Demand response

White paper

SIEMENS

1. Intelligent, integrated energy systems for smart cities

In 2007, the number of people living in conurbations around the world surpassed that of those living in rural areas. Today, large cities worldwide account for 75 percent of energy demand, and generate a large percentage of total carbon dioxide emissions. For this reason, a number of cities and metropolitan areas have set themselves ambitious goals towards reducing emissions by increasing the efficiency of their infrastructures. These goals aim to have a positive impact on the environment, while continuing to enhance the quality of life of growing urban populations.

The transition to a new "electrical era" in which electricity is becoming the preferred energy source for most everyday applications is currently taking place. This is governed by three key factors: demographic change, scarcity of resources, and climate change. In the meantime, two development trends are of particular interest:

- the demand for electricity is continuing to grow
- the energy system is subject to dramatic changes

The latter is caused by increased electricity production and fluctuating power supply sources:

- in a concentrated form such as with wind farms on the edge of the grid
- in a distributed form such as with photovoltaic cells on roofs

Until recently, load dictated production, a method which influenced how interconnected power systems were designed. Power generation was centralized, controllable, and above all, reliable. The load was statistically predictable, and energy flow was unidirectional, that is from producer to consumer.

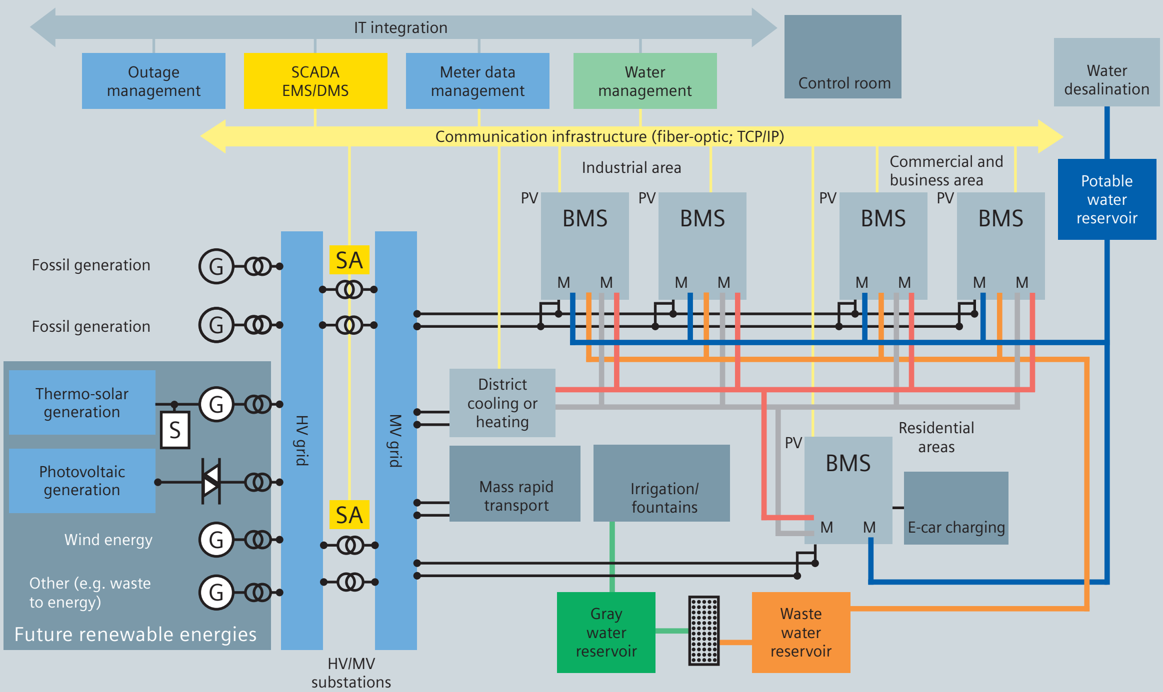
These aspects of power generation are changing. Firstly, the rising percentage of fluctuating production within the energy mix brought about by renewables reduces the level of power generation control available. Secondly, the energy flow is no longer unidirectionally sent from producer to consumer; now the consumer is slowly turning into a "prosumer," a term which denotes a person who produces and consumes energy. More and more consumers are installing their own renewable energy products to increase energy efficiency. These prosumers are cogenerating heat and power with their own solar panels or microCHPs, for example. This trend is set to continue, as government bodies continue to provide incentives to domestic users to become "prosumers" as part of their increased energy efficiency policies.

Ultimately, the way of the future will have to be that load follows energy availability.

1.1 Smart cities – optimum coexistence of multiple networks

Power grids with centralized and distributed production, as well as bidirectional energy flows, are dependent on large-scale information and communications technology if they are to supply power reliably. This applies all the more to smart urban energy management for smart cities, which involves both the provision of electric power and the integration and coordination of all other grids, such as water, wastewater, communications, and mobility. Of course, all these utilities also require electric power. On the other hand, non-electrical grids and systems often provide energy storage capacities that can be used for comprehensive energy management. Currently, these grids are being operated and optimized independently of each other. However, a number of cities are already employing combined management systems for numerous grids and only some of these management systems are capable of multi-utility optimization.

The significance of cities in energy strategy debates as a whole is justified, given that buildings consume around 40 percent of total energy worldwide and are responsible for 21 percent of greenhouse gas emissions. Opportunities for improving efficiency by using new heating and air-conditioning systems, innovative lighting, and modern automation technology are equally significant. Exploiting these opportunities requires integrating buildings actively into the grid as flexible consumers, as energy producing facilities (by using geothermal energy, heat pumps, or solar panels on the roof), and as energy storage facilities.



HV – high voltage; MV – medium voltage; M – meter devices; SA – station automation; BMS – building management system; EMS – energy management system; DMS – distribution management system

Figure 1: Overall energy grid layout for smart urban energy management

In the smart city of the future, all grids will be monitored and controlled by one integrated system, minimizing overall energy requirements and incorporating renewables efficiently. For example, whenever surplus solar power is available, storage devices for heating and cooling systems will be recharged. In turn, as soon as clouds gather in the sky, the energy consumption of the storage devices will be throttled. The outcome will be a reduction in both solar irradiation and cooling demands. Similarly, surplus energy generated by renewables will also be used for driving pumps to fill water reservoirs. In addition, e-cars of the future will have their battery storage capacity integrated into the power grid. This will allow surplus wind energy to be transmitted to the batteries when the load on the grid is low. In turn, the car batteries will be used to stabilize the grid by feeding it during peak load periods – a concept that offers enormous potential.

1.2 Smart cities – a complete overview of all management systems

The Energy Management System (EMS) plays a crucial role in the smart energy management of cities. EMS monitors the availability of "green" energy in real-time and synchronizes its monitoring data with other management systems, such as those used for the drinking water supply, district heating, district cooling, and building systems. The objective at all times is to make the most efficient use possible of renewables. EMS predicts power generation from renewables and anticipates consumption by various loads connected to the grid. It also produces optimum electricity purchase plans for large-scale power consumers. These schedules are then communicated to, and synchronized with, all other management systems.

EMS is also capable of preventing overloads by evaluating present power transmission and distribution potential, taking all-important scheduled shutdowns for maintenance and repairs into account in the process. EMS also monitors the balance within the power grid in real-time and sends correction signals to subordinate management levels as necessary. If the power being generated by renewables is less than expected due to unforeseen weather conditions, EMS can throttle the amount of electricity being fed to large consumers or draw power from energy storage devices in order to meet the current demand. If, on the other hand, too much energy suddenly becomes available, EMS recharges the available energy storage devices to prepare the grid for the next peak period.

The "smart meter" introduces communication over the "last mile" from an energy management viewpoint. It integrates "home automation" and similar approaches. Regulatory considerations need to be taken into account since the "smart meter" operator and the energy supplier can be independent of one another. Information is gathered from these meters by a collecting infrastructure. A back-end system then manages and processes the data so that it can be used by the EMS for making predictions about future demand to improve the quality of the power supply. If smart meters are connected to intelligent domestic appliances within a "smart home" environment, these can be operated with maximum efficiency and in tandem with the current energy availability. This is ultimately a win-win situation for both consumer and supplier: attractive new tariff models developed for the end consumer offer low-load prices which at the same time help the grid operator level out consumption patterns. Furthermore, business models such as "performance contracting" for the provision of space heating using heat pumps or cogenerated heat and power are also conceivable.

1.3 Smart cities – buildings virtually grouped together

Just like virtual power plants, building and residential units can also be "grouped" together to allow a central control system to plan and control energy consumption. This ensures that energy needs are met and also that reserve energy can be made available to a higher-level grid control system. Any existing distributed power producer (renewables) can also be integrated into this kind of control system. As in the case of a virtual power plant that groups only power generating units together, both a planning phase and a near-real-time control system are also required for operating clusters of buildings, irrespective of whether there are only energy consuming units in these buildings or energy generating units are also installed. During the planning phase, the energy required for the next day is predicted and procured on the energy market as cheaply as possible while taking sustainability into account. Of course, purchasing is already optimized by the flexibility of the system. The remaining flexibility, or energy storage options, can then be used to define a power capacity band that can be made available as reserve energy to the higher-level grid operator. It goes without saying that if auto-generation is also part of the portfolio, in the form of cogeneration plants or emergency diesel generators, it must also be included in the planning and optimization process.

The huge increase in wind power, which is now also taking place offshore, is the most significant change occurring within the energy mix and poses new challenges to grid operation. Firstly, the production of electricity from wind does not follow actual demand. Secondly, its supply into the grid is regulated by laws and regulations such as the Renewable Energy Sources Act. As a result, often the only option available in the event of a surplus of wind power is to throttle back conventional power plants or shut them down entirely. The flexibility in energy procurement for buildings offers a way to get around this problem by enabling transmission network operators to resort to using primary control capacity to compensate for fluctuations in wind energy. Ultimately, Smart Grids can couple smart cities and wind farms in order to compensate for the latter's fluctuating infeed as efficiently as possible.

Electric cars with grid connections will also need to be included in these planning and optimization efforts in the future. Initially, these cars will comprise nothing more than controllable loads (when they are plugged into the grid to be "filled up," probably overnight in most cases). However, visions for the future also see the electric car's battery serving as a mobile energy storage device, which can be made available to the grid both as a controllable load and as a source of electric power at times when the car is not being used.

1.4 Smart cities – everything hinges on communication

A secure, reliable, and economical power supply depends to a large degree on a fast and dependable communications infrastructure. The planning and commissioning of infrastructure communications networks requires the same care and diligence as the construction of the power supply grids themselves. In a "smart network," this entails integrating all system components of all elements into the power supply process efficiently, according to an overall concept. For this reason, it is essential that the challenges associated with syntactic and semantic interoperability be mastered. From a communications viewpoint, every system can be a provider or a user of information, usually both at the same time. Furthermore, most systems are made up of several subsystems featuring their own special internal communications.

Full interoperability requires communication structures that are consistently based on TCP/IP standards. The new challenges facing tomorrow's power supply grids are:

- migration of the previously passive consumers to active "prosumers," possibly with distributed autogeneration
- increasing the percentage of renewables in our energy mix
- wide-scale integration of electric cars as electricity storage devices

Communication between subsystems will comprise two main applications:

- real-time communication for monitoring and controlling the energy system
- the data exchange between systems involved in planning, management, trading, and billing processes

2. Demand response – the technical concept behind it

Demand response refers to all functions and processes applied to influence the behavior of energy consumption. This can range from simple signaling, e-mail, SMS, or a phone call to a person who switches a load on or off, to fully integrated load management, where many consumption devices are dynamically controlled according to availability or to the price of energy.

Since the demand for electrical energy in many cases is closely connected to the demand for alternative forms of energy, heating and cooling energy, or mechanical energy, demand response solutions must reach far beyond the electrical grid itself. In particular, optimization must include all energy forms which are interconnected.

Figure 2 shows an overview of the demand response landscape. Key demand response data is located in a control center. Here, information required for balancing energy will be collected by the appropriate communication infrastructure. The control center retrieves all information about the availability and cost of energy. It may also supervise the energy supply grid and monitor energy consumption. This makes the control center the ideal platform for hosting all applications which support energy balancing. This includes forecasting, supply optimization, market interfaces, real-time monitoring and control, and archiving.

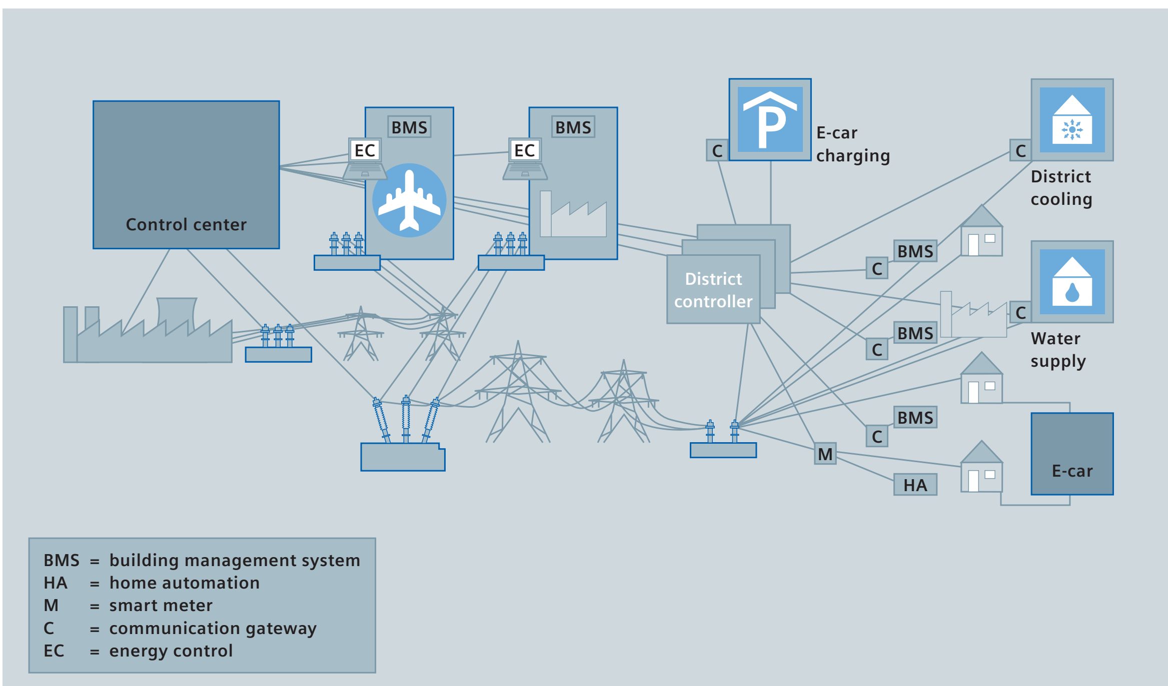


Figure 2: Application overview for demand response

The real-time monitoring and control application uses the energy automation communication infrastructure[1] to collect dynamic status information about the grid and about the energy flow. Due to the vast dimension of the distribution grid, not all information can be collected by the control center, since this would overload its data model. Even if future computer generations were able to handle such data models, the maintenance of these models would become extremely complex and labor-intensive. Therefore, distributed data aggregation is needed to reduce the amount of data to be processed by the control center. A typical location for such data aggregations are in building automation systems, smart meters, meter data systems, and substation or feeder automation systems. Large consumers, like big factories, refineries, or airports, may even have their own control centers equipped with their own demand response applications.

[1] Here the communication between control center and substation is meant, not the meter data communication infrastructure.

Along with distributed data aggregation, decentralized control is also required, since a central control application will not be able to manage each individual load connected to the grid. Decentralized control also becomes necessary when flexible energy tariffs are used to influence energy demand; in other words, it is necessary when energy prices are high during peak load periods and when prices are lower during non-peak load periods. In this case, the consumers can decide individually whether they want to save energy costs by reducing energy consumption during peak-load periods, which may have a negative impact on their convenience. This decision might also be made using decentralized automation and optimization systems.

Another aspect for decentralized intelligence is partial load shedding to relieve an overloaded feeder from a non-vital load. Since non-electrical supply grids also require electrical energy for water pumps, chillers, etc., the control of these grids needs to be integrated with the demand response applications of the electrical grids. Dependent on the quantity of energy consumed, these devices might be controlled by a central load management or by decentralized applications.

The energy required to charge e-cars also has to be considered in overall demand response. Since this energy demand places a new burden on the distribution grid, it must be coordinated to avoid a peak-load increase. Furthermore, the huge energy consumption spikes created by the public's quick-charging of e-cars might even make it necessary to have a decentralized energy buffer, which would require demand response management.

2.1 Communication infrastructure for demand response

Since many components must be integrated to interface within a demand response solution, a suitable communication infrastructure is of paramount importance.

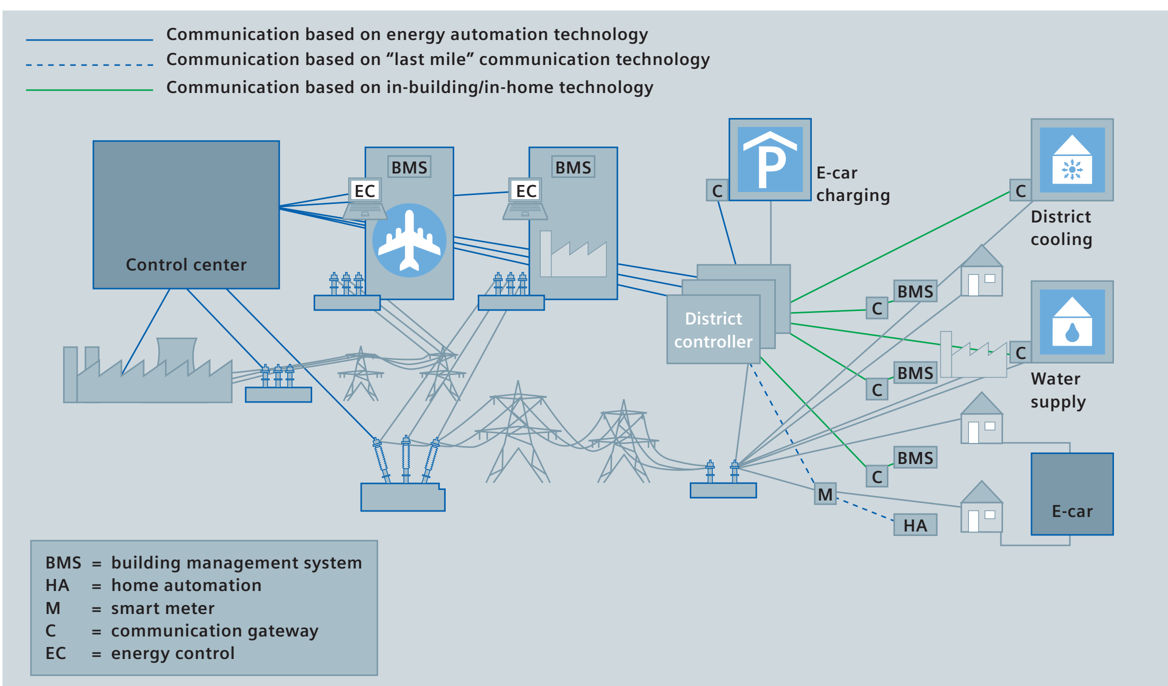


Figure 3: Demand response communication infrastructure

Figure 3 shows the typical communication paths in a demand response solution, together with the implementation technology. At the current state of technological developments, the technology for the communication path can be split into three categories:

1. Energy automation related communication

This part of the communication path is typically implemented by communication technology similar to the technology used between the control center and substation(s).

2. "Last mile" communication technology

This covers mainly the last mile communication between the consumers premises and a data concentrator, which is typically connected to a category 1 communication infrastructure. Power line carriers, meshed radio, TV white space and broadband (Internet) are typically used.

3. In-home/in-building communication technology

This system communicates between various building technology devices. This can be either wired communication (BACnet, KNX, etc.) or wireless communication (KNX RF, ZigBee, etc.).

As shown in Figure 3, the so called "district controller" becomes the gateway between the energy automation and the building automation infrastructure. In residential areas, smart metering infrastructure might also be used for demand response. The detailed internal logic of the district controller is described later in this document. Despite the international standardization body's (IEC) initiative to define communication standards for demand response, there is a vast array of communication protocols installed on both sides of this gateway. Since there is only one northbound communication towards the central demand response component in the control center, it can be assumed that the support of a few standard protocols like OPC-UA, IEC 60870 or IEC 61850 will suffice in the short term. In the long term, however, only IEC 61850 should be used for the communication between the control center and district controller. For demand response solutions installed by the distribution grid operator, it can be expected that district controllers will be installed in substations, which means that they can share the communication link with the substation automation system. This can only be done as long as there is enough spare communication bandwidth available. In cases where the demand response operator and the distribution grid operator differ, other communication paths like ADSL or GPRS must be supported, and the district controller logic could be implemented somewhere else, as in the building itself, or in the server room of the demand response operator.

On the southbound side, the district controller has to communicate with multiple systems. This means a larger variety of legacy building automation protocols can be expected. In the long term, communication should be based on BACnet, KNX, or IEC 61850 protocol standards.

For residential homes, the communication infrastructure for demand response requires some additional aspects to be considered. An existing smart metering infrastructure could also be used for the demand response communication, assuming both the right interfaces and sufficient available bandwidth are available. However, in regions with liberalized energy markets, regulations which deny communication infrastructure sharing may prohibit this. In multi-family homes, the electricity meter might also be installed in the utility room basement, but the home automation system and the water and heating meters must be installed within the individual residential units, and the e-car should be parked in the parking deck. All this requires adequate communication links within the building.

2.2 Energy loads or sources which may be influenced by demand response

There is a variety of equipment connected to the grid, which may be included in a demand response solution. Such devices can act as an energy source or load. Some devices can act as both an energy source and a load alternately, depending on the operation mode selected. In response to load peaks or shortages, selected generation sources can be switched on, loads switched off, and storages discharged. In addition, loads with buffer or storage capacity can be switched on to make use of preferred energy generation when available.

As shown in the table below, some device types provide storage or buffer capability for energy. A storage device can give back the energy in the same type as it was filled. An example of this is a battery. A buffer device, however, can store energy only in a converted form, in the way that a boiler stores energy by heating up water; it is only capable of load-shifting. Devices capable of storage, however, can be utilized fully for energy balancing within the electrical grid.

Table: Demand response communication infrastructure

Device type	Influenceable		Storage/ buffer	Comment
	Generation	Consumption		
Wind turbine	■			Only reduction of actual generation
Photovoltaic generation	■			Only reduction of actual generation
Backup generators	■			
Solar water radiators		■	B	Additional electrical heating in boiler required
Combined heat and power	■	■	B	Additional electrical heating in boiler required
Heat pump with boiler		■	B	
Electric radiators		■		
Central air-conditioning		■	B	
Decentral air-conditioning		■		
Drives for ventilation		■		
Drives for water pumps		■	B	Requires water tanks on top of buildings
Other drives		■		Elevators, escalators, etc.
Household appliances		■		Washing machines, tumble dryers, dishwashers, etc.
Industrial processes		■	S/B	Storage/buffer capability depends on process type
Batteries and supercaps	■	■	S	
E-cars (home charging)	■	■	S/B	Feedback is currently only future option
E-cars (public charging)		■		

While using the device types for demand response listed above, operation restriction must be taken into consideration as well. There is a maximum time for switching off the ventilation or the temperature range for the boiler. Since all these operational limits cannot be fully modeled by centralized demand response control, a demand control solution can only work as a distributed application. The central component plans and monitors the overall energy balance in the grid. Depending on the energy balance at any given time, this component sends out a request to the distributed demand response components (a district controller) to increase or decrease the energy consumption. For better control performance, this request might vary its severity.

The distributed demand response components maintain a list of influenceable devices (loads or sources). Depending on this list, they forward the demand response request to the controller of the device. The device controller checks whether it can respond to the request: if the current operational situation does not allow a response, as in when the water tank is empty and the pump to fill it up must run, the distributed demand response components use the next device on its list to fulfill the request from the central component.

This means that a demand response control loop has no reliable responsiveness; therefore, the controller behavior must avoid a swing-up of the system. Demand response alone is not suitable to make small parts of a distribution grid independent from the overlying transmission grid. To achieve such independence, also called micro-grid capability, a certain part of the generation or load must be directly controllable with a very high degree of responsiveness, like batteries or supercaps interconnected using power electronics.

2.3 Central demand control application

Planning

Planning the central demand control application involves calculating the availability of preferred energy (solar, wind, etc.) for a future period. This is achieved by importing forecast schedules for energy production and for energy demand. A planning schedule for energy transactions (buy or sell) may also be imported. Based on this input, a schedule is derived that specifies the periods of availability or shortage of the preferred energy type. This schedule is distributed to the connected district controller. If there is more than one district controller, each district controller is allocated a fraction of the available preferred energy to its schedule. The value of the fraction depends on the amount of controllable energy connected to the district controller. The total overall schedule is the sum of all distributed schedules. Figure 4 shows a block diagram of the demand response planning application.

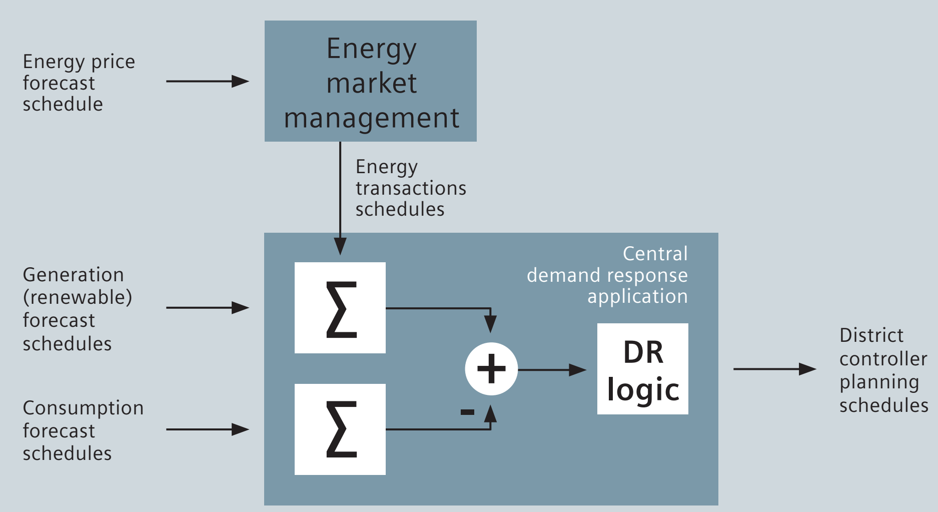


Figure 4: Block diagram for planning the central demand response application

Real-time part

The real-time[2] part of the central demand control application is responsible for overall energy balancing as well as for detecting and mitigating local grid problems such as overloads. This requires the central demand control application to be interfaced with SCADA (system control and data acquisition) and DNA (distribution network application). If the control system is also responsible for generation control, the central demand control application needs to be interfaced with AGC (automatic generation control). If demand response is also to be used to reduce energy purchasing costs by reducing peak load, the central demand control application is to be interfaced with EMM (energy market management) applications. Figure 5 shows the block diagram for the central demand response application and its interfaces to other applications.

[2] Real-time in this context does not mean full real-time capability, it is more a "fast enough" application.

Based on the measured values retrieved from SCADA, the central demand control application has to sum up the overall consumption and compare it with the available generation potential. Based on the deviation, the application instructs the distributed demand control application to increase or decrease the energy consumption accordingly. Since slow response performance is characteristic of the demand response infrastructure, the central demand control application requires some kind of trend determination for the consumption, and, where possible, also for generation. Since renewable generation is difficult to predict and is very specific, the central demand control application uses an additional interface to make external short-term generation forecasts.

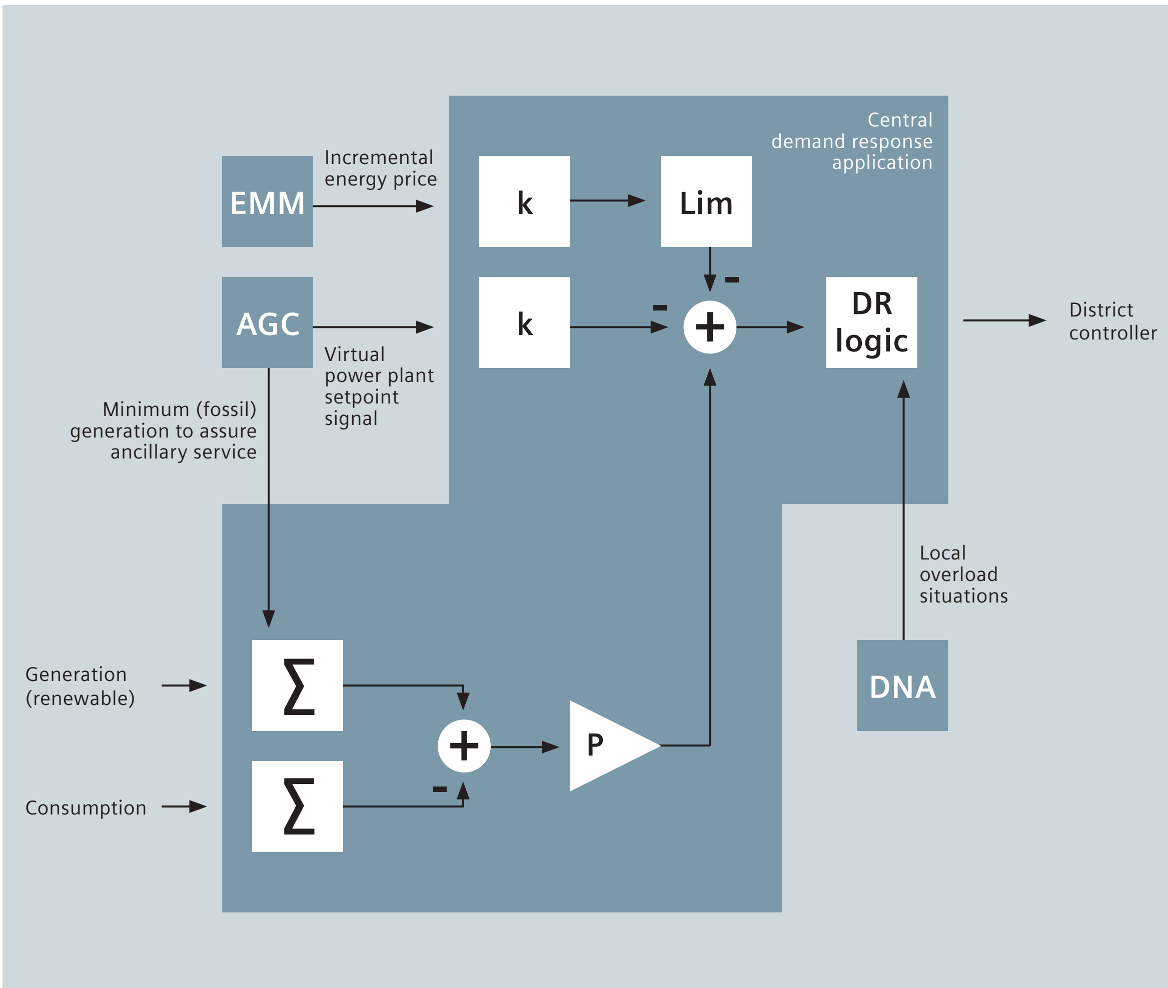


Figure 5: Block diagram for the real-time part of the central demand response application

Based on the difference between generation and consumption, the central demand control application determines the severity of the discrepancy and sends out corresponding consumption increase or decrease commands to the control-distributed demand response applications.

In configurations where the demand response works together with generation control, the AGC application determines the discrepancy between generation and consumption, the so-called area control error. This means demand response can be controlled by AGC similarly to a virtual power plant, but the set-point needs to be inverted. An AGC request for higher generation means that consumption must be lowered and vice versa. If there is a mixture of renewable and fossil generation, then demand response could feature a sub-task to optimize the utilization of renewable energy and minimize the utilization of fossil energy. In this case the demand response application will monitor the discrepancy between renewable generation and the overall consumption and try to adapt the consumption according to the availability of renewable energy. AGC functions on minimum dispatchable (typical fossil) generation. This generation is called ancillary services. The demand for ancillary services must be added to the available renewable energy, to prevent the demand response from lowering consumption too much.

To keep up with fluctuations within the energy market, the demand response application must be capable of processing information on the incremental energy price, based on EMM. When energy prices are high, the demand response application should aim to reduce costly consumption and save money for energy purchasing. This mechanism should only respond if the incremental energy prices exceed a certain level. However, contractual obligations may limit potential counter-measures made by the demand response to high purchasing prices. For this reason it must be possible to define an upper limit for the value of this price correction signal.

In the event of both AGC and EMM being present in a single system, AGC carries out the economic optimizations using its economic dispatch component. In this case AGC needs suitable energy cost parameters that represent the controllable load for the virtual power plant.

If the distribution network application detects a local overload in the grid, it notifies the demand control application, specifying the degree (kW) of overload and the loads that are creating the bottleneck. The centralized demand control application determines the corresponding distributed control applications and sends a decrease consumption command. For a certain period, it ignores further overload messages for the same location in order to allow the demand response infrastructure sufficient time to react. If there is still an overload message for this location after the "dead time," the centralized demand control application sends out a second decrease consumption command with higher severity to the corresponding distributed control applications. This will be repeated until no more overload messages are received for this location, or until the highest severity level available has been reached.

2.4 Demand response logic

The demand response logic component in Figure 5 converts and distributes the global demand response request into individual demand response requests for each connected district controller. Distribution of the global demand response request must also take local constraints, like bottlenecks in the distribution grid, into account.

Some kind of "handshaking" between the demand response logic in the central application and the connected district controllers is needed. To ensure that energy management provides sufficient response performance on the one hand, but avoids overshooting and instability on the other, it must also be ensured that the energy distribution is done in a "fair" manner. This means avoiding a situation whereby, in periods of energy shortage, some consumers experience major inconvenience while others are able to consume as normal. Furthermore, contractual restrictions may also have a negative influence on energy management, if load shedding is only allowed for a defined number of times a year, or a defined period of time.

2.5 Distributed demand control application (district controller)

The distributed demand control application, also called the district controller, bridges the central applications with the control systems of the individual properties. If the demand response solution is to cover all consumers in a given area, it should be located at the ring main unit or at the feeder head station to control the demand within the corresponding rings or feeders. In this case the district controller must fulfill environmental requirements pertaining to electrical substations, like voltage withstand[3], temperature range, etc.

If the demand response solution is to cover only selected consumers, for instance when a general merchandise chain wants to implement demand response for its shops, the district controller is usually implemented outside the energy grid infrastructure.

[3] Voltage withstand specifies the resistance of I/O terminals against overvoltage caused by grid failures or lightning.

The internal logic of the district controller has to maintain all dispatchable loads within its assigned control area. For each dispatchable load, the data model of the district controller must know its capabilities for demand response as well as its limitations; in other words, it should know the maximum switch-off time, minimum operation time, minimum time between two switch-off commands, etc.

In the planning phase, the optimization and scheduling component receives an availability forecast on preferred energy from the central demand response application and plans the energy consumption so that

- the preferred energy is utilized as much as possible
- additional demand levels above the preferred energy supply is minimized as much as possible

For real-time operation, the district controller translates the received instructions from the upper level demand response component (typically the control center application, see section 2.3) into suitable selections of loads which are then requested to increase or decrease their consumption. The district controller ensures that demand response requests are distributed in a “fair” manner. This means that over time, all loads contribute equally to the demand response requirements. A load which contributes to a request at a given time will not be requested to fulfill future requests, as long as there are loads available which have not been participating in demand response requests up to that point in time.

Demand response performance monitoring is carried out by the district controller. The communication between district controller and property controller requires some kind of success response in order to do this. If the property controller is unable to react to a request because of its operational restrictions, such as when a ventilator cannot stop due to bad air quality, the property controller must send back a failure signal to allow the district controller to select another load to carry out the request. This kind of handshaking aids the fast detection of undershooting and takes immediate corrective measures. This stabilizes the demand response process and prevents instability.

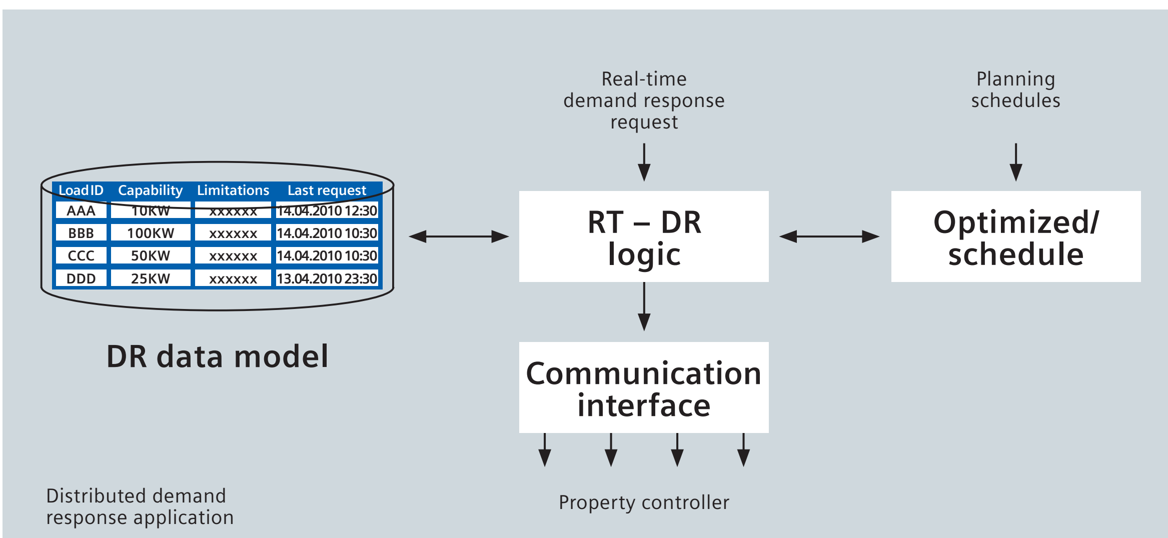


Figure 6: Block diagram for distributed demand response application (district controller)

2.6 Home automation gateway

The energy in residential environments is dominated by heating and cooling as shown in Figure 7. In many countries there is a regulatory push towards more energy efficiency in the residential sector of energy consumption. Technologies like heat pumps or combined heat and power production, together with home automation, make the fulfillment of these regulatory obligations possible. Since thermal systems can provide some demand response capability, the home automation controller should interface with the demand response mechanism. Additionally, some household appliances like washing machines, tumble dryers, dishwashers, electric immersion heaters, electric floor heating, or radiator heaters, could be included into a demand response solution, by allowing remotely controlled starting within a defined time period. In the future, the home charging of e-cars can also be used for demand response in the residential sector.

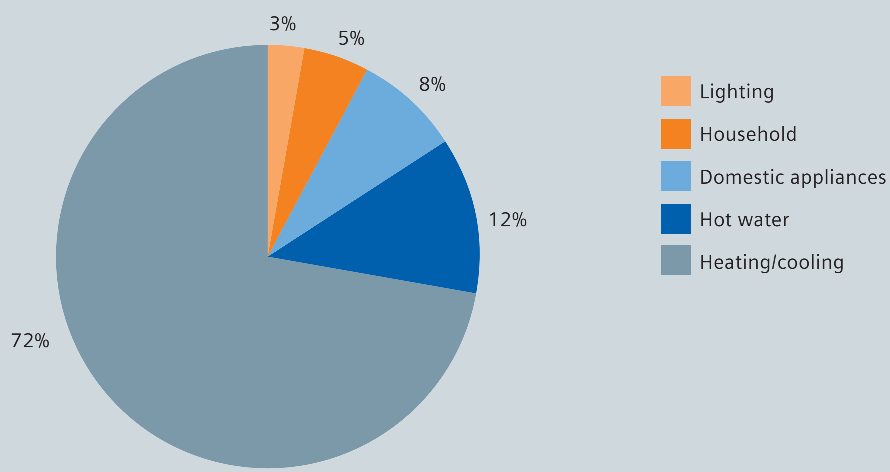


Figure 7: Energy allocation in residential environments

The communication between the home control unit and the next layer of the demand response infrastructure (the district controller) needs to be flexible. It should be based on TCP/IP communication to become independent of the physical layer. This allows using existing ADSL infrastructure, GPRS, or other radio communication, and, where applicable, existing smart metering communications, if the meters' communication gateways have a TCP/IP interface.

3. Conclusion

The implementation of demand response integrates a number of systems on different levels, from the EMS at the top all the way through to control units of energy consuming or producing devices at the bottom. So broad expertise in energy management for electrical distribution grids, for non-electrical grids, and within industrial, commercial, and residential buildings is required if a demand response solution targets an entire energy system rather than just a few dedicated aspects, like remotely switching air conditioners on or off, for example.

It is, therefore, clear that, in the long run, only demand response concepts based on an integrated approach will be capable of creating truly smart energy systems that can master the challenges of the future.