Emerging Products

# DEMAND RESPONSE READY POOL PUMPS FOR RESIDENTIAL RETROFIT USING ZIGBEE/WI-FI

*DR12.08.02*

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Southern California Edison's (SCE's) Emerging Products (EP) group is responsible for this project. It was developed as part of SCE's Emerging Products program under internal project number DR12.08.02. EP project manager Neha Arora conducted this technology evaluation with overall guidance and management from Paul Delaney. For more information on this project, contact neha.arora@sce.com.

**Disclaimer**

# EXECUTIVE SUMMARY

This study evaluates the operation and capabilities of Demand Response (DR) controllers applied to single-speed residential pool pumps using ZigBee as the communication link between the SCE smart meter and the gateway. Communication to the DR controller is a component of the tested systems. Demand reduction can be achieved when the utility sends a signal to turn off the pump motor during demand response events.

The main objectives of the project are to:

- Evaluate the controller response to the DR signal for the duration of the DR event
- Determine the state of the pool pump motor before the DR event is initiated
- Determine the DR reduction attributable to the controller

Four residential sites with pools were selected to test the controller operation and its DR potential. Two types of DR control products were tested in this study. The products installed used two primary pieces of hardware; a load controller (a switch that turns the pump motor on or off), and a communication gateway to receive and transmit DR signal using ZigBee wireless signal protocols.

Power was monitored on the test pumps in 5-minute intervals. In addition, on/off time stamped status of the motor operation was monitored and logged. The trial study started in Q4 2012 and concluded in Q4 2014. Monitored data from the pumps showed they operated during mid-day, which would make them candidates for DR control.

Equipment problems were encountered during the implementation and testing of the DR control devices. The primary problem encountered was establishing clean and stable communication between the gateway, the load controller and the smart meter.

A summary of the issues that occurred during this trial are described here. The gateway had trouble communicating with the load controller due to signal interference at all houses. When it did work it would turn the pumps off but not turn them back on after the event concluded. Repeaters were added that temporarily resolved the issue for some houses. Power line carrier devices were added to get gateway signals closer to the load controller, but this also had temporary improvement to the signal. New firmware was added, but it did not fix the whole problem. After continued problems and multiple attempts to troubleshoot and solve the communication problem the trials were abandoned.

Neither of the two systems were successful at communicating signals reliably to initiate DR events for the pool pump motor load controllers during this trial. As a result of these failures and internal discussion with SCE’s Advanced Technology Organization, no further testing of the ZigBee 1.x products will be pursued by SCE.

# ABBREVIATIONS

| | |
|---|---|
| APP | Web Application |
| CT | Current Transducer |
| DR | Demand Response |
| DRLC | Demand Response Load Control |
| HP | Horse Power |
| kW | kilowatt |
| kWh | kilowatt hour |
| SCE | Southern California Edison |

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# FIGURES

# INTRODUCTION

This study evaluates the operation and capabilities of Demand Response (DR) controllers applied to single-speed residential pool pumps. The communication strategy and success of implementation of the controllers were among the tested parameters of this evaluation. Demand reduction can be achieved when the utility sends a signal to turn off the pump motor during demand response events. Four residential customer sites with pools were selected to participate in this study.

# BACKGROUND

Residential swimming pool pumps are used to circulate and filter swimming pool water in order to maintain clarity and sanitation. In residential properties, pool pumps are generally the largest single electrical end-user. Residential pump motors range in size from one half to three horsepower (hp), are operated an average of about 5.2 hours per day and draw an average of 1.364 kW.[1] They often run during the day so they don't create noise at night and disturb sleeping residents or neighbors. Operation during the day often is coincident with utility peak periods as shown in Figure 1.[1]

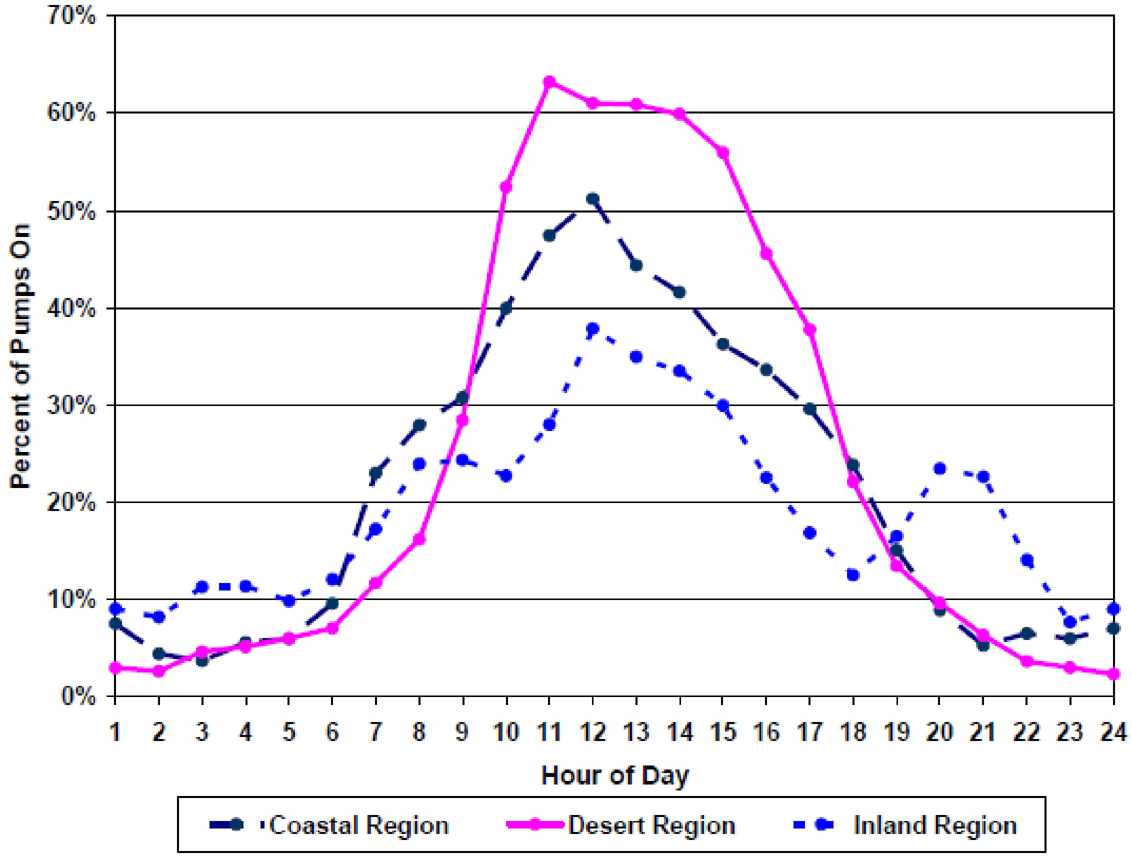


FIGURE 1. POOL PUMP PERCENTAGE ON PROFILES BY SCE REGION

No codes regulate the operation of private residential pool pumps as long as the pools are maintained and do not become a breeding ground for mosquitoes. A leaf strainer is usually integrated with the pump and aids in priming the pump when it is installed higher than the pool surface. Pools may use multiple pumps for pool filtration, bottom cleaning (pool sweep), and for operating water jets for adjoining spas or water features.

# ASSESSMENT OBJECTIVES

Southern California Edison (SCE) is testing the implementation of DR controls added to existing pool pump systems. The DR control is installed on single-speed pumps to test the potential demand reduction during DR events.

The main objectives of the project are to:

- Evaluate the controller response to the DR signal for the duration of the DR event
- Determine the state of the pool pump motor before the DR event is initiated
- Determine the DR reduction attributable to the controller

In order to verify the project objectives, electric load monitoring was conducted.

# TECHNOLOGY/PRODUCT EVALUATION

This is a field study of DR controls for single-speed pool pumps. Four similar residential pools were selected to test the product operation and savings potential and two different systems were tested at these four sites.

System 1 had two primary components. One is a load controller and the other is a communications gateway. The load controller is a metering dual load controller, shown in Figure 2. It has a 30 Amp capacity rating that is sufficient for any residential pool equipment. The load controller is linked wirelessly using ZigBee SE 1.x communication protocols to the Gateway device as shown in Figure 3. The gateway connects to the homeowner's internet router via an Ethernet cable. This allows the customer to access and control the pump schedule of operation through a computer or mobile device. The gateway also communicates with the customer's SCE smart meter using ZigBee SE1.1. Other features promoted for the customer include monitoring and energy management based on demand or energy consumption, price, and home automation of appliances.

FIGURE 2. SYSTEM 1 LOAD CONTROLLER


FIGURE 3. SYSTEM 1 GATEWAY DEVICE

System 2 (from a different manufacturer) also has a load controller and a communications gateway. The load controller of System 2, shown in Figure 4, has a 30 Amp capacity rating for motors up to 3 hp that is sufficient for any residential pool pumps. The load controller is linked wirelessly using ZigBee SE1.x communication protocols to the gateway device. The gateway connects to the homeowner's internet router via an Ethernet cable. This allows the customer to access and control the pump schedule of operation through a computer or mobile device.

**FIGURE 4. SYSTEM 2 LOAD CONTROLLER**

The single-speed pool pumps, see Figure 5, were originally controlled using a standard electro-mechanical 24-hour time clock, shown in Figure 6. During installation of the load controllers the time clocks were removed to avoid conflicting schedules.

**FIGURE 5. SINGLE SPEED POOL PUMP**

**FIGURE 6. ORIGINAL MECHANICAL 24-HOUR TIMER**

Testing began with the installation of System 1 installed on pool pump motors at four homes. Two of those same pool pumps were later outfitted with System 2 for testing as the other two locations dropped off. The communication architecture schematic depicting the system setup is shown in Figure 7.

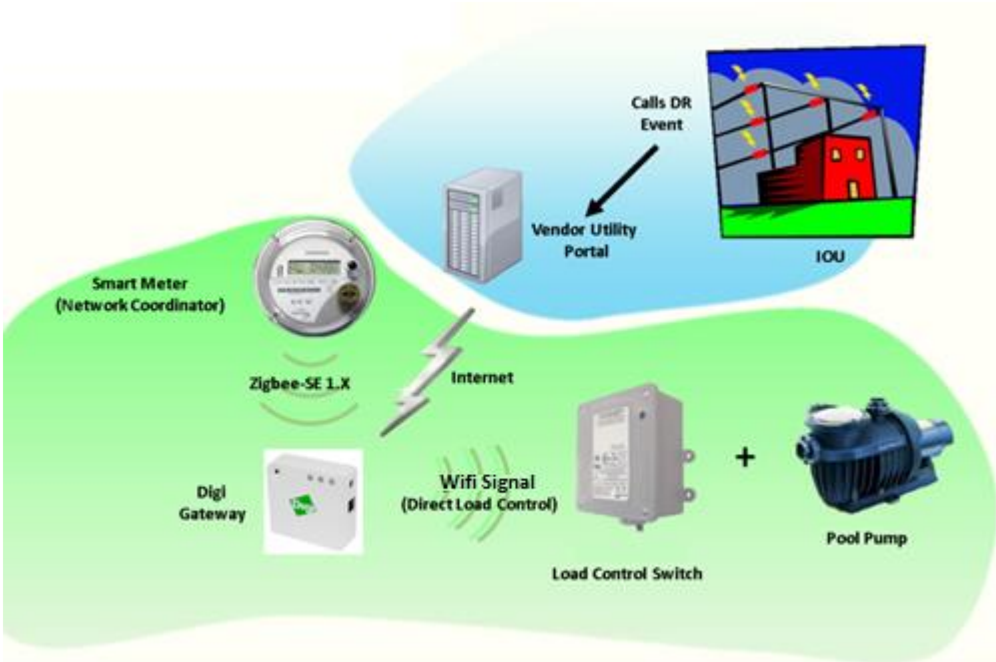


FIGURE 7. COMMUNICATION ARCHITECTURE

# TECHNICAL APPROACH/TEST METHODOLOGY

In order to characterize the demand reduction resulting from the DR testing of controllers, a Measurement and Verification plan was prepared and adapted to these sites.

The residential test sites are located in eastern Los Angeles County. Monitored data was recorded and collected to determine pump schedule and response to DR events.

The methodology for the study was to monitor the time series load profile for the pool pump motors for a period of time prior to the DR test events and continue through all DR testing. During the first visit to the pool pumps loggers were installed to record current draw of the motor and the motor ON/OFF status. Three loggers were installed for each pool pump motor. One logger monitored Amps to record the load on the pump motor when it was operating and the other two monitored exactly when the motor turned on or off. A current transducer (CT) with a Hobo external channel logger (model U12-006) was used to record the current of the motor in 5-minute interval snapshots, shown in Figure 8. These were installed inside the original time clock enclosure and accessed each time the data was collected. A split-core CT with an appropriately sized Amp rating was used with the logger. Also inside the time clock enclosure a 120 volt (V) relay and Hobo State logger were installed to record when power was turned ON or OFF to the pump motor. A Hobo U9-004 Motor on/off logger was strapped to the motor, shown in Figure 9, and recorded the date and time stamps of these events. The motor on/off loggers and state loggers were installed to record exact times when the motor turned ON or OFF. Deploying both of them provided a backup measurement for redundancy purposes. The logger clocks were synchronized to the NIST clock available on the web. The Hobo loggers have a time accuracy of ± 1 minute per month.

FIGURE 8. CURRENT TRANSDUCER AND HOBO LOGGER IN TIMER BOX

FIGURE 9. MOTOR ON/OFF LOGGER STRAPPED TO TOP OF MOTOR

Two sets of DR test events were conducted. The first set of DR test events were conducted using System 1 and the second set were conducted on System 2.

# DATA AND TESTING RESULTS

This section presents and discusses the data collected from monitoring the primary pool pumps at the two test sites. In addition, this section discusses the results of the DR control system operation.

## DATA RESULTS

DR events are typically scheduled during summer afternoons on weekdays. Data was processed from the two sites where data was collected during the summer. The average percent load for the two pool pumps was calculated for the entire summer of 2013 and is charted in Figure 10. Both pumps operated only during the day. One typically runs four hours per day and the other eight hours per day. The average percent load during the California statewide grid peak period of 2:00 P.M. to 5:00 P.M. is approximately 45%. The data as presented in Figure 10 does ***not*** represent actual data collected on site. It only represents the demand reduction that ***could*** be obtained if the pool pump loads could be turned OFF using DR controls during a typical event. It is an indication that pool pumps are a good source of DR potential.

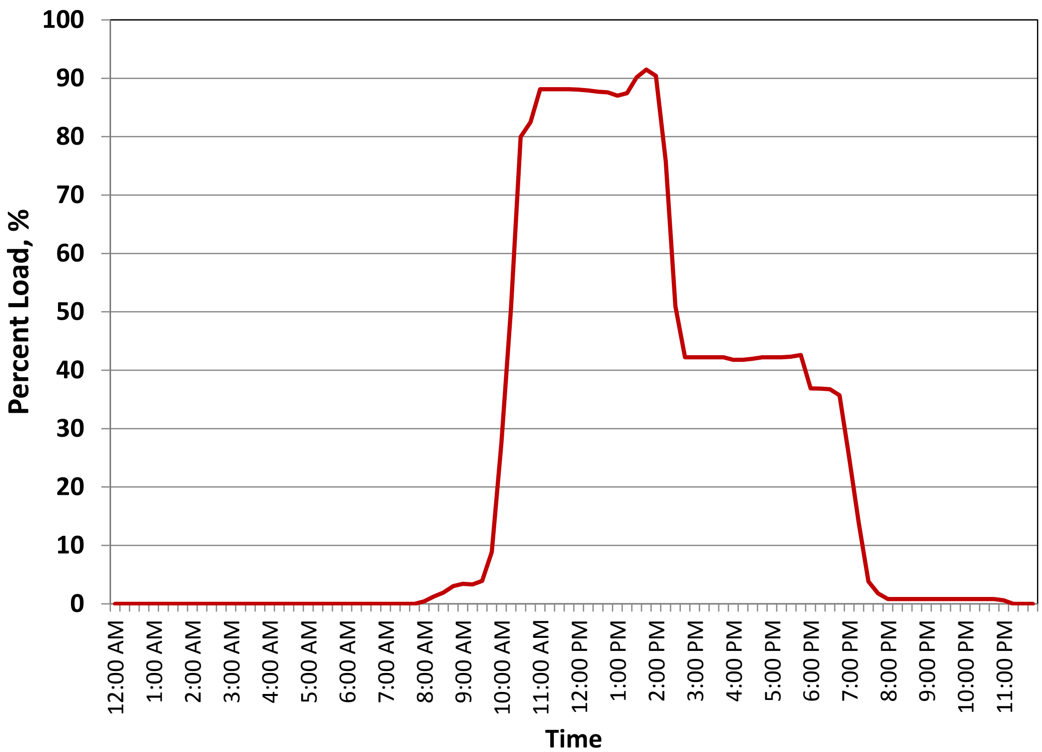


FIGURE 10. AVERAGE DAILY LOAD PROFILES OF TWO POOL PUMP MOTORS DURING SUMMER

# TESTING RESULTS

During initial setup and commissioning of System 1 the installers ran into a variety of obstacles while trying to perform DR event testing. The events were documented and the issues they faced are presented below:

1. After installation the load controller made the pool pumps turn ON and OFF at random times of the day. Sometimes the pump never came on for multiple days and sometimes it ran continuously for multiple days.
2. The smart meter could not communicate with the load controller. After much troubleshooting it was discovered that the gateway installed in the customer's house did not have enough range to establish the clear ZigBee connection between the smart meter and the load controller.
3. At some homes repeaters were installed to resolve the communication issue. Initially, it seemed to have connected everything. However, after a few hours the gateway and the load controller started to drop out again.
4. Another round of troubleshooting was done to discover that there were some bugs in the firmware and several patches were installed to fix this issue. This exercise still did not resolve the issue.
5. Another firmware upgrade was installed. This resolved the communication issue at three of the four houses. At the fourth house, a power line carrier had to be installed between the gateway and the load controller. This was needed to accommodate this house having a larger footprint than the other test sites.
6. After testing commenced again, two of the three houses "fixed" with the firmware upgrade stopped communicating. At the first house, the smart meter with cell relay failed. The smart meter was replaced promptly. At the second house, the System 2 manufacturer tried troubleshooting the communication problem.
7. During mock testing, it was found that when a DR event was called the load controller turns the pump OFF, but does not have the logic to turn it back ON or make up for the lost flow time after the event is concluded. This was part of the functionality marketed to SCE by the manufacturers of System 1.
8. The System 1 energy management application available for mobile devices did not account for changes in daylight savings. The date on the APP was incorrect. The kW reading on the APP was also incorrect; i.e., 2 kW was displayed as 2000 kW.
9. As of the last week of March 2013, all participants confirmed that the load controller was not communicating at all. They had to manually turn the pump ON otherwise it never came on at all. As a result one of the pool sites started to grow small insects in it.
10. On contacting System 1 manufacturers, they responded that they were still working to figure out the communication problems.

The primary problem encountered was establishing clean and stable communication between the gateway, the load controller, and the smart meter using ZigBee. After continued problems and multiple attempts to troubleshoot and solve the communication problem the trials of System 1 were abandoned.

Although there is not the same documentation for System 2, the problems encountered were similar in the sense that the controller and the gateway were unable to maintain reliable and consistent connection among themselves as well as the Smart meter. As a result the pool pumps were unable to turn ON and OFF at the programmed schedules and were starting to grow green. Due to these issues and the issues seen during the implementation of System 1, further commissioning efforts for System 2 were abandoned as well.

# CONCLUSIONS

The following conclusions are based on the main objectives of this project.

1. Evaluate the controller response to the DR signal for the duration of the DR event:
   The controllers did not consistently respond to DR event test signals. Too often they did not respond at all to the request to turn OFF or end the event and turn back ON.
2. State of the pool pump motor before the DR event was initiated:
   There were no real test events but some testing occurred as part of controller commissioning. Those tests were unsuccessful and did not show any consistent change in the state of the pool pump.
3. Demand Reduction attributable to the controller:
   No DR was attributed to the controller for this project because it was abandoned due to unsuccessful commissioning.

Neither of the two systems were successful at communicating signals reliably to initiate DR events for the pool pump motor load controllers during this trial. As a result of these failures, and internal discussion with SCE's Advanced Technology Organization, no further testing of the ZigBee 1.x products will be pursued by SCE. However, important data gathered for the project such as when a certain percentage of pumps are on during the day, magnitude of pool pump load, etc. may be useful information for studies related to pool pumps.

# RECOMMENDATION

Since none of the tested technologies proved to be reliable, SCE will not pursue further testing of ZigBee 1.x products.

# REFERENCE

1. Pool Pump Demand Response Potential Study, DR07.01, SCE, 2008.