
General Information	
Installation Path	C:\Program Files\PIPC\AF\
Version	2.10.0.8628

AF Server

PI AF Backup	
Backup File Name	C:\PIBackup\AF\$$PIFD.bak
Backup File Size	32477.000000
Last backup date	2018-07-31
AF Link to PI Group	
AF Link to PI Group Members	N/A
Linked PI Server Name	N/A
PI AF Service	
First Failure	Take No Action
Second Failure	Take No Action
Subsequent Failure	Take No Action
Log On As	NT SERVICE\AFService
Startup Type	Auto
Connection Information	
Connection String	Persist Security Info=False;Integrated Security=SSPI;server=UCR_1;database=PIFD;Application Name=AF Application Server;
SQL Database	PIFD
Name/Instance	UCR_1
Security	SSPI
Streamed Port	5459

General Information	
Path	C:\Program Files\PIPC\AF\
Version	2.10.0.8628
SQL Information	
PI AF Database Folder	c:\Program Files\Microsoft SQL Server\MSSQL11.MSSQLSERVER\MSSQL\DATA \PIFD.mdf
Server Version	Microsoft SQL Server 2012 - 11.0.2100.60 (X64) Feb 10 2012 19:39:15 Copyright (c) Microsoft Corporation Express Edition (64-bit) on Windows NT 6.2 <X64> (Build 9200:)

AF Server SQL

AFServers Group	
Members	NT SERVICE/AFService

Buffering

Configuration	
PIClient.ini file	[PISERVER] LONGPROCNAME=0 [APIBUFFER] BUFFERING=0
PIBuffServ	
Enabled	false
Log On As	LocalSystem
Start Mode	Disabled
Version	1.6.8.26
PIBufss	
Version	4.7.0.37
Enabled	false
Dependencies	pinetmgr
Service Log On As	LocalSystem
Start Mode	Manual
PI SDK Buffering	
Enabled	False

HostsDump

Host file	
hostsdump	# Copyright (c) 1993-2009 Microsoft Corp. # # This is a sample HOSTS file used by Microsoft TCP/IP for Windows. # # This file contains the mappings of IP addresses to host names. Each # entry should be kept on an individual line. The IP address should # be placed in the first column followed by the corresponding host name. # The IP address and the host name should be separated by at least one # space. # # Additionally, comments (such as these) may be inserted on individual # lines or following the machine name denoted by a '#' symbol. # # For example: # # 102.54.94.97 rhino.acme.com # source server # 38.25.63.10 x.acme.com # x client host # localhost name resolution is handled within DNS itself. # 127.0.0.1 localhost # ::1 localhost 10.10.10.211 CTRL_SVR #LWM Control Server

IIS

General Information	
Version	8

Interfaces

General Information	
List of PI Interfaces in 32 bit	OPCInt_Plugins_ReadOnly,OPCInt_ReadOnly

OPCInt_Plugins_ReadOnly

General Information	
Installation Path	C:\Program Files (x86)\PIPC\Interfaces\OPCInt\Plug-Ins
Version	2.6.15.3

OPCInt_ReadOnly

General Information	
Installation Path	C:\Program Files (x86)\PIPC\Interfaces\OPCInt_ReadOnly\
Version	2.6.15.3

opcint_ReadOnly1.bat

Configuration	
Current Configuration	"C:\Program Files (x86)\PIPC\Interfaces\OPCInt_ReadOnly\opcint_ReadOnly.exe" 1 /AF=N /AM=800 /AR=Y /DA=CONNECT /DI=IDENTIFY /DB=0 /ER=000:00:01 /ES=CACHE /GL=Y /GS=Y /IF=N /IS=N /IT=N /MA=N /NT=N /SERVER="10.10.10.211::RSLinx OPC Server" /SQ=N /TS=N /VN=2 /AG=Advise /PG=Poll /EG=Event /OU=Write /PS=OPC /ID=1 /host=UCR_1:5450 /pisdk=0 /maxstoptime=120 /PercentUp=100 /perf=8 /f=00:00:01 /f=00:00:01 /f=00:00:01 /f=00:00:02
Executable Name Used	opcint_ReadOnly
Host	UCR_1
Interface ID	1
Point Source	OPC

Failover	
Failover Configured	False
UFO Tag List	No tags found
UFO Tag Values	No tags found
Monitoring	
Performance and Health Tag List	No tags found
Performance and Health Tag Values	No tags found
PI ISU Tag Name	sy.is.UCR_1.opcint_ReadOnly1
Service Configuration	
First Failure	Take No Action
Service Logon	.\Control
Service Name	opcint_ReadOnly1
Second Failure	Take No Action
Service Start Mode	Auto
Subsequent Failure	Take No Action

PI AF Builder

General Information	
Excel Version	2013
Version	2.10.0.8628

PI Analysis Service

Configuration	

```
<?xml version="1.0" encoding="utf-8"?>
<configuration>
  <configSections>
    <section name="nlog" type="NLog.Config.ConfigSectionHandler, NLog" />
  </configSections>
  <startup>
    <supportedRuntime version="v4.0" sku=".NETFramework,Version=v4.6.2" />
  </startup>
  <configProtectedData>
    <providers>
      <add name="ANConfigurationFileToAFConnector"
type="OSIsoft.AN.ANConfigurationFileToAFConnector, OSIsoft.Analytics.SDK,
Version=1.0.0.0, Culture=neutral, PublicKeyToken=6238be57836698e6" />
    </providers>
  </configProtectedData>
  <system.diagnostics>
    <trace>
      <listeners>
        <add name="PIAnalysisServiceEventLog"
type="System.Diagnostics.EventLogTraceListener, System, Version=2.0.0.0,
Culture=neutral, PublicKeyToken=b77a5c561934e089" initializeData="PI
Analysis Service" />
      </listeners>
    </trace>
  </system.diagnostics>
  <runtime>
    <gcServer enabled="true" />
  </runtime>
  <appSettings file="">
    <clear />
    <add key="PISystem" value="." />
    <add key="TraceSwitch" value="Error, Warning, Information" />
    <add key="ClientSettingsProvider.ServiceUri" value="" />
```

PIAnalysisManager.exe.config

```
  </appSettings>
  <system.serviceModel>
    <services configProtectionProvider="ANConfigurationFileToAFConnector">
      <EncryptedData>
        <AFAttributeReference path="WCFService|services" />
      </EncryptedData>
    </services>
    <bindings configProtectionProvider="ANConfigurationFileToAFConnector">
      <EncryptedData>
        <AFAttributeReference path="WCFService|bindings" />
      </EncryptedData>
    </bindings>
    <behaviors configProtectionProvider="ANConfigurationFileToAFConnector">
      <EncryptedData>
        <AFAttributeReference path="WCFService|behaviors" />
      </EncryptedData>
    </behaviors>
  </system.serviceModel>
  <system.web>
    <membership defaultProvider="ClientAuthenticationMembershipProvider">
      <providers>
        <add name="ClientAuthenticationMembershipProvider"
type="System.Web.ClientServices.Providers.ClientFormsAuthenticationMembershi
pProvider, System.Web.Extensions, Version=4.0.0.0, Culture=neutral,
PublicKeyToken=31bf3856ad364e35" serviceUri="" />
      </providers>
    </membership>
    <roleManager defaultProvider="ClientRoleProvider" enabled="true">
      <providers>
        <add name="ClientRoleProvider"
type="System.Web.ClientServices.Providers.ClientRoleProvider,
System.Web.Extensions, Version=4.0.0.0, Culture=neutral,
PublicKeyToken=31bf3856ad364e35" serviceUri="" cacheTimeout="86400" />
      </providers>
    </roleManager>
  </system.web>
  <!-- OSISoft Nlog Configuration - DO NOT CHANGE - Any Change will be
overwritten during upgrade of product -->
  <!-- Users should make changes in Analysis.UserNLog.config file -->
  <nlog xmlns="http://www.nlog-project.org/schemas/NLog.xsd"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" autoReload="true"
throwExceptions="false" internalLogLevel="Off" internalLogFile="C:
\ProgramData\OSIsoft\PIAnalysisNotifications\Logs\pianalysismanager-
nlog.txt">
    <extensions>
      <add assembly="OSIsoft.Analytics.SDK" />
    </extensions>
    <variable name="fmt" value="${longdate}|${level:uppercase=true}|
${logger:shortName=true}|${trim-whitespace:inner=${message} ${all-event-
properties}${newline}${anexception:format=tostring}}" />
    <variable name="eventLogFmt" value="${longdate}|${logger}|${trim-
whitespace:inner=${message} ${all-event-
properties}${newline}${exception:format=tostring}}" />
    <variable name="logPath"
value="${specialfolder:folder=CommonApplicationData}\OSIsoft
\PIAnalysisNotifications\Logs" />
    <include file="Analysis.UserNLog.config" ignoreErrors="true" />
    <targets>
      <target name="logfile" xsi:type="File"
fileName="${logPath}\pianalysismanager-log.txt"
archiveFileName="${logPath}\archives\pianalysismanager-log-{#}.zip"
keepFileOpen="true" createDirs="true" archiveEvery="Day"
archiveNumbering="Date" maxArchiveFiles="21" concurrentWrites="false"
layout="${fmt}" enableArchiveFileCompression="true" />
```

```
<?xml version="1.0" encoding="utf-8"?>
<configuration>
  <configSections>
```

PIAnalysisProcessor.exe.config	`<section name="nlog" type="NLog.Config.ConfigSectionHandler, NLog" />` `</configSections>` `<runtime>` `<gcServer enabled="true" />` `</runtime>` `<appSettings>` `</appSettings>` `<system.diagnostics>` `<trace>` `<listeners>` `<add name="PIAnalysisServiceEventLog" type="System.Diagnostics.EventLogTraceListener, System, Version=2.0.0.0, Culture=neutral, PublicKeyToken=b77a5c561934e089" initializeData="PI Analysis Service" />` `</listeners>` `</trace>` `</system.diagnostics>` `<startup>` `<supportedRuntime version="v4.0" sku=".NETFramework,Version=v4.6.2" />` `</startup>` `<!-- OSISoft Nlog Configuration - DO NOT CHANGE - Any Change will be overwritten during upgrade of product -->` `<!-- Users should make changes in Analysis.UserNLog.config file -->` `<nlog xmlns="http://www.nlog-project.org/schemas/NLog.xsd" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" autoReload="true" throwExceptions="false" internalLogLevel="Off" internalLogFile="C:\ProgramData\OSIsoft\PIAnalysisNotifications\Logs\pianalysisprocessor-nlog.txt">` `<extensions>` `<add assembly="OSIsoft.Analytics.SDK" />` `</extensions>` `<variable name="fmt" value="${longdate}\|${level:uppercase=true}|${logger:shortName=true}\|${trim-whitespace:inner=${message} ${all-event-properties}${newline}${anexception:format=tostring:showalldetails=false}}" />`

```
    <variable name="logPath"
value="${specialfolder:folder=CommonApplicationData}\OSIsoft

\PIAnalysisNotifications\Logs" />

    <variable name="eventLogFmt" value="${longdate}|${logger}|${trim-

whitespace:inner=${message} ${all-event-

properties}${newline}${exception:format=tostring}}" />

    <include file="Analysis.UserNLog.config" ignoreErrors="true" />

    <targets>

      <target xsi:type="AsyncWrapper" name="logfileAsync"

queueLimit="200000" fullBatchSizeWriteLimit="20" timeToSleepBetweenBatches="

50" overflowAction="Discard">

        <target name="logfile" xsi:type="File"
fileName="${logPath}\pianalysisprocessor-log.txt"
archiveFileName="${logPath}\archives\pianalysisprocessor-log-{#}.zip"
keepFileOpen="true" createDirs="true" archiveEvery="Day"
archiveNumbering="Date" maxArchiveFiles="21" concurrentWrites="false"
layout="${fmt}" enableArchiveFileCompression="true" />

      </target>

      <target name="externalStatistics" xsi:type="File"

fileName="${logPath}\processor-externalcalls.csv"

archiveFileName="${logPath}\archives\processor-externalcalls-{#}.zip"

keepFileOpen="false" createDirs="true" archiveEvery="Day"

archiveNumbering="Date" maxArchiveFiles="21" concurrentWrites="false"

enableArchiveFileCompression="true">

        <layout xsi:type="CsvLayout" delimiter="Comma" withHeader="true">

          <column name="Time" layout="${date:format=dd-MMM-yy HH\:mm\:ss}"

/>

          <column name="Adapter" layout="${event-properties:Adapter}" />

          <column name="FunctionName" layout="${event-properties:Name}" />

          <column name="AverageDuration" layout="${event-

properties:AverageDuration}" />

          <column name="TotalCount" layout="${event-

properties:EvaluationCount}" />
```

	``<column name="FastEvaluationPercentage" layout="${event-properties:FastEvaluationPercentage}" /> <column name="LastEvaluation" layout="${event-properties:LastEvaluation:format=dd-MMM-yy HH\:mm\:ss}" /> </layout> </target> <target name="eventLog" xsi:type="EventLog" layout="${eventLogFmt}" source="PI Analysis Service" /> </targets> <rules> <logger name="OSIsoft.AN*" levels="Fatal" writeTo="eventLog" /> <logger name="*:Evaluation" minlevel="Info" writeTo="logfileAsync" final="true" /> <logger name="*:Scheduling" minlevel="Info" writeTo="logfileAsync" final="true" /> <logger name="*:Recalculation" minlevel="Info" writeTo="logfileAsync" final="true" /> <logger name="*:DataRetrieval" minlevel="Info" writeTo="logfileAsync" final="true" /> <logger name="*:Config```

PIRecalculationProcessor.exe.config	``` <?xml version="1.0" encoding="utf-8"?> <configuration> <configSections> <section name="nlog" type="NLog.Config.ConfigSectionHandler, NLog" /> </configSections> <startup> <supportedRuntime version="v4.0" sku=".NETFramework,Version=v4.6.2" /> </startup> <runtime> <gcServer enabled="true" /> </runtime> <appSettings> </appSettings> <system.diagnostics> <trace> <listeners> <add name="PIAnalysisServiceEventLog" type="System.Diagnostics.EventLogTraceListener, System, Version=2.0.0.0, Culture=neutral, PublicKeyToken=b77a5c561934e089" initializeData="PI Analysis Service" /> </listeners> </trace> </system.diagnostics> <!-- OSISoft Nlog Configuration - DO NOT CHANGE - Any Change will be overwritten during upgrade of product --> <!-- Users should make changes in Analysis.UserNLog.config file --> <nlog xmlns="http://www.nlog-project.org/schemas/NLog.xsd" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" autoReload="true" throwExceptions="false" internalLogLevel="Off" internalLogFile="C: \ProgramData\OSIsoft\PIAnalysisNotifications\Logs\pirecalculationprocessor- nlog.txt"> <extensions> <add assembly="OSIsoft.Analytics.SDK" /> </extensions> <variable name="fmt" value="${longdate}\|${level:uppercase=true}| ${logger:shortName=true}\|${trim-whitespace:inner=${message} ${all-event- properties}${newline}${anexception:format=tostring}}" /> <variable name="eventLogFmt" value="${longdate}|${logger}\|${trim- whitespace:inner=${message} ${all-event- properties}${newline}${exception:format=tostring}}" /> <variable name="logPath" value="${specialfolder:folder=CommonApplicationData}\OSIsoft \PIAnalysisNotifications\Logs" /> <variable name="recalculationLogPath" value="${specialfolder:folder=CommonApplicationData}\OSIsoft \PIAnalysisNotifications\Data\Recalculation" /> <include file="Analysis.UserNLog.config" ignoreErrors="true" /> <targets> ```

```
      <target xsi:type="AsyncWrapper" name="logfileAsync"
queueLimit="200000" fullBatchSizeWriteLimit="20" timeToSleepBetweenBatches="
50" overflowAction="Discard">
        <target name="logfile" xsi:type="File"
fileName="${logPath}\pirecalculationprocessor-log.txt"
archiveFileName="${logPath}\archives\pirecalculationprocessor-log-{#}.zip"
keepFileOpen="true" createDirs="true" archiveEvery="Day"
archiveNumbering="Date" maxArchiveFiles="21" concurrentWrites="false"
layout="${fmt}" enableArchiveFileCompression="true" />
      </target>
      <target name="recalculationcsvlogfile" xsi:type="File"
fileName="${recalculationLogPath}\recalculation-log.csv"
archiveFileName="${recalculationLogPath}\archives\recalculation-log-{#}.zip"
keepFileOpen="true" createDirs="true" archiveEvery="Day"
archiveNumbering="Date" maxArchiveFiles="21" concurrentWrites="false"
enableArchiveFileCompression="true">
        <layout xsi:type="CsvLayout" delimiter="Auto" withHeader="true">
          <column name="Analysis" layout="${event-properties:Analysis}" />
          <column name="Id" layout="${event-properties:Id}" />
          <column name="Type" layout="${event-properties:Type}" />
          <column name="OutputBehavior" layout="${event-
properties:OutputBehavior}" />
          <column name="RequestedBy" layout="${event-
properties:RequestedBy}" />
          <column name="TimeRange" layout="${event-properties:TimeRange}" />

          <column name="Status" layout="${event-properties:Status}" />
          <column name="CompletionTime" layout="${event-
properties:CompletionTime}" />
          <column name="EventsProcessed" layout="${event-
properties:EventsProcessed}" />
          <column name="Reason" layout="${event-properties:Reason}" />
        </layout>
      </target>
      <target name="eventLog" xsi:type="EventLog" layout="${eventLogFmt}"
source="PI Analysis Service" />
      <target name="externalStatistics" xsi:type="File"
fileName="${logPath}\recalculation-externalcalls.csv"
archiveFileName="${logPath}\archives\recalculation-externalcalls-{#}.
```


General Information

Installation Path	C:\Program Files\PIPC\Analytics\
Version	2.10.0.8628
Version	2.10.0.8628
Version	2.10.0.8628

Service Information

First Failure	Take No Action
Log On As	NT SERVICE\PIAnalysisManager
Second Failure	Take No Action
Startup Type	Auto
Subsequent Failure	Take No Action

PI APIx64

General Information

APISnap Validation	False
Version	1.6.8.26

PI Collective Manager

General Information

Installation Path	C:\Program Files (x86)\PIPC\CollectiveManager

Version	1.4.1.11

PI Data Archive

Current State	
Auto Creation for Primary Archive	True
Last Backup	4, 31-jul-18 03:15:02, 31-jul-18 03:17:23, 31-jul-18 03:16:54, [0] success, 0, 8193, 31, 13, 0, 44, incremental, 1, 1, 0, 0, 16, 31-jul-18 03:15:04, 31, 312, 31-jul-18 03:15:02, 31-jul-18 03:15:02, 0;
PI Archive Snapshot Dump	Counters for 31-Jul-18 13:14:01 (all tags); Point Count: 17 0; Snapshot Events: 1887 0; Out of Order Snapshot Events: 0 0; Snapshot Event Reads: 17 0; Events Sent to Queue: 1064 0; Events in Primary Queue: 0 0; Number of Queue Files: 2 0; Events in Queue: 0 0; Estimated Remaining Capacity: 4294967295 0;
PI License Dump	------ General ------ ; ActivationLimit - 0; Creator - SYSTEM; ExpTime - Never; FileType - ; FileUid - fdbf636f-ff94-461f-add5-3cf7c9b99fd2; GenTime - 30-Jul-18 11:19:57; GracePct - 0.; GraceTime - 0; HAGraceTime - 2592000; InstallationID - 2686197; PctMatch - 50.; Version - 10; ------ Usage ------ ; FirstRun - 31-Dec-69 16:00:00; Activation Count - 0; License File ID - fdbf636f-ff94-461f-add5-3cf7c9b99fd2; Generation - 1; HA Grace Period Start Time - ; Current PctMatch - -1.; Usage Storage - 31-Dec-69 16:00:00; ------ License ID History ------ ;
Primary Archive	archive[0]: c:\program files\pi\arc\ucr_1_2018-07-30_14-09-27.arc (4096mb, used: 0.0%) ;

General Information	
PI Data Archive Version	3.4.420.1182
PI Folder	C:\Program Files\PI\
PI ADM Directory Shortcut on Desktop	File not found
PISrvStart Shortcut On Desktop	File not found
PISrvStop Shortcut On Desktop	File not found

PI Archive Subsystem	
Dependencies	pinetmgr;piupdmgr
Log On As	LocalSystem
Startup Type	Auto
Version	3.4.420.1182

PI Backup Subsystem	
Dependencies	pinetmgr

Log On As	LocalSystem
Startup Type	Auto
Version	3.4.420.1182
PI Base Subsystem	
Dependencies	pinetmgr;piupdmgr
Log On As	LocalSystem
Startup Type	Auto
Version	3.4.420.1182
PI Database Security	
PIAFLINK	"piadmin: A(r,w) | piadmins: A(r,w) | PIWorld: A()"
PIARCADMIN	"piadmin: A(r,w) | piadmins: A(r,w) | PIWorld: A()"
PIARCDATA	"piadmin: A(r,w) | piadmins: A(r,w) | PIWorld: A()"
PIAUDIT	"piadmin: A(r,w) | piadmins: A(r,w) | PIWorld: A()"
PIBACKUP	"piadmin: A(r,w) | piadmins: A(r,w) | PIWorld: A()"
PIBatch	"piadmin: A(r,w) | piadmins: A(r,w) | PIWorld: A(r)"
PIBATCHLEGACY	"piadmin: A(r,w) | piadmins: A(r,w) | PIWorld: A(r)"
PICampaign	"piadmin: A(r,w) | piadmins: A(r,w) | PIWorld: A(r)"
PIDBSEC	"piadmin: A(r,w) | piadmins: A(r,w) | PIWorld: A(r)"
PIDS	"piadmin: A(r,w) | piadmins: A(r,w) | PIWorld: A(r)"
PIHeadingSets	"piadmin: A(r,w) | piadmins: A(r,w) | PIWorld: A(r)"
PIMAPPING	"piadmin: A(r,w) | piadmins: A(r,w) | PIWorld: A()"
PIModules	"piadmin: A(r,w) | piadmins: A(r,w) | PIWorld: A(r)"
PIMSGSS	"piadmin: A(r,w) | piadmins: A(r,w) | PIWorld: A(w)"
PIPOINT	"piadmin: A(r,w) | piadmins: A(r,w) | PIWorld: A(r)"
PIReplication	"piadmin: A(r,w) | piadmins: A(r,w) | PIWorld: A()"
PITransferRecords	"piadmin: A(r,w) | piadmins: A(r,w) | PIWorld: A(r)"
PITRUST	"piadmin: A(r,w) | piadmins: A(r,w) | PIWorld: A()"
PITUNING	"piadmin: A(r,w) | piadmins: A(r,w) | PIWorld: A()"
PIUSER	"piadmin: A(r,w) | piadmins: A(r,w) | PIWorld: A(r)"
PI DataLink Usage	
All PI ProcessBook Unique Users	fe80::816e:e0c0:dcd8:3e69%17,
Total PI DataLink Unique Connections	1
PI License Subsystem	
Dependencies	pinetmgr
Log On As	LocalSystem
Startup Type	Auto
Version	3.4.420.1182
PI Message Subsystem	
Dependencies	pinetmgr
Log On As	NT SERVICE\pimsgss
Startup Type	Auto
Version	3.4.420.1182
PI Network Manager Subsystem	
Antecedencies	piarchss;pibackup;pibasess;pibufss;pilicmgr;pimsgss;pishutev;pisnapss;pisqlss;pitotal;piupdmgr
Log On As	NT SERVICE\pinetmgr
Startup Type	Auto
Version	3.4.420.1182

PI Security Entries	
PI Groups	piadmins;PIGroupIncompatible;piusers
PI Identities	PI Users;PIEngineers;PIOperators;PIWorld
Mappings - PI Identity	piadmin piadmin
Mappings - Windows Account	UCR_1\Control UCR_1\jackm
PI Users	piadmin;pidemo;PIUserIncompatible
PI Shutdown Subsystem	
Dependencies	pinetmgr;piupdmgr
Log On As	LocalSystem
Startup Type	Auto
Version	3.4.420.1182
PI Snapshot Subsystem	
Dependencies	pinetmgr;piupdmgr
Log On As	LocalSystem
PI Snapshot Subsystem Service Startup Type	Auto
Version	3.4.420.1182
PI SQL Subsystem	
Dependencies	pinetmgr;piupdmgr
Log On As	LocalSystem
Startup Type	Auto
PISQL number of tags	5000
Version	3.4.420.1182
PI Totalizer Subsystem	
Dependencies	pinetmgr;piupdmgr
Log On As	LocalSystem
Startup Type	Auto
Version	3.4.420.1182
PI Update Subsystem	
Version	3.4.420.1182
Tuning Parameters	
Archive_AutoArchiveFileRoot	C:\Program Files\PI\arc\UCR_1
Archive_FutureAutoArchiveFileRoot	C:\Program Files\PI\arc\future\UCR_1
readretry	250
readtimeout	50000
Server_AuthenticationPolicy	3
Snapshot_EventQueuePath	C:\Program Files\PI\queue\
writeretry	250
writetimeout	50000

OSIsoft.

Installation Details

(31-Jul-18)

User Added	
PISQL.ini	[OPTIONS] qep=0 execsafe=0 aggrtimestart=0 subset=0 [TAG] length=80 [PIPOINT] numtags=5000 [PICOMP] estimate_margin=1.2F daysonline=0 [EXECUTION] maxtimerange=0 maxrows=0 numvalues=0 timeout=0

PI DataLink

General Information	
Excel Version	2013
Installation Path	C:\Program Files\PIPC\
Version	5.4.2.0

PI ICU

General Information	
Installation Path	C:\Program Files (x86)\PIPC\ICU
Interfaces Loaded	OPCInt
Version	1.4.16.79

PI SDKx64

Configuration	
PIPC Folder Location	C:\Program Files\PIPC\

General Information	
Version	1.4.7.516

PI SDKx86

Configuration	
Allow login prompts	False
Computer-wide Default PI Server	UCR_1
Computer-wide Default User	pidemo
Connection to PI Server	Successful
Default PI Data Archive alias	localhost
PIPC Folder Location	C:\Program Files (x86)\PIPC
Protocol Order	Trust;SSPI;DefaultUser

General Information	
Version	1.4.7.516

Installation Details

(31-Jul-18)

PI System Management Tool

General Information	
Installation Path	C:\Program Files (x86)\PIPC\SMT3
Version	3.6.0.13

PI Vision

Configuration	
Administration Group	UCR_1/Control
Users	NT AUTHORITY/Authenticated Users;UCR_1/Control
Website	Default Web Site
Website Port	80
General Information	
Installation Path	C:\Program Files\PIPC\PIVision\
Version	3.3.1.0
Web.Config	
AF Servers Allowed	UCR_1#NUGREEN;UCR_1#TEST
Connection String	utf-8
Database	PIVision
Name\Instance	UCR_1
PI Data Archives Allowed	UCR_1

PI Web API

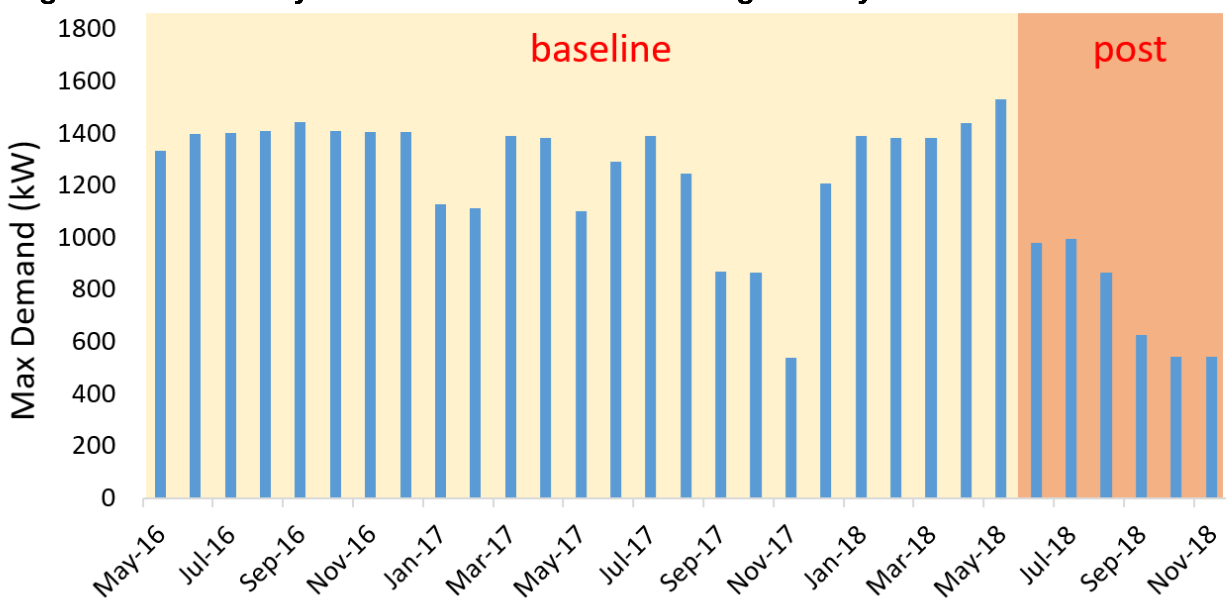
Configuration	
Data Directory	C:\ProgramData\OSIsoft\WebAPI\
PI Web API Admins	UCR_1/Control
General Information	
Installation Directory	C:\Program Files\PIPC\WebAPI\
Version	1.11.0.640
Service Information	
Log On As	NT Service\piwebapi
Startup Type	Auto

Appendix C: Solar Conference 2019 Flyer

APPENDIX D: Cucamonga Valley Water District 1-C Site Statistical Data Analysis

The peak electricity demand per billing cycle for site 1-C at CVWD is shown in Figure D-1. The data from May 2016 to May 2018 is designated as the baseline period and the data from June 2018 to November 2018 as the post implementation period. The last significant changes in water production operation of the 1-C site were carried out in May of 2018. The monthly peak demand is modeled as a constant.

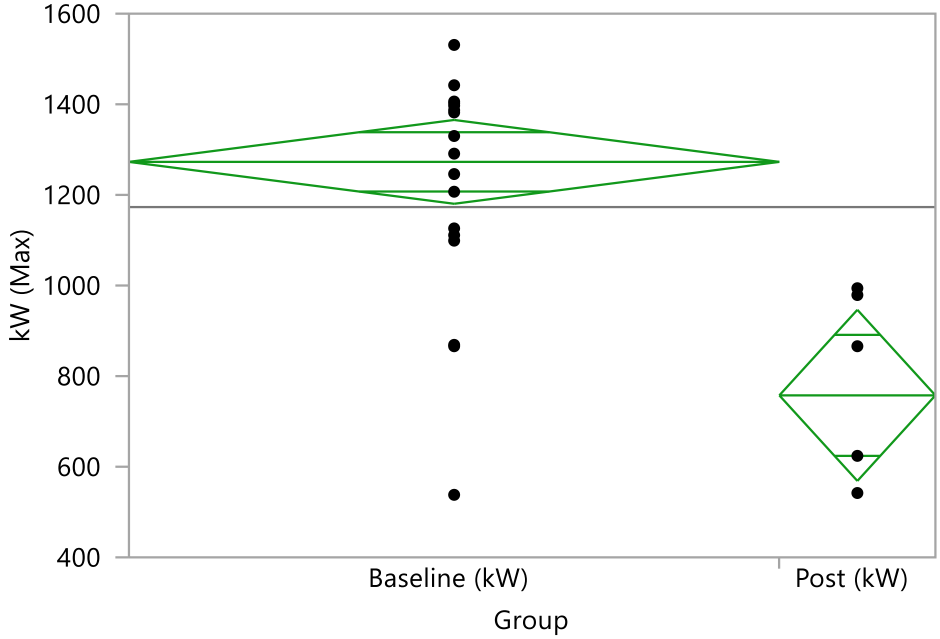
Figure D-1: Monthly Peak Demand for Cucamonga Valley Water District 1-C Site



Source: University of California, Riverside

Figure D-2 shows the difference between means of the baseline peak demand and the post-implementation peak demand at the CVWD 1-C site. The green diamonds in the graph indicate the 95% confidence interval for the two groups. The mean difference between the two groups is -515.4 kW, which shows a peak demand reduction of 41% in the post implementation period compared to baseline period. A two-sample t-test analysis, confirming that the mean difference between the two groups is statistically significant, is presented in Table D-1. One-way ANOVA (Analysis of variance) Summary of Fit parameters are presented in Table D-2.

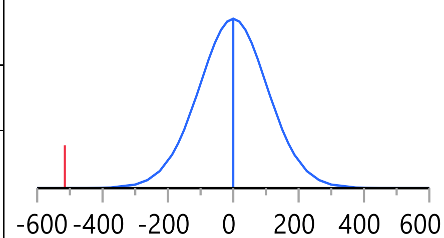
Figure D-2: One-way Analysis of Baseline vs Post-implementation Peak Demand



Source: University of California, Riverside

Table D-1: Post (kW)-Baseline (kW) (Assuming equal variances)

Difference	-515.38	t Ratio	-5.0123
Std Err Dif	102.82	DF	29
Upper CL Dif	-305.08	Prob > |t|	<.0001*
Lower CL Dif	-725.68	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001*



Source: University of California, Riverside

Table D-2: One-Way ANOVA Summary of Fit

Rsquare	0.464185
Adj Rsquare	0.445708
Root Mean Square Error	226.1807
Mean of Response	1173.129
Observations (or Sum Wgts)	31

Source: University of California, Riverside