SCE DRET Findings
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DR12.21: Evaluation of Residential Room Air Conditioner Control with Smart Plugs for Peak Load Reduction

SMART PLUGS USED TO CONTROL RESIDENTIAL ROOM AIR CONDITIONERS FOR PEAK LOAD REDUCTION

Plug loads today are predominantly under manual control by consumers, who manually switch their end-use devices on and off. Many plug loads remain always on such as electronic plug loads manufactured with internal sleep modes. Less than 1% of plug loads today are being managed externally with smart plugs as part of a plug load energy management system. Demand Response (DR) capabilities have been introduced into the marketplace to control room air conditioners (ACs) using smart plugs, controllable outlets that ACs can plug into.

The objective of the study is to field trial a sample of smart plug technologies to understand and verify their demand reduction capabilities, among products commercially available in the marketplace. Project goals included conducting laboratory evaluation of selected technologies in order to assess demand savings, accuracy of power usage reporting of the technologies, and the impact of room AC fan speed settings on results.

The thinkeco modlet smart plug was selected for this study for both field and lab testing. A Friedrich Kuhl room air conditioner with Wifi connectivity was selected for lab testing under control by the modlet, and without the modlet as well. By enabling existing room ACs operating during critical times to respond to DR events, smart plugs like the modlet offer potential for automated peak load reduction to utilities. The technology also offers remote control convenience and thermostat-based control in support of system load balance. By augmenting existing room ACs with DR capability, the technology does not necessitate new investment in connective window ACs in order to support utility DR programs.

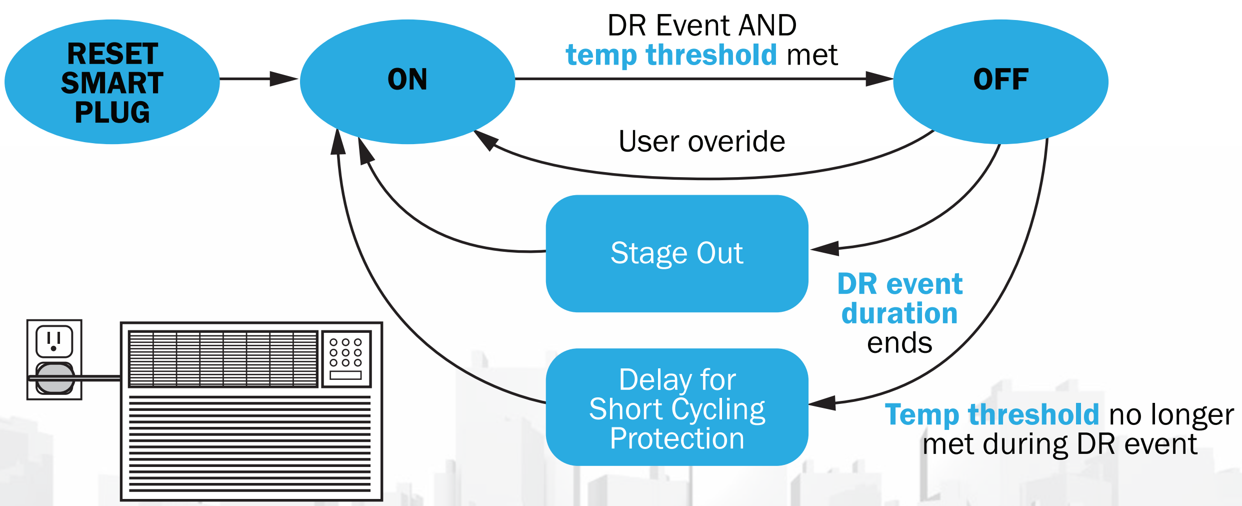

Figure 1: State Diagram Description of Modlet Operation of Window Air Conditioner (Source: EPRI)

INTRODUCTION

What Is This Technology?

SMART PLUG DEVICE PAIRED WITH W-IFI ENABLED RESIDENTIAL ROOM AC UNIT

The smart plug device chosen for evaluation is called a Thinkeco Modlet. The modlet is designed specifically for controlling existing room air conditioners in response to demand response (DR) events. The modlet comes with a separate remote controller that has a built-in thermostat for reading indoor temperature. The thermostat provides the ability of the modlet to control ACs plugged into the modlet, based on indoor temperature conditions. Both Wi-Fi and Zigbee versions of the modlet are commercially available for establishing connectivity in the home. The Zigbee version requires a separate gateway connected to a router, while the Wi-Fi version establishes connectivity to an existing home router using Wi-Fi. A Friedrich Kuhl room air conditioner with Wi-Fi connectivity was selected for lab testing under control by the modlet, and without the modlet as well.

FUNCTIONS AND CABPABILITIES

ThinkEco Modlet

STAND ALONE

- Requires vendor gateway

APPLICATIONS

- Measured Power Usage
- Off-premises on/off control
- Schedulable Control
- Configurable rules-based automation
- Demand Response
- Power Usage Reporting
- Real-time feedback
- Temperature- sensing controls
- Local remote for control

ACCESS

- Online app
- Smart phone/table app

What We Did

LABORATORY AND FIELD TESTING

The modlet was first field tested to control existing air conditioning units of customers before being lab-tested with a connective window air conditioner. The field trial identified different types of impacts achieved with ACs under modlet control.

FIELD TRIAL OVERVIEW

The field trial deployed six Thinkeco modlets (or smart plugs) at select SCE residential customer sites having broadband and Wi-Fi access. The modlets were located near existing room air conditioners and physically plugged into a wall outlet, in order to control the nearby room air conditioner. Each modlet was provisioned at the customer site and usernames and passwords were established for each customer through an online self-registration process on the ThinkEco platform.
The data collection plan included tracking:

- Power consumption per room AC participating during DR events
- Indoor temperature conditions
- User override per event
- ACs that were on during events

LAB TESTED TECHNOLOGIES

Two technologies for room air conditioner control were tested in EPRI's Knoxville, Tennessee laboratory facility. These technologies are illustrated in the figures below. Figure 1 depicts a Wifi-connected room air conditioner, and Figure 2 depicts the modlet that was the subject of customer field trial.

1. The impact of a Window AC's fan speed on power draw,
2. The power draw reporting accuracy of the ThinkEco modlet in comparison to a Wifi connected Window AC (by Friedrich), and
3. The demand savings achievable by a modlet-controlled window AC at select setback temperatures.

The lab trial also served to inform the development of recommendations for smart plug product enhancements to better support utility peak load reduction objectives with connected devices.

Figure 2: Thinkeco Modlet and Thermostat Remote Control

FINDINGS

DATA ANALYSES REVEALS FIELD RESPONSE OUTCOMES CAN BE GROUPED INTO THE FIVE TYPES

1. Demand impact achieved due to setback temperature relative to indoor temperature
2. Partial impact achieved due to customer override during the course of a DR event
3. Impact achieved in the form of delayed cycling (or cycling suppression during DR event)
4. Impact achieved only from 10-minute forced off “feature” at start of DR event
5. No impact. Since the AC was not on at start of DR event, the DR setback temperature was lower than the actual indoor temperature, and/or customer overrides occurred at start of DR event.

The days of impact occurred on the highest temperature days when test events were conducted.

SMART PLUG TECHNOLOGIES PERFORM AS MARKETED In both field and lab testing, the ThinkEco Modelet and the Friedrich Kuhl room air conditioner with Wi-Fi connectivity performed as described in manufacturer marketing literature.

FAN IMPACT ON POWER DRAW In the case of a window AC, both the fans (indoor and outdoor) are installed on the same straight shaft on a single motor. When the fan speed is reduced, not only does the internal air flow (on the evaporator) decrease but also decreases on the external fan (condenser). The condenser due to the reduced airflow at low fan speeds cannot reject as much heat as it could with a higher fan speed for the same ambient temperature. This reduction in air flow results in higher condensing pressures making the compressor work hard and hence the higher power. The difference is negligible at the lower end of ambient temperatures (75°F) due to the milder conditions which makes heat rejection easier.

DEMAND SAVINGS - Actual outcomes depended on many factors such as room occupancy, consumer override, outdoor temperature conditions and the size of the AC unit relative to the physical indoor space within it is located (e.g., room size and building envelope leakage).

POWER REDUCTION In a lab test, the modlet achieved 49-55% reduction in average power consumption, with setbacks of 75°F to 78°F, compared to baseline window AC operation at 72°F target temperature and no modlet. In a lab test, the Friedrich window AC achieved 14-21% reduction in average power consumption, with setbacks of 75°F to 78°F, compared to a baseline of 72°F target temperature.

Figure 3: Friedrich Kuhl Window AC

CONCLUSIONS

What We Concluded

DEMAND SAVINGS

Impacts observed from the field trial of modlet devices varied from reduced power consumption of controlled window AC units (e.g., through cycling achieved during DR events) to no impact (e.g., due to continuous running of the AC). Actual outcomes depended on many factors such as room occupancy, consumer override, outdoor temperature conditions and the size of the AC unit relative to the physical indoor space within it is located.

Reported power consumption values from smart plug platforms can be based on measured values or approximations involving no instrumentation. Consequently, power consumption reported by smart plug devices can vary in accuracy and be biased, impacting assessed demand savings. It is important to distinguish the method of power usage reporting being utilized due to possible wide variation in accuracy of reported values. Under lab test, the modlet power measurements were within 4% of the EPRI's lab measurements and were biased lower than lab measurements. The Friedrich window AC platform reported a static value for power consumption based on the window AC model's power rating.

These Findings are based on the reports "Evaluation of Residential Room Air

Conditioner Control with Smart Plugs for

Peak Load Reduction which is available from the ETCC program website, https://www.etcc-ca.com/reports.

Lessons Learned

TESTING SEASON

The DR field test events were initiated in the fall season, after the summer season had passed. The field data collected revealed a general lack of AC usage at customer sites during many DR test events. Consequently, the project was extended in 2015 with a lab trial to assess power savings from modlet-controlled cycling.

LITERATURE IMPROVEMENTS

Details of how products operate to support DR are generally left undocumented in normal marketing literature for the consumer. This marketing literature could be greatly improved upon to successfully market technology for DR events.
Smart plug vendor assertions of product support for demand response capabilities could be better clarified and documented to distinguish support for time scheduling operation of devices (e.g., under TOU rates) from capabilities to receive and process DR event signals.

SETUP PROCESS IMPROVEMENT

The process of self-registration of Wifi devices is a non-trivial task, commonly requiring manual entry of Wifi keys and codes. In contrast, an automated process could greatly simplify the process.