Energy Management Through Peak Shaving and Demand Response:

New Opportunities for Energy Savings at Manufacturing and Distribution Facilities

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Introduction

Energy efficiency initiatives are increasingly making their way into many manufacturing and distribution facilities as part of corporate initiatives to reduce energy use, costs and also meet sustainability goals. Various strategies can be employed to manage energy usage at industrial and manufacturing facilities such as peak shaving and demand response. This white paper will highlight the key aspects of peak shaving and demand response. In addition, the paper will also highlight Advanced Charging Technologies' products and solutions supporting energy management programs.

Understanding the Electric Bill

For large users, such as manufacturing and distribution facilities, the electricity bill consists of two components: energy consumption and demand charges (Fig. 1).

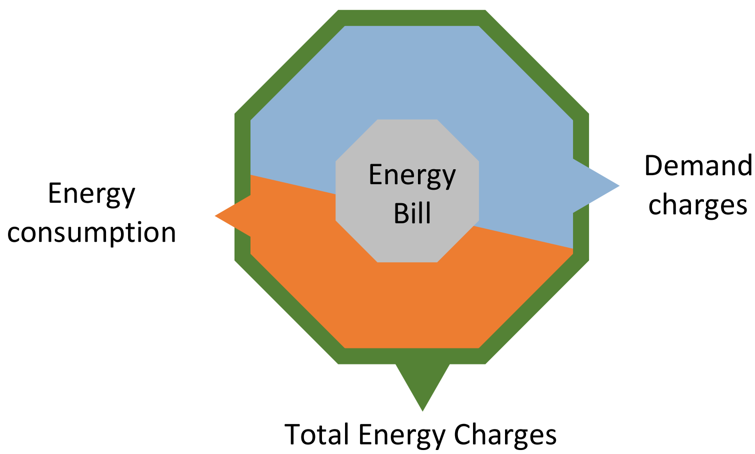

Fig. 1: Components of electricity bill

- **Energy consumption**: The total amount of electricity used measured in kWh. Energy consumption is a straightforward aggregation of the energy used regardless of the instantaneous power variations. While energy consumption rates may vary between summer and winter months as well as between day and night hours, these variations are typically small.
- **Demand Charges**: Demand is a measure of the rate at which energy is consumed. Demand charges are monthly charges based on the highest 15-minute monthly peak within a 12-month period, which is measured in kW (kilowatt). Demand charges typically account for 30–70% of an electricity bill and differ by season and time of the day. Demand charges are quite higher in

the summer months as compared to winter months as well as day hours versus night hours.

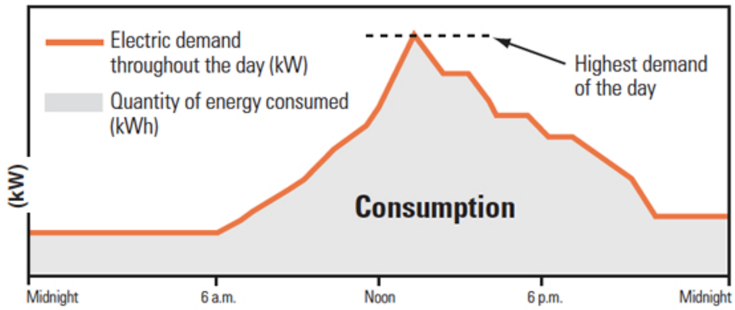

Fig. 2: Demand charges

One can use the analogy of filling a 5-gallon bucket of water using a low flow versus a high flow faucet as shown in Fig. 3. The low flow faucet fills the bucket slower than the high flow faucet. The flow rate is the equivalent to demand while the 5 gallons of water are equivalent to consumption. While filling both buckets has the same "consumption", they have very different "demands."

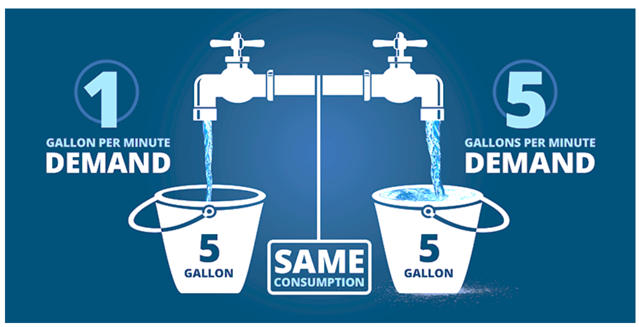

Fig. 3: Energy components analogy

An example of the difference between energy consumption costs and demand charges is shown in the table below.

Customer A	Customer B
Load: 50kW load for 50 hours Usage: ▪ Energy = 50 kW x 50 hrs = 2,500 kWh ▪ Demand = 50 kW Bill: ▪ Energy = 2,500 kWh x $0.15 = $375 ▪ Demand = 50kW x $28.00 = $1,400 **TOTAL = $375 + $1,400 = $1,775**	Load: 5kW load for 500 hours Usage: ▪ Energy Used = 5 kW x 500 hrs = 2,500 kWh ▪ Demand = 5 kW Bill: ▪ Energy = 2,500 kWh x $0.15 = $375 ▪ Demand = 50kW x $28.00 = $140 **TOTAL = $375 + $140 = $515**

While both customers use the same amount of energy, namely 2,500 kWh, customer A demand is higher than customer B, namely 50kW versus 5kW. As such, the demand charges for customer A are quite higher resulting in higher energy bill.

The Nature of Electric Demand

The electric demand in a power system reflects the aggregate demand of all loads connected to the distribution network. In a typical power system, adequate generation capacity is installed to meet the peak demand of the system (Fig. 4). Grid operators must meet peak demand reliably with all available generation resources. An increase in peak demand can be met with a corresponding increase in supply-side power, which may entail building additional generation, transmission, and distribution networks. On the other hand, the increased peak demand can also be met with a reduction in demand-side power through load curtailment and shifting to lower peak periods.

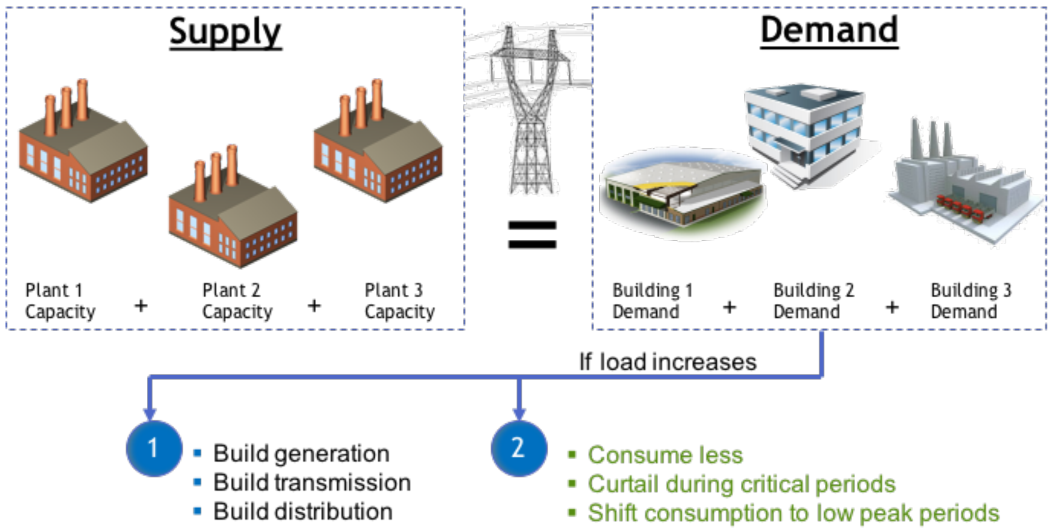

Fig. 4: Supply and demand in a power distribution system

From a user perspective, demand kW usage is dictated by the type and number of loads and equipment operated at a given point in time. Demand kW usage varies throughout the day and throughout the year. Fig. 5 shows a sample demand curve over a 24-hour period.

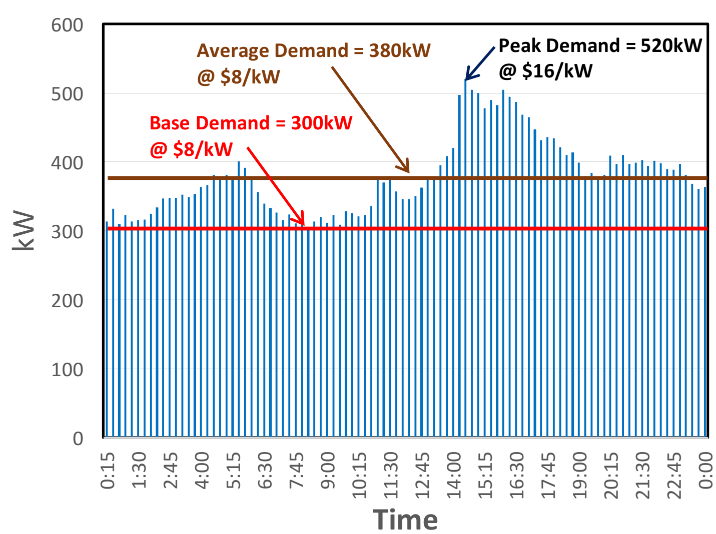

Fig. 5: Sample daily demand curve

As shown in Fig. 5, the base (minimum) demand over a 24-hour period is 300kW and the corresponding rate for 300kW peak demand is $8/kW. The average demand is slightly higher than the base demand, namely 380kW and the demand charge rate is still the same. However, the peak demand is 520kW and the corresponding rate for such level of demand is $16/kW.

Note that the peak demand is typically determined based on the maximum amount of electricity drawn from the grid or over a short period of time, typically 15 minutes. When customers are billed for demand charges, they are billed based on the highest amount of demand registered during the billing period (the peak demand) as shown in Fig. 6.

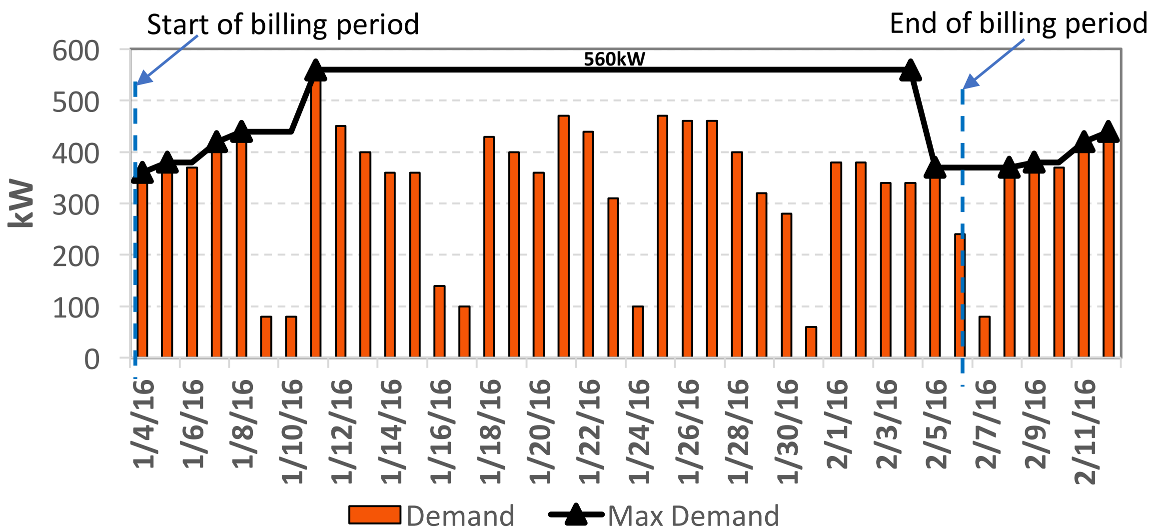

Fig. 6: Typical demand curve over a billing period showing peak demand for the period

Time of Use Rates (TOU)

The electricity prices that large end users pay depend on the time of day energy is used as well as the season. Typically, there are three different rates corresponding to three time periods, namely:

- On-peak (highest price)
- Semi-peak (lower price)
- Off-peak (lowest price)

The table below shows sample on-peak, semi-peak, and off-peak periods for a typical utility.

	Summer (Ex: May 1 to October 31)	**Winter** (Ex: November 1 to April 30)
On-Peak	11am – 6pm (Mon. to Fri.)	5pm – 8pm (Mon. to Fri.)
Partial-Peak	6am – 11am, 6pm – 10pm (Mon. to Fri.)	6am – 5pm, 8pm – 10pm (Mon. to Fri.)
Off-Peak	10pm – 6am (Mon. to Fri.) Weekends and holidays	10pm – 6am (Mon. to Fri.) Weekends and holidays

TOU rates are typically reflected on the customer's energy bill. The table below shows a sample monthly electric bill with itemized TOU charges.

Season: Summer	Energy
On-Peak	37,048.000 @ $0.23357
Partial-Peak	31,319.000 @ $0.09502
Off-Peak	58,381.000 @ $0.06978
Total Energy Cost	**$11,998**
Season: Summer	**Demand**
Max. On-Peak	362.000 @ $14.5900
Max. Partial-Peak	361.000 @ $3.41000
Max. Off-Peak	361.000 @ $11.85000
Total Demand Charges	**$10,802**

As shown from the above table, the on-peak energy rates are quite high, almost 3 times off peak rates. The on-peak demand rates are even higher, almost 4 to 5 times the off-peak rates. In some areas, the on-peak demand rates can be 10 or 15 times higher the off-peak rates prompting users to action to reduce their on-peak demand.

Reducing Peak Demand: Peak Shaving

One way to reduce peak demand is to control or reduce electrical usage during periods of maximum demand on the power utility. This allows end users to reduce demand penalties and the corresponding demand charges during peak periods. In addition, peak shaving also helps the utility provide maximum base load power without starting expensive to operate peaking generators. As such, utilities may also offer incentives to customers implementing peak shaving programs. In fact, C&I customers can realize 10% - 30% in demand cost savings depending on the type of loads and flexibility of the loads. Fig. 7 shows an example of daily peak shaving via load management.

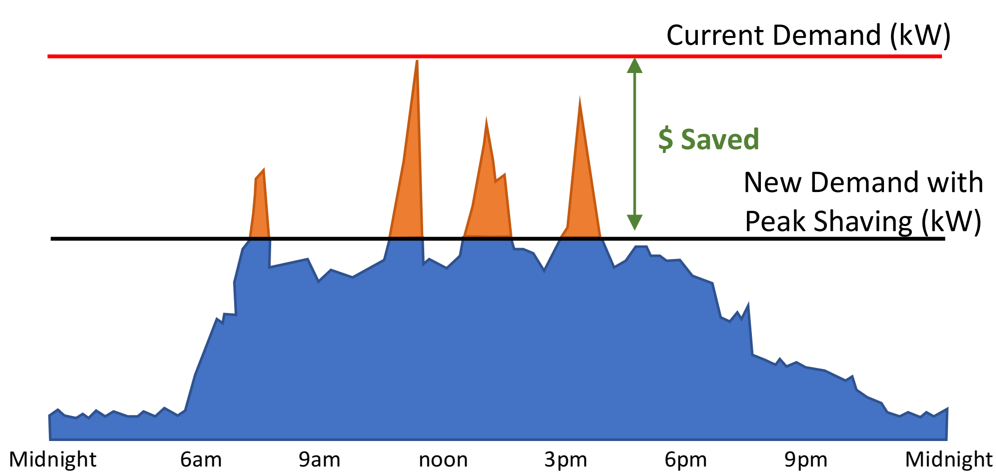

Fig. 7: Reducing peak demand through peak shaving

Peak shaving can be realized using several ways including[1]:

- **<u>Load Shedding</u>**: Entails switching off loads during periods of maximum peak demands. Facility managers typically identify sheddable loads, which can easily be turned off and restarted without serious impact on processes or staff. Typical sheddable loads include HVAC systems, non-sensitive industrial machines, and some lighting.
- **<u>Adding Capacity via On-Site Generation</u>**: For sites with limited sheddable loads, facility managers can add capacity using on-site generation to increase available power without increasing demand. Renewable energy sources – such as solar PV, and battery energy storage – are slowly becoming favorites for peak shaving programs due to its fast dispatchable nature and ease of control.

Demand Response (DR) Programs

Demand Response (DR) is a class of demand-side management programs in which utilities offer commercial and industrial (C&I) customers incentives to reduce their demand for electricity during periods of critical system conditions or periods of high market power costs. DR focuses on reducing demand temporarily in response to a price changes or other type of incentive, particularly during the system's peak periods. End-users receive compensation – either through utility incentives or rate design – to reduce non-essential electricity use or to shift electric load to a different time, without necessarily reducing net usage. Fig. 8 shows an example of a demand response event where a customer reduces their peak demand by almost 300kW from a baseline of 1,285kW to 965kW during the hours of 2:00 pm to 4:00 pm.

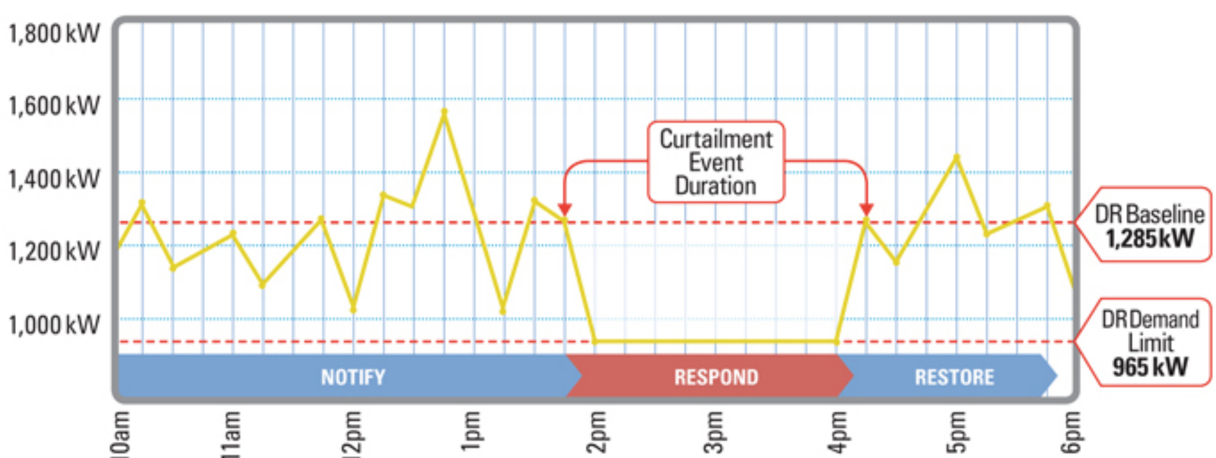

Fig. 8: An example of DR events

Demand response programs can be realized using several ways including load shedding, load shifting, and load displacement (Fig. 9).

[1] Schneider Electric: Reducing Energy Costs with Peak Shaving in Industrial Environments

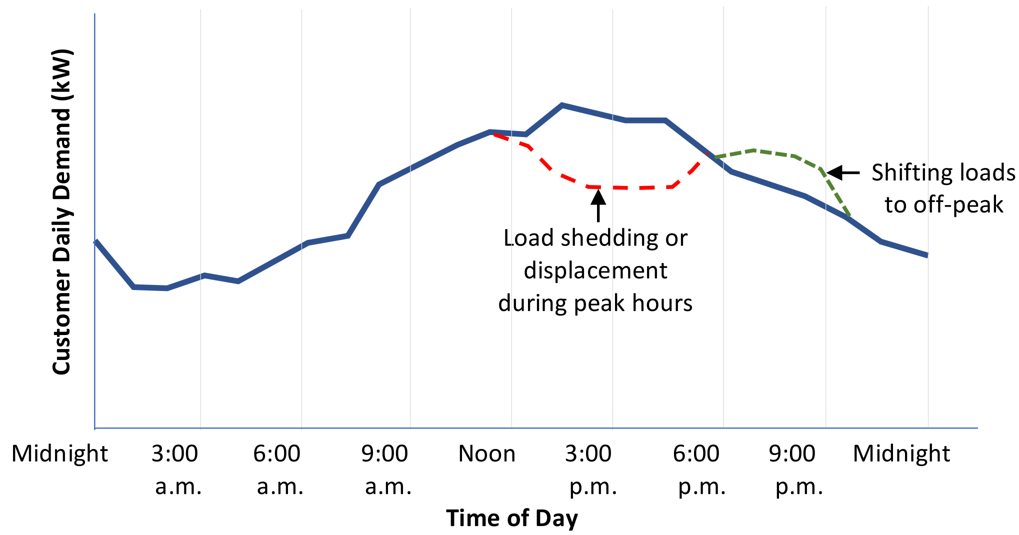

Fig. 9: Peak load management options

- **Load Shedding**: Similar to peak shaving, non-critical loads are switched off during periods of maximum peak demands. For example, office lighting and non0critical office equipment can be switched off during DR events.
- **Load Shifting**: This entails moving consumptions to time periods outside the DR event or when the price of electricity is lower. For example, cold storage facilities can shift their load and reduce peak demands by pre-cooling their refrigerators to a lower temperature prior to the DR event, then allowing the temperature to rise naturally. Proper temperature monitoring will ensure that product quality is not compromised.
- **Load Displacement**: This entails offsetting peak demand with on-site generation such as renewable sources and battery energy storage.

DR End User's Benefits

C&I customers can enjoy many benefits from implementing DR programs including[2]:

- **DR Payments**. Utility customers get paid, in cash or as bill credits, for participating in DR programs. Some utilities offer a payment for enrolling as well as a payment per event
- **Reduced Power Consumption**. Customers can reduce their power consumption and energy costs if their DR actions lead less overall electricity usage.
- **Lower Energy Market Prices**. Reducing demand during peak times minimizes utilities' need to secure energy from more expensive sources such as peaking generators or spot markets. As such, electricity rates are reduced as well.
- **Payments for DR Equipment**. Some programs compensate participants for installing automated controls that can assist with carrying out DR measures.

[2] CEATI International: Demand Response for Small to Midsize Business Customers – Reference Guide

- **Enhanced Energy Security**. Energy security is a critical benefit of demand response. Blackouts impose tremendous economic and social costs, including equipment damage, lost revenue from damaged or spoiled products, lost wages and reduced productivity.

Dynamic Energy Management

Dynamic Energy Management is an innovative approach to managing energy at the demand-side (end user). It incorporates the conventional energy use management principles such as peak shaving, demand response, and distributed energy resource programs and merges them in an integrated framework that results into permanent energy savings, demand reductions, and short term peak load reductions[3].

Dynamic Energy Management is accomplished through a system is comprised of smart end-use devices (e.g. smart appliances), highly advanced controls, and integrated communications capabilities that enable dynamic management of the overall system (Fig. 10). These components build upon and interact with one another to realize a dynamic infrastructure that is fully-integrated, highly energy efficient, automated, and capable of learning.

- **Smart Appliances**: These are intelligent equipment and devices equipped with embedded controls, two-way communications, and automated control. Industrial appliances are typically highly efficient, internet protocol (IP) addressable, and can be controlled by external signals from the utility, end-user, or other authorized entity.

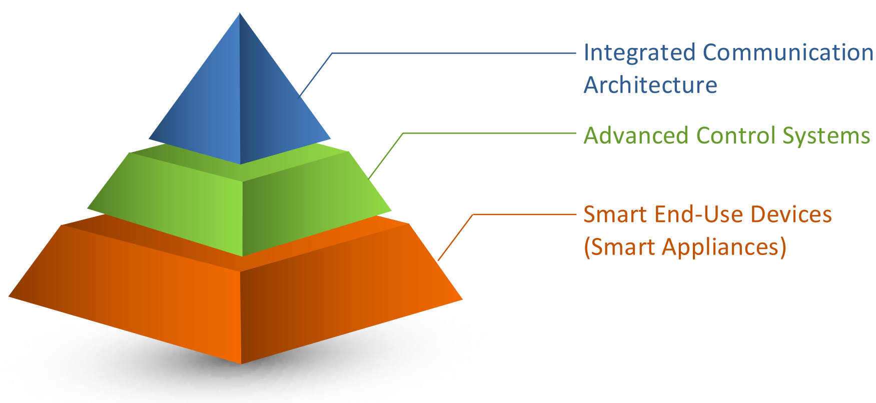

Fig. 10: Dynamic energy management components

- **Integrated Communication Architecture**: This entails an integrated open architecture communication system that enable interoperability and communications between devices. Such system allows automated control of the smart appliances in response to external signals and commands such as pricing or emergency demand reduction signals from the utility.

[3] "Dynamic Energy Management," 2008 ACEEE Summer Study on Energy Efficiency in Buildings.

ACT Quantum Chargers' Energy Management Capabilities

The Quantum charger, ACT's flagship products, is the industry's first smart industrial charger appliance that feature many advanced energy efficiency and energy management capabilities as well as communication and smart grid integration (Fig. 11). The Quantum chargers is first industrial smart appliance that is highly efficient, internet protocol (IP) addressable, and can be controlled by external signals from the utility, end-user, or other authorized entity.

Fig. 11: ACT Quantum chargers: Industry's first smart charging appliance

Quantum chargers boast high peak efficiencies of > 94% and high charge cycle energy efficiencies of >93%, greatly reducing the kWh usage and corresponding energy costs.

Further, Quantum chargers incorporate an integrated communication architecture with two-way wireless communication, allowing for remote monitoring and control as well as cloud integration. With and open communication network architecture, Quantum data is easily uploaded to ACT's ACTview cloud application, allowing users to centrally manage their charger assets, optimize battery and fleet performance, troubleshoot charger issues, and implement energy management programs.

Advanced energy management functionalities of Quantum chargers allow end users to implement and participate in peak shaving and DR programs. Through ACT's ACTView cloud application, smart grid integration is facilitated, allowing facility managers to centrally manage energy usage, implement peak shaving programs, and participate in DR programs.

Quantum chargers support various energy management functionalities including lockout modes and static peak shaving schedules (Fig. 12).

- **Lockout Mode**: The Quantum chargers can be disabled (not allowed to operate) during high peak demand periods, which allows for load shifting to other low peak periods. This mode can be programmed both manually and remotely, and schedules can be set for specific days of the week or hours of the day.

- **Static Peak Shaving Schedules**: In this mode, the maximum output power of Quantum chargers can be limited during high peak demand periods by setting a maximum power limit factor (in percentage) for each Quantum charger. This capability can be programmed both manually and remotely, and schedules can be set for specific days of the week or hours of the day.

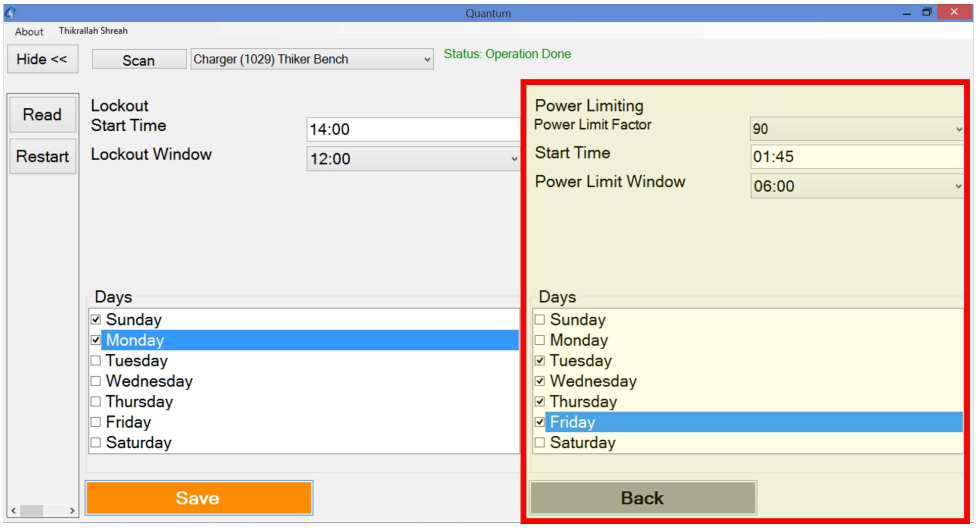

Fig. 12: Quantum charger lockout and static peak shaving programming screen

Additionally, the Quantum chargers support various DR programs including dynamic peak shaving schedules and DR events.

- **<u>Dynamic Peak Shaving Schedules</u>**: The Quantum chargers can be dynamically programmed for reduced peak power based on customer's changing demands. Under dynamic peak shaving, a maximum power limit for the entire charger fleet can be set where a dynamic peak shaving algorithm dynamically sets and adjusts the individual maximum power limit for each charger based on the battery charging needs. For example, deeply discharged batteries will be given priority where the corresponding charger power limit will be set to maximum while chargers connected to partially discharge batteries will have lower maximum power settings.

- **<u>Demand Response / Curtailment</u>**: Similar to dynamic peak shaving, Quantum chargers can dynamically respond to external DR events / curtailment signals to reduce peak power. Algorithms for optimizing battery fleet charging during reduced peak power periods are being developed.

The above energy management functions can be programmed locally or remotely through the ACTview cloud platform (Fig. 13). Future integration is planned with automated DR through OpenADR, a communications data model designed to facilitate sending and receiving DR signals between a utility or independent system operator (ISO) and electric customers.

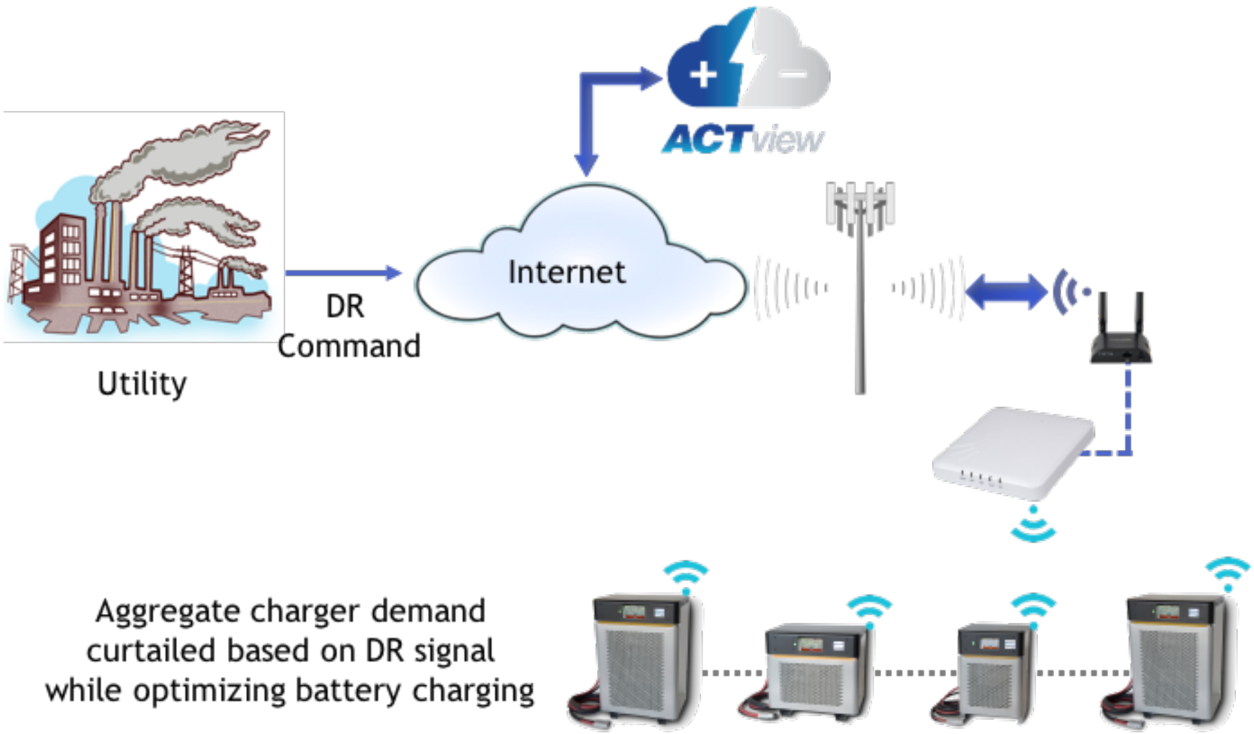

Fig. 13: Quantum chargers automated DR architecture

Conclusion

Automated energy management technologies can greatly enhance a facility's ability to reduce energy consumption and peak load demands through peak shaving and dynamic DR programs, ultimately realizing greater energy efficiency and cost savings. C&I customers can achieve energy savings of 20 to 40 percent when automated technologies are utilized[4]. Technologies with two-way communication capability can further enhance the energy savings potential as it enables utilities to verify load reductions in near-real time.

ACT's Quantum charger platform is first industrial smart appliance that is highly intelligent, internet protocol (IP) addressable, and can be remotely controlled, allowing facility managers to include their charger fleets in their energy management programs.

[4] "Demand Response: An Introduction," Rocky Mountain Institute, 30 April 2006.