WHITE PAPER

Peak shaving

Reduce energy cost using
battery energy storage

Table of contents

Can you control electricity cost?

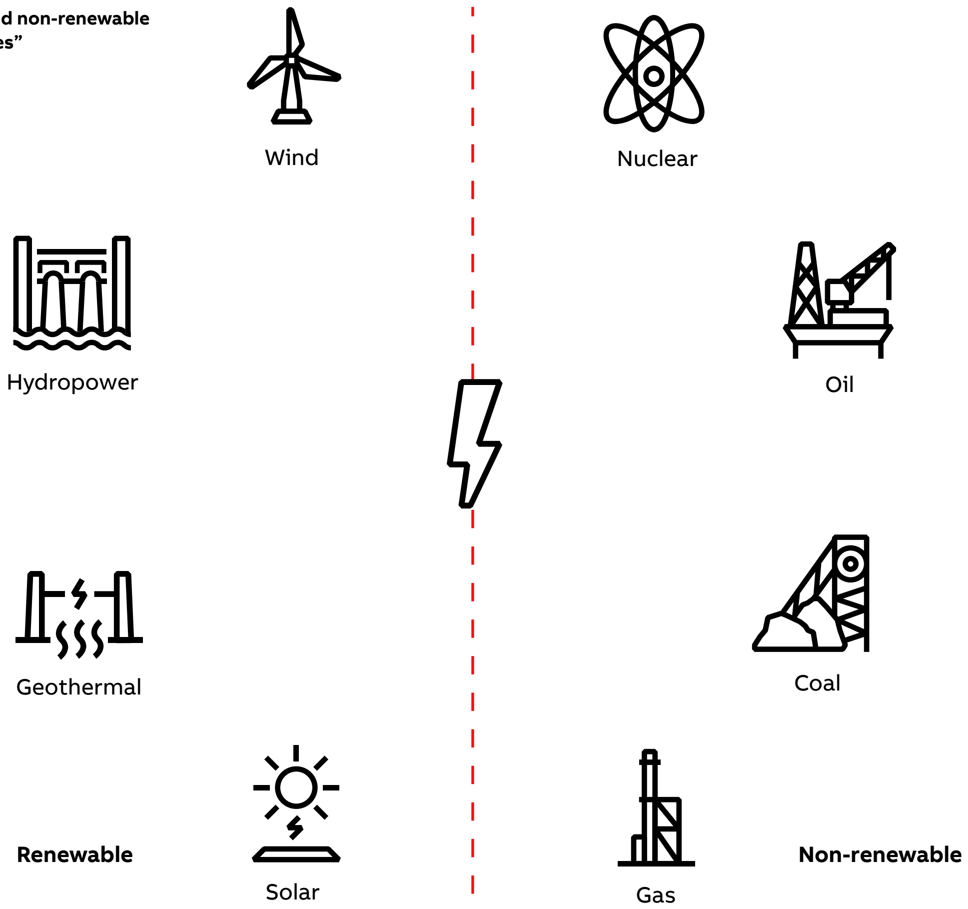
Why peak shaving matters

Modern consumers actively seek cost-effective energy solutions and sustainable practices. This white paper explores peak shaving as an effective method to minimize energy costs. Energy and facility managers will gain valuable insights into how peak shaving applications can help unlock the full potential of energy storage systems.

The electrical energy systems sector is a cornerstone of modern society, generating, transmitting, and distributing electricity for residential, commercial, and industrial use. According to the U.S. Energy Information Administration (EIA), the commercial and industrial sector is responsible for approximately 60% of the electricity consumption in the United States while the residential sector uses up most of the remaining electricity.[1]

Natural gas is the primary source of power for the electric grid, with nuclear, coal, renewables, and other sources also contributing to the grid.[2] In pursuit of environmental sustainability, the U.S. government aims to have a 100% carbon-pollution-free electricity supply by 2035, highlighting the important role of renewable energy in achieving this objective.[3] Renewable energy, though continuously replenished, has limitations in the amount of energy it can provide at a given time.

—
Renewable and non-renewable energy sources"



Due to the intermittent nature of renewable sources, storing energy for later use when these sources are not producing is essential.

Projections from the International Energy Agency indicate a 75% increase in renewable energy capacity, expected to exceed 280 gigawatts by 2027, with photovoltaics solar and wind energy driving much of this expansion.[3] This is the fastest growth expected and it is anticipated to boost renewable energy adoption and contribute to emission reductions, thereby mitigating the effects of climate change.

Managing the surplus energy from both renewable and conventional sources is beneficial, mainly when they are abundant or less expensive. Energy storage systems, such as Battery Energy Storage System (BESS), are pivotal in managing surplus energy. These systems have gained traction with the emergence of lithium-ion batteries.

BESS supports grid networks with grid stabilization, frequency regulation, reducing transmission losses, load leveling, peak shaving, and power quality improvement.[4] Among these applications, peak shaving is particularly critical due to the substantial demand charges levied by electric utilities. Demand charge management involves strategies to reduce demand charges, and this can be achieved by implementing peak shaving.

Peak shaving through BESS is poised to play a vital role in future grid systems.[5] It involves the strategic use of BESS to even out the peaks in electricity demand. By managing overall electricity consumption, peak shaving effectively mitigates abrupt surges in power usage. This approach is key in reducing the expenses associated with demand charges, which are typically incurred during high electricity demand periods. Explore this whitepaper to discover how ABB's energy-efficient products can enhance the performance of a BESS.

What makes up the peak cost?

Electricity bills for consumers encompass a variety of charges, including distribution, fixed, demand, and consumption fees. A particularly significant charge in today's industry is the peak demand charge. This charge is determined by the average electricity usage of consumers over a specific timeframe, typically measured by the maximum power drawn during a 15-minute interval.

Demand charges are a significant component of electricity costs, constituting above 30% of the total bill for commercial and industrial consumers.[6] These charges can accumulate rapidly, especially when multiple high-energy devices are used simultaneously, such as during startup or to accelerate a production process, exceeding the energy needed for basic operations.

For example, on hot summer days, the extensive use of air conditioners leads to higher energy consumption, creating peaks in demand and placing additional strain on the electrical grid. This increase in demand can result in consumers drawing more power than required for essential functions like lighting, thereby elevating their demand charges. When electricity usage surpasses contract limits, consumers may be compelled to increase their contracted power, raising their fixed costs.

Demand charge

In power systems, the load profile often includes brief periods of peak loads when substantial power is required. These peaks in demand occur at various times throughout the day, can vary with the season, and the specific composition of the load.[7][8] These peaks significantly affect the economic efficiency of power systems. Electric utilities charge customers for varying demand peaks, which are used to ensure sufficient capacity in their generation, transmission, and distribution systems to meet the maximum demand.

The demand charge is a tool electrical utility provider's use to recoup costs associated with maintaining the necessary capacity to meet customer needs at all times.[7] These charges are common among commercial and industrial consumers, primarily due to the high-capacity demands resulting from the startup of large equipment.

Consumers generally incur two types of charges on their electricity bills: consumption and demand charges.

- **Consumption charges** are based on the total volume of electricity used and are measured in kilowatt-hours (kWh).
- **Demand charges** focus on the peak rate of electricity usage during the billing period and are measured in kilowatts (kW).

There are multiple strategies used to manage demand charges, including peak shaving, load shifting, participating in demand response programs, maintaining equipment regularly, upgrading to energy-efficient technologies, and utilizing on-site energy generators.

It is essential to differentiate peak shaving from load shifting. Load shifting involves adjusting energy consumption patterns or postponing electricity usage to a later time.

Smooth peaks
Strengthen savings

Peak shaving, sometimes called load shedding, involves reducing the peak electricity demand to lower demand charges. This technique is often employed by commercial and industrial electricity consumers who aim to momentarily reduce their grid-power consumption to help avoid spikes in their energy usage. Peak shaving can be accomplished by activating on-site power generation systems, such as diesel generators, or utilizing a battery energy storage system. During peak shaving, the consumer's overall electricity consumption remains consistent, but a portion of their demand is met through the BESS instead of drawing power from the grid.

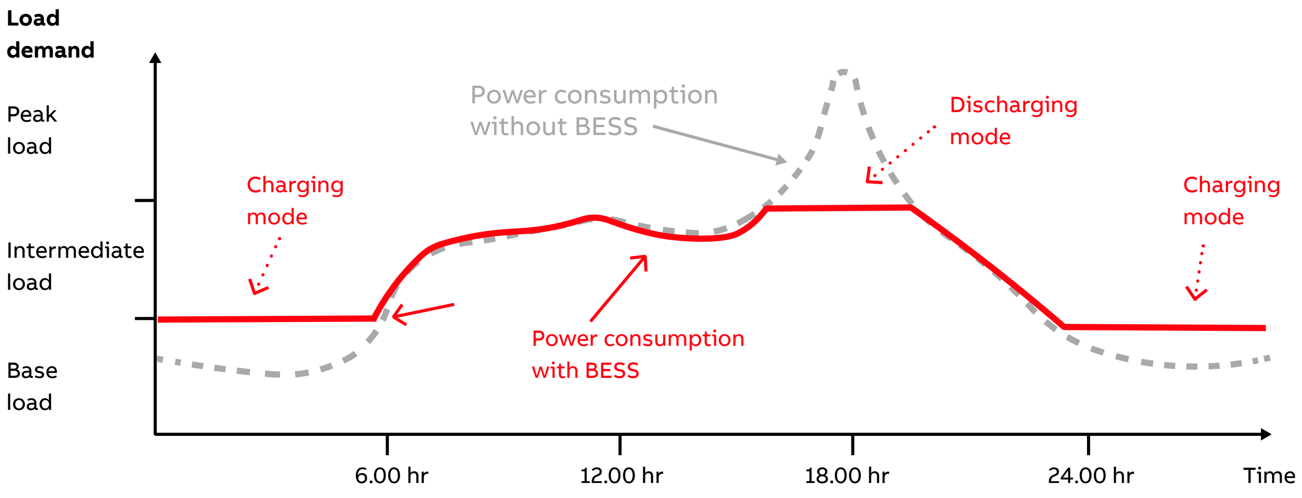
Energy storage systems are notably effective in mitigating demand charges throughout the billing cycle with minimal environmental impact. By storing energy during low-demand periods and using it during peak times, these systems help commercial customers level out their demand profile.

Peak shaving helps consumers to utilize stored energy during periods of high demand. It reduces the need to draw power from the grid, thereby lowering peak demand charges.

According to the National Renewable Energy Laboratory (NREL), about 5 million commercial customers in the United States who are subject to retail energy rates pay demand charges exceeding $15 per kilowatt (kW).[6]

Figure 2 illustrates the charging and discharging cycles of a BESS used in peak shaving. The red line depicts the scenario where both the grid and BESS are engaged in meeting the load demand. Depending on the demand, the BESS is either charged or discharged. The dotted gray line shows the building's power consumption from the grid without a BESS. In this example, the BESS enters charging mode during periods of low load demand, which typically occurs before 6:00 hr. Conversely, the battery switches to discharging mode during peak load times, around 18:00 hr. This discharging action at peak times results in a leveled or flattened demand profile, as indicated by the red line. The graph effectively demonstrates how BESS can be utilized to manage and stabilize demand profiles, reducing reliance on the grid during peak consumption periods.

—
Figure 2: Optimal charging and discharging of BESS for peak shaving[9]



Benefits of peak shaving

Peak shaving provides significant economic, technical, and sustainability advantages:

- **Economic:** Controlling power helps eliminate penalties due to excess power usage and limits usage during peak rate hours, which leads to significantly reduced energy costs.
- **Technical:** Controlling power reduces the likelihood of malfunctions, aging of system components, or worse, blackouts due to plant overload.
- **Sustainability:** Utilizing power from renewable energy sources like solar or wind power and storing the energy with BESS lowers greenhouse gas emissions and fosters a more sustainable energy future.

The advantages of utilizing peak shaving applications extend beyond the limited points above and will continue to increase as the adoption of BESS increases.

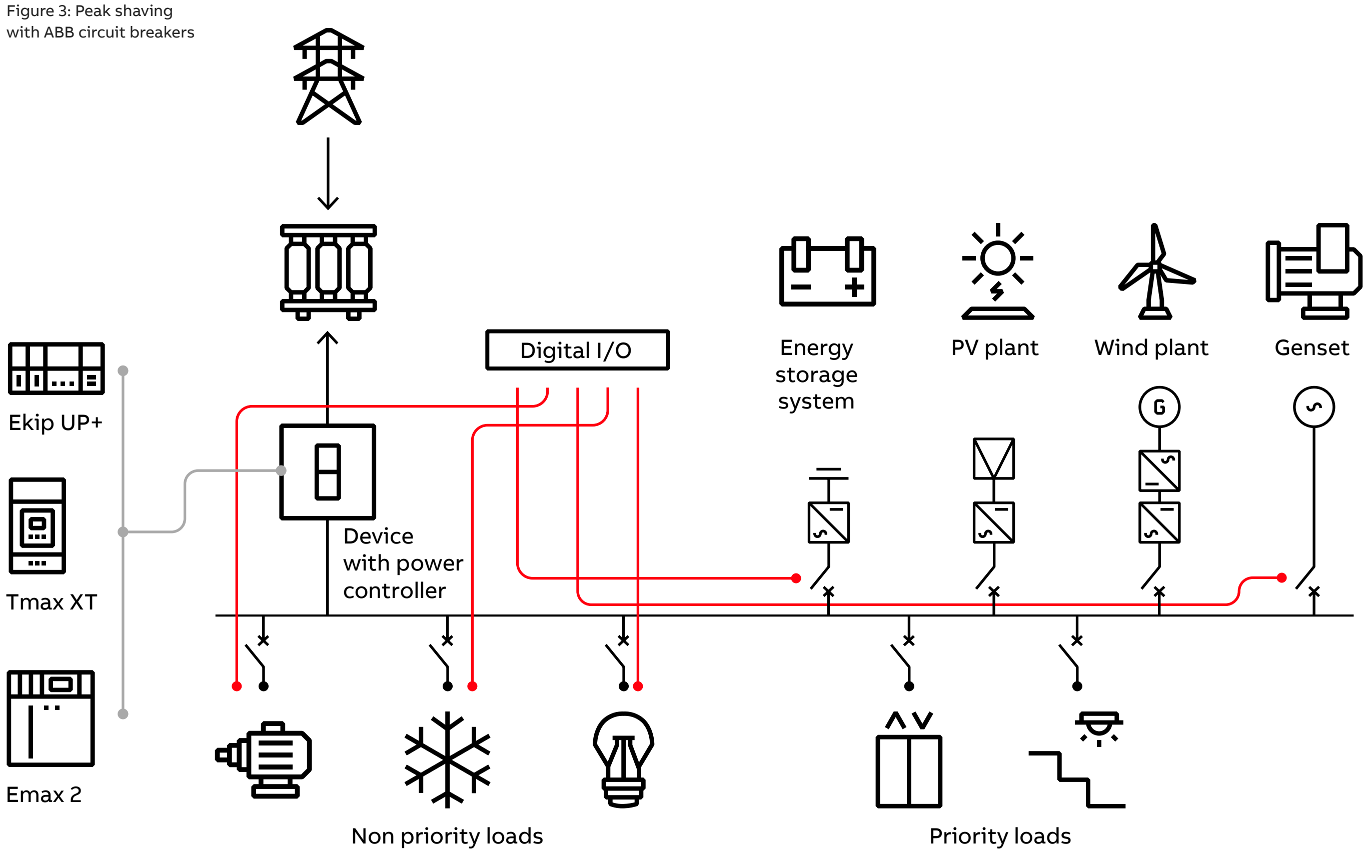
Overview on essential components

Peak shaving involves selectively transferring specific loads within a facility from the grid to an energy storage system. This process is accomplished by disconnecting the power supply of a specific load(s) from Source A (typically the grid) and connecting them to Source B (an energy storage system). Several vital components including recombiners, collectively called the Balance of System (BOS), are necessary to facilitate this switch.

The BOS components play a critical role in ensuring the efficient performance of the energy storage system. They include various elements essential for the operation and management of the system. Figure 3 presents a single-line diagram illustrating how a BESS is used for peak shaving. This diagram showcases the essential components and their configuration for effectively implementing peak shaving with a BESS.

BESS installed on the consumer's side of the utility service meter is called behind-the-meter BESS. Only behind-the-meter BESS are used for peak shaving since they are controlled and managed by the customer, not the utility company.

—
Figure 3: Peak shaving with ABB circuit breakers



Peak Shaving

Enables peak savings

Below are two simplified scenarios of hypothetical bills for two consumers that use the same amount of energy per billing cycle:

—

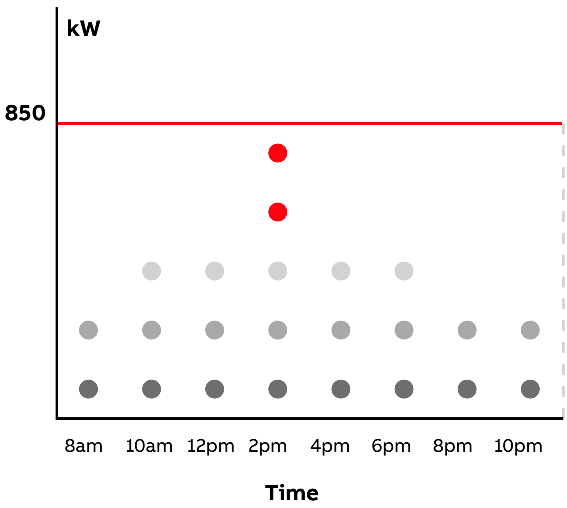
Table 1: Hypothetical scenario of two consumers. One has implemented peak shaving, and the other has not.

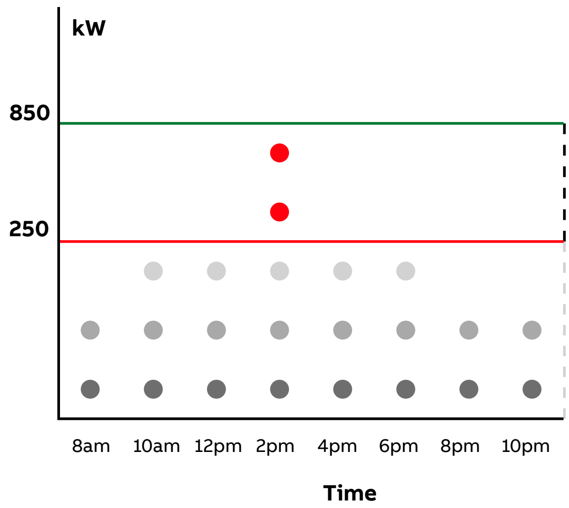
CONSUMER A

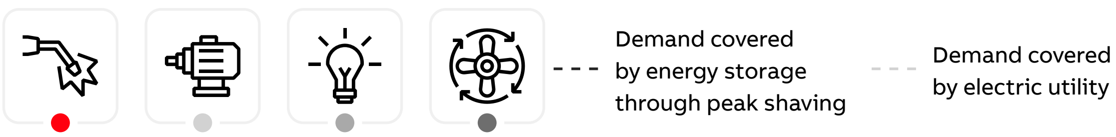
	(without peak shaving)
Total energy consumption	35,000 kWh
Consumption charge cost per unit is $0.15	35,000 kWh × $0.15 = $5,250
Demand charge cost per unit is $9.00	850 kW × $9.00 = $7,650
Total energy bill	$12,900

CONSUMER B

	(with peak shaving)
Total energy consumption	35,000 kWh
Consumption charge cost per unit is $0.15	25,000 kWh × $0.15 = $3,750
Demand charge cost per unit is $9.00	250 kW × $9.00 = $2,250
Total energy bill	$6,000







Assuming two consumers with similar energy usage profiles, each consuming 35,000 kWh monthly and using the same electric utility. Both operate energy-intensive machinery for a welding process lasting about 30 minutes daily.

Consumer A runs its welding machines directly from the grid without peak shaving measures. In contrast, Consumer B utilizes a battery energy storage system to power its welding process. Despite identical overall energy usage, Consumer A incurs higher costs due to peak demand charges.

As detailed in Table 1 and the figures above, Consumer A's peak demand is 850 kW, while Consumer B's is only 250 kW, which is attributed to effective peak shaving, leading to substantial savings.

Some electric utilities apply a ratchet clause in their billing. A ratchet clause imposes a year-long minimum demand charge, which is determined by the highest peak demand recorded in the last eleven months. Under the ratchet clause, a consumer's demand charge is based on a percentage of their highest peak over a previous set period, often 11 months. The utility has the discretion to set the percentage charge.[10]

For example, if a consumer's demand in January is 500 kW at a rate of $9 per kW, leading to a demand charge of $4,500. If this consumer's demand drops to 200 kW in April, their demand charge would be $3,600 rather than $1,800. This is because April's demand charge is calculated as a percentage of January's peak demand; 80 percent of 500 kW is 400 kW, and at $9 per kW, this amounts to $3,600. This increase is due to the demand ratchet clause in the rate schedule.

Peak shaving systems can help maintain uniform demand levels throughout the year to help to avoid high ratchet demand costs.

Loads suitable for peak shaving

Peak shaving offers greater benefits for certain applications over others. Here are some of the applications where peak shaving yields the most significant advantages.

—

HVAC – These systems consume significant energy to maintain optimal comfort levels within a building. Peak shaving can be used to mitigate the inflated cost of running HVAC during peak demand periods.

—

Industrial processes – Several industrial processes are energy-intensive and often operate for limited durations. Peak shaving is a great approach for meeting the energy demands of these processes while reducing demand costs.

—

Electric vehicle chargers – With the emerging demand for fast E.V. charging infrastructure, BESS is an alternative to grid upgrades, enabling integration of these new peak loads with a limited impact on the site electrification and on the grid. Peak shaving is an excellent application for the expansion of E.V. charging infrastructure.

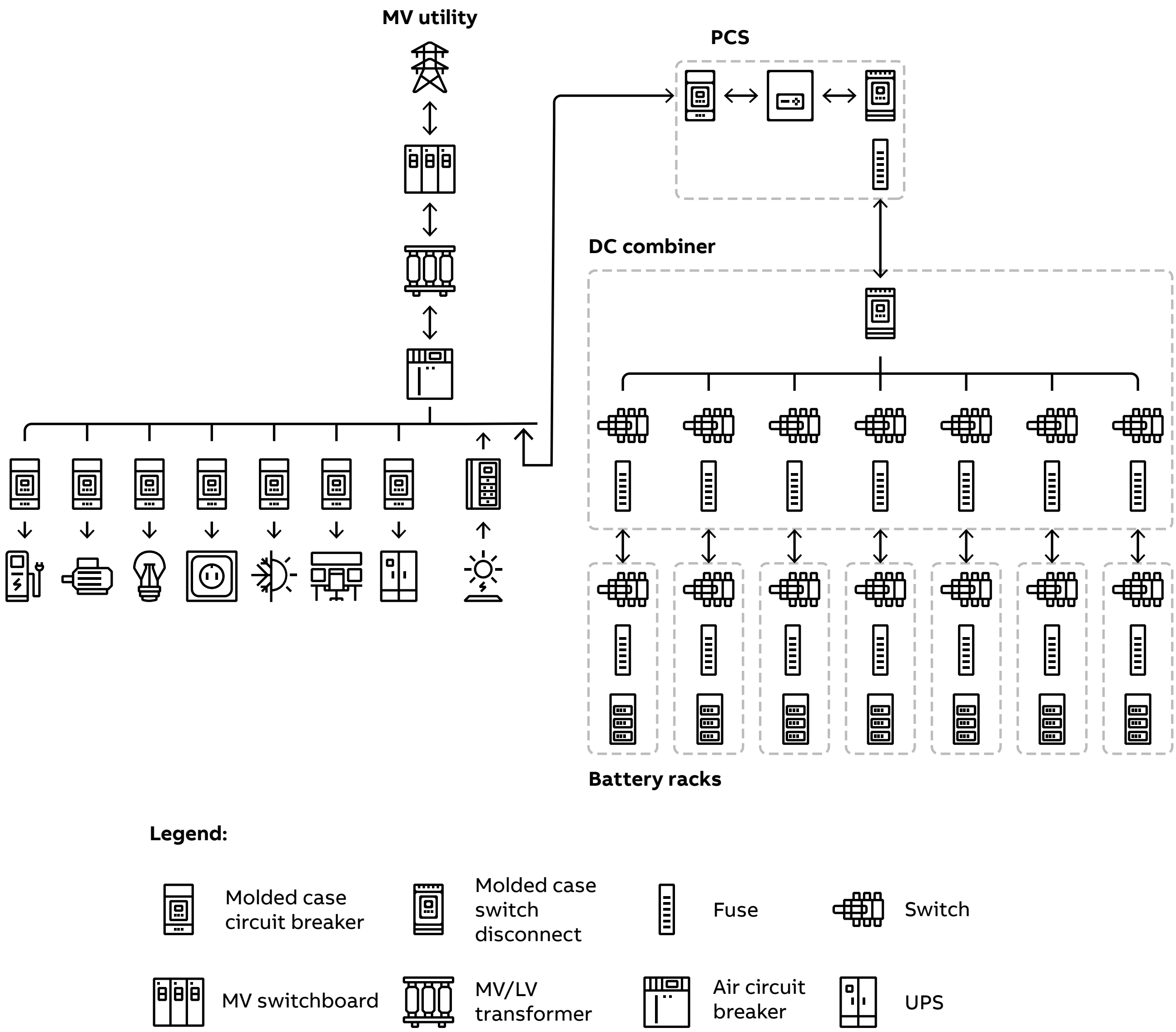
—

Energy-intensive appliances – Numerous energy-intensive appliances such as pumps and motors are good for peak shaving. Peak shaving is a great application for meeting the power demands of these appliances.

ABB products used in peak shaving applications

A typical BESS includes components such as battery strings, a battery management system, an inverter, switchgear, a transformer, protection mechanisms, and a control system. As the push to electrify everything intensifies, creating a greater strain on the electrical grid, a key challenge lies in maximizing the efficient functionality BESS-related components. The efficient operation of each component is essential to the overall performance and effectiveness of the BESS.

Several ABB products are used for peak shaving applications. These products can be used for switching, monitoring, controlling, measuring, and protecting the battery energy storage system, as demonstrated in the figure below.

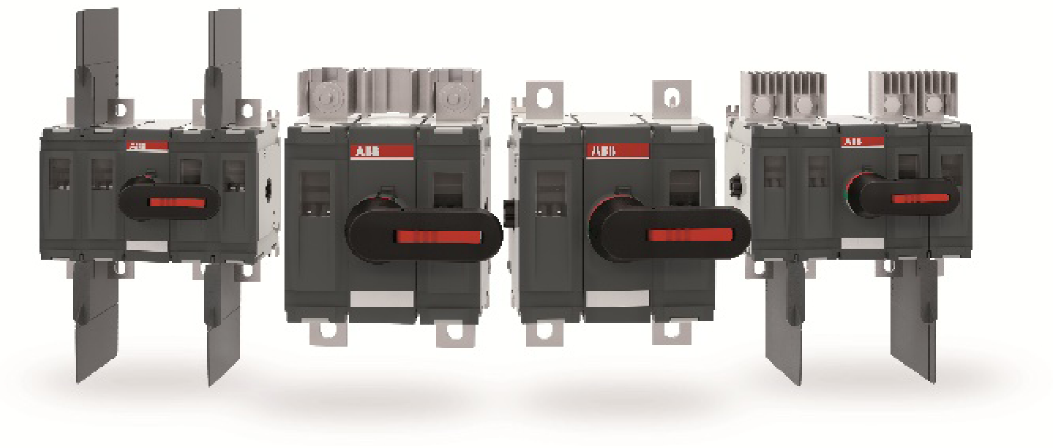


DC open type disconnects

Switch disconnects play a pivotal role in isolating and disconnecting specific electrical circuits from the power supply during peak shaving activities. Disconnects are also crucial in controlling the charging and discharging operations of the energy storage system by facilitating the connection and disconnection from the power grid.

ABB's open type disconnects (OTDC) range of disconnects for Energy Storage System (ESS) applications spans from 16 A to 1,000 A. These disconnects offer dependable switching for ESS applications, such as peak shaving, supporting up to 1,500 VDC. In ESS contexts, these OTDC disconnects are typically employed as the main switch in energy storage Power Conversion Systems (PCS) and/or for safeguarding battery racks. They can be the primary switch to isolate the DC-side of Energy Storage PCS, the battery section, or before the battery rack.

With the OTDC range extending to higher currents of up to 1,000 A and 1,500 VDC, compliant with UL98B, ABB disconnects are designed to meet the requirements of high-power inverters and recombiners. This makes them a versatile and essential component in various ESS applications, especially where high-capacity and reliable switching are necessary.



Insulation monitoring devices

Insulation monitoring devices (IMDs) are relays used to monitor the insulation resistance of an electrical network such as BESS. IMDs help improve system reliability through preventive fault detection.

ABB's CM-IWx insulation monitoring devices are designed to enhance the reliability and efficiency of battery storage systems by helping to prevent disruptions due to severe secondary insulation faults. These devices are adept at detecting insulation degradation in real time. The CM-IWx relays offer continuous and dependable monitoring of insulation quality in battery storage systems, effectively minimizing downtime and optimizing operational efficiency. Integrating CM-IWx insulation monitors promote enhanced security and optimization of maintenance processes.

Circuit breakers

Circuit breakers play a pivotal role in peak shaving applications, particularly in power distribution and optimization of energy storage systems. Safely de-energizing specific parts of electrical systems during peak shaving is important for helping to prevent damage to electrical equipment. Circuit breakers are especially valuable in managing the connections and disconnections of batteries from the grid and specific loads, thereby facilitating controlled charging and discharging of the batteries.

Furthermore, circuit breakers act as a protective barrier, safeguarding the electrical system against overcurrent and fault conditions. This protective feature is essential in maintaining the integrity and reliability of the system, especially in dynamic operating environments like those involving peak shaving and energy storage.

ABB offers a range of circuit breakers designed to meet the varied requirements of consumers. Each model in their lineup is tailored to address specific needs, ensuring consumers can select a solution that aligns perfectly with their unique operational demands and constraints. This diverse offering underscores ABB's commitment to providing effective, customized electrical safety and energy management solutions.

Medium voltage breakers

Some industrial and large commercial facilities operate at medium voltage levels (typically above 4 kV and up to 35 kV), an MV breaker is required to handle the higher voltage levels safely. Most facilities that require peak shaving solutions may have parts of their electrical distribution system operating at these voltage levels. MV breakers are necessary for protection and control purposes if the distributed energy resources are integrated into the medium voltage part of the electrical system. ABB offers the following ANSI indoor vacuum circuit breaker: ADVAC, AMVAC, VD4-IEEE, VM1-IEEE, and VD4-CS.

SACE® Emax 2

The SACE™ Emax 2 circuit breaker embeds several functionalities to become the all-in-one solution able to manage the low-voltage distribution systems. Its range helps ensure extreme performance with ratings up to 6,000 A, breaking capacity and short-time current up to 100 kA.

Low voltage circuit breakers (SACE® Emax 2 MS/DC-E)

The SACE® Emax 2 MS/DC-E is a cutting-edge air switch-disconnector designed explicitly for 1,500 VDC applications, offering tailored solutions for various customer needs.

For installations compliant with UL standards, the UL range addresses 1,500 VDC systems, adhering to both UL489B for Photovoltaic systems and UL489F for Battery Power Supplies. It features a rated short-time current (Icw) of up to 100 kA, ensuring robust performance under high current conditions. The Emax 2 MS/DC-E offers a rated current of up to 2,500 A for UL489B and UL489F and extends to 3,200 A for applications under UL489B.

SACE® Tmax® XT molded case circuit breakers (MCCBs)

The SACE® Tmax® XT molded case circuit breaker (MCCB) range helps ensure performance and protection features up to 1,200 A. Tmax XT MCCBs are designed to maximize ease of use, integration, and connectivity and are built to deliver safety, reliability, and quality. For Tmax XT MCCBs, everything you need is self-contained within the breaker, requiring no external relays or other devices to purchase, install, or wire.

Ekip power controller

Ekip power controller is an advanced real-time control system primarily designed to regulate the average power consumption within each predefined time interval to a specified maximum value, often aligned with the contractual power agreement. The Ekip Power Controller function plays a pivotal role in peak shaving by efficiently managing various loads and generators. This system strikes an optimal balance between reliability, simplicity, and cost-effectiveness.

The power controller function, an optional feature in the Ekip electronic trip unit, helps eliminate the need for complex control systems and the implementation of dedicated software programs. The Ekip power controller can be used with the Emax 2 and Tmax XT breakers.

Transfer switches

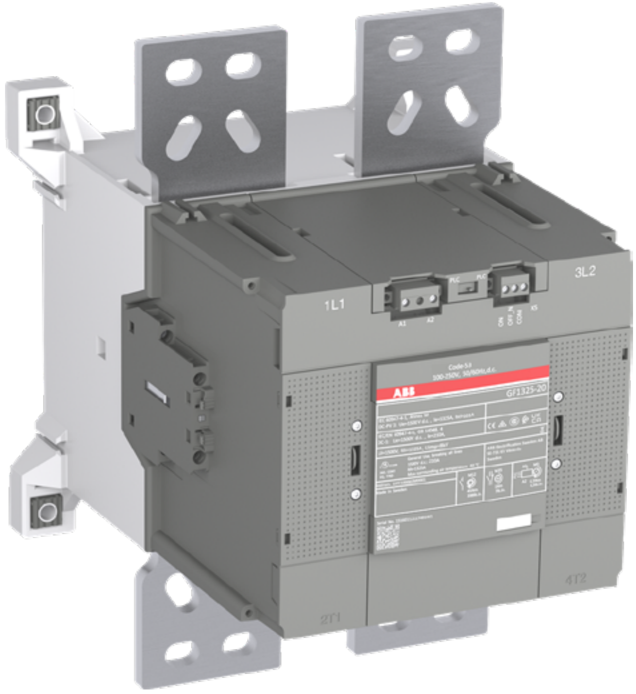
Transfer switches are essential for the smooth and swift transition of electricity between various sources, such as the grid or a BESS. These switches facilitate the effortless selection of a power source and are key in safeguarding against power quality issues during the transition process. Their seamless operation is vital in maintaining the reliability of the BESS.

ABB's latest innovation in this domain is the TruONE, and it can only be used on the A.C. side of a BESS. The TruONE offers versatility for various applications from 200 A to 1,600 A. TruONE, when equipped with a level 4 controller, enables it to measure currents, voltages, active, reactive, and apparent power, and energy. These capabilities make the TruONE an advanced and comprehensive solution for automatic transfer switching needs.

Contactors

Contactors serve as safeguarding mechanisms against overcurrent, overvoltage, or short-circuit incidents within the BESS. Additionally, they can be programmed to function under specific time schedules, aligning with periods of peak and off-peak energy demand. This programming allows for the modulation of power supply to specific equipment during peak hours, either by switching it off or reducing its power, and then resuming normal operations in off-peak hours.

ABB's AF contactors can be used for 25 to 2,850 A, up to 600 VAC and wide range of control voltage options covering 24 V to 500 V 50/60 Hz and 20 V to 500 VDC. It is offered in the screw, push-in spring, and ring tongue connection types. It also has a built-in surge suppression and has easy-to-use accessories through snap-to-connect function.



Contactors for DC switching

Contactors are important in maintaining safety in high-voltage or high-current circuits within BESS. They are used for connecting or disconnecting different battery modules or strings to optimize the performance and lifespan of the battery. ABB's GF, GAF, and GA contactors are specifically designed for switching D.C. circuits up to 1,500 V.

This product range is one of the most compact on the market for energy storage system applications because of the efficient breaking of D.C. circuits. ABB's standard AF contactor range (discussed above) can also be used for switching DC from 850 VDC and below.

Conclusion

Peak shaving is critical in supporting more sustainable electrification while managing costs. BESS is one of the most effective ways to achieve a sustainable future.

The decision to adopt peak shaving as a strategy should be carefully assessed by consumers on a case-by-case basis. Peak shaving is particularly relevant in regions where Time-of-Use (TOU) rates are implemented by electric utilities and where demand charges are substantial. To determine whether peak shaving is the most suitable option, consumers can follow these best practices:

1. Evaluate the load profile.
2. Define the objectives.
3. Pick the most appropriate storage technology.
4. Consult with the appropriate team.

ABB's technologies can help accomplish sustainable electrification when combined with BESS. By leveraging these technologies, consumers can achieve significant cost savings, reduce their environmental impact, and contribute to the overall stability and sustainability of their energy systems and the power grid.

References

(1) “Electricity explained - Use of electricity”. U.S. EIA, Dec 2023. https://www.eia.gov/energyexplained/electricity/use-of-electricity.php

(2) “Electricity Data Browser”. U.S. EIA, Dec 2023. https://www.eia.gov/electricity/data/browser/#/topic/0?agg=2,0,1&fuel=vvg&geo=g&sec=g&linechart=ELEC.GEN.ALL-US-99.M~ELEC.GEN.COW-US-99.M~ELEC.GEN.NG-US-99.M~ELEC.GEN.NUC-US-99.M~ELEC.GEN.HYC-US-99.M&columnchart=ELEC.GEN.ALL-US-99.M~ELEC.GEN.COW-US-99.M~ELEC.GEN.NG-US-99.M~ELEC.GEN.NUC-US-99.M~ELEC.GEN.HYC-US-99.M&map=ELEC.GEN.ALL-US-99.M&freq=M&start=200101&end=202309&ctype=linechart&ltype=pin&rtype=s&pin=&rse=0&maptype=0

(3) “Renewables 2022 - Analysis and forecast to 2027”. IEA, Jan 2023. https://iea.blob.core.windows.net/assets/ada7af90-e280-46c4-a577-df2e4fb44254/Renewables2022.pdf

(4) K. Ananda-Rao, R. Ali, and S. Taniselass, “Battery energy storage system assessment in a designed battery controller for load leveling and peak shaving applications,” “Journal of Re-newable and Sustainable Energy, vol. 9, no. 4, p. 044107, Jul. 2017, doi: https://doi.org/10.1063/1.4991455

(5) G. Karmiris and T. Tengnér, “Peak shaving control method for energy storage.” Available: https://www.sandia.gov/ess-ssl/EESAT/2013_papers/Peak_Shaving_Control_Method_for_Energy_Storage.pdf

(6) J. McLaren, P. Gagnon, and S. Mullendore, “Identifying Potential Markets for Behind-the-Meter Battery Energy Storage: A Survey of U.S. Demand Charges.” 2017, Available: https://www.nrel.gov/docs/fy17osti/68963.pdf

(7) A. V. Rocha, T. A. C. Maia, and B. J. C. Filho, “Improving the Battery Energy Storage System Performance in Peak Load Shaving Applications,” Energies, vol. 16, no. 1, p. 382, Dec. 2022, doi: https:/doi.org/10.3390/en16010382.

(8) R. Martins, H. Hesse, J. Jungbauer, T. Vorbuchner, and P. Musilek, “Optimal Component Siz-ing for Peak Shaving in Battery Energy Storage System for Industrial Applications,” Ener-gies, vol. 11, no. 8, p. 2048, Aug. 2018, doi: https://doi.org/10.3390/en11082048.

(9) T. H. Mehr, M. A. S. Masoum and N. Jabalameli, “Grid-connected Lithium-ion battery energy storage system for load leveling and peak shaving,” 2013 Australasian Universities Power Engineering Conference (AUPEC), Hobart, TAS, Australia, 2013, pp. 1-6, doi: 10.1109/AUPEC.2013.6725376.

(10) “What is a demand ratchet?” Pacific Northwest National Laboratory, https://feds.pnnl.gov/faq/what-demand-ratchet (accessed Dec. 23, 2023).

—
CONTACT US
Do you have a similar project and are you searching for the right Application configuration?
Contact us and talk to our experts!

—
U.S HQ Office:
ABB
305 Gregson Drive
Cary, NC 27511
United States
Phone: (800) 435-7365

electrification.us.abb.com

9AKK108469A4315