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# WD 18012-3

## Information technology –
## Home Electronic System (HES)

Guidelines for product interoperability –
Part 3: Application models

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# FOREWORD

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# INTRODUCTION

This part of ISO/IEC 18012 was prepared by Joint Technical Committee ISO/IEC JTC 1, Information technology, Subcommittee SC 25, Interconnection of Information Technology Equipment.

ISO/IEC 18012 consists of the following parts, under the general title Information technology — Interconnection of information technology equipment — Home Electronic System — Guidelines for product interoperability:

- Part 1: Introduction
- Part 2: Taxonomy and Lexicon
- Part 3: Application models

The following applications models are included in Part 3:

- Model of an energy management system for HES
- Lighting model for HES
- Model a security system for HES

# ISO/IEC 18012-3: Information technology — Interconnection of information technology equipment — Home Electronic System — Guidelines for product interoperability — Part 3: Application models

## 1 Scope

The model presented here for energy management is intended to be generic and representative of a wide range of situations. Utilities have developed many methods for managing the electricity supply network, called the “electricity grid,” and for helping consumers manage energy usage inside their premises. The goal is to match the customer demand for power with the available supply. Also, homebuilders, suppliers, manufacturers, and consumers have shown a growing interest in premises energy efficiency. This model focuses primarily on a method known as demand response (DR), although other methods are also addressed. The need for such methods results from:

- Electric supply limitations
- Public resistance to building large generating plants
- Public concern for environmental pollution, including greenhouse gases
- Public opposition to siting of new transmission lines
- An anticipated demand for and availability of electricity for charging electric vehicles
- Public interest and support for renewable sources of energy
- The introduction of distributed energy resources (DER) with local generators such as wind turbines and solar photo-voltaic (PV) panels
- The variable and unpredictable nature of wind and solar distributed generation with output that may fluctuate with time and weather
- The development of batteries and other advanced premises storage technologies plus power conditioning and management equipment
- The introduction of alternative electricity pricing methods or tariffs that encourage efficiency

Because demand response systems extend beyond the meter into customer premises, those impacted by demand response technology choices include utilities, third-party suppliers of demand response services, home network developers, and appliance manufacturers. An example of a third-party provider of demand response services is an aggregator serving a large building or neighbourhood.

Three types of demand response are specified in this standard: direct control (Section 6.2), local control (Section 6.3.2), and distributed control (Section 6.3.3). The choice of demand response method will vary by utility to achieve the load shape that aligns with supply limitations, transmission and distribution capabilities, regulatory constraints, and business considerations. However, distributed control offers consumer the most flexibility in adapting appliance operation to constraints imposed by the utility. The links between a utility communications network and a home area network facilitate effective distributed control, as specified.

As the market develops for energy management products, consumer electronics companies, appliance manufacturers, and other residential suppliers may offer products that combine load management using demand response with energy conservation. Energy conservation may offer consumer methods for reducing energy consumption overall, in addition to reducing consumption at times of peak demand.

Demand response is one element in the concept of the “smart grid.” The smart grid for electricity integrates subsystems for generation, transmission and distribution, and customer services to improve the reliability and efficiency of electricity systems. The smart grid also extends these subsystems to accommodate distributed energy resources and demand response. A goal of the smart grid is to enable all these subsystems to interoperate using information technology. Therefore, this standard is an important contribution to the smart grid.

## 2 Normative references

ISO/IEC 14543-2: Information technology – Home Electronic System (HES) Architecture

ISO/IEC 15045-1, Information technology — Home Electronic System (HES) — Gateway — Part 1: Introduction

ISO/IEC 18012-1, Information technology — Home Electronic System (HES) — Guidelines for product interoperability — Part 1: Introduction

ISO/IEC 18012-2, Information technology — Home Electronic System (HES) — Guidelines for product interoperability — Part 2: Taxonomy and Lexicon

ISO/IEC 24752-1, Information technology — User interfaces — Universal remote console — Part 1: Framework

## 3 Terms, definitions and abbreviations

### 3.1 Terms and definitions

For the purposes of this International Standard, the following terms and definitions apply.

**3.1.1**
**demand charge**
a charge for electricity based on the total power consumed during a specified interval of time

**3.1.2**
**demand response**
a method for matching the demand for energy to the available supply of energy

**3.1.3**
**direct load control**
a method of demand response via remote control of one or more appliances

**3.1.4**
**disaggregated bill**
a utility bill that shows energy consumption by major appliances

**3.1.5**
**distributed load control**
a method of demand response based on dynamic price data or event notices sent from the utility to smart appliances or to an energy management controller

**3.1.6**
**energy management controller**
a set of functions that manage energy consumption as an agent for the customer

**3.1.7**
**HAN device**
a device located in the home that can be connected to a home are network (HAN)

**3.1.8**
**local load control**
a method of demand response via publication of time-of-use electric rates

**3.1.9**
**residential gateway**
a communications function that interconnects two or more networks using different communications protocols, with at least one network outside the house and one or more networks inside the house

**3.1.10**
**smart appliance**
a home appliance that exchanges command and control data with other devices on a home area network

**3.1.11**
**utility gateway**
a residential gateway facilitating direct or distributed load control

**3.1.12**
**value-added services**
optional services offered by a utility that may or may not be related to energy and may generate additional revenue

**3.1.13**
**white goods**
large kitchen appliances

NOTE: This term is used in the appliance industry for large kitchen appliances such as a refrigerator, range, oven, and dish washer.

### 3.2 Abbreviations

The following acronyms and abbreviations are used in this standard and commonly used in other industry publications.

| | |
|---|---|
| CFL | Compact Fluorescent Lamp |
| DER | Distributed Energy Resources |
| DR | Demand Response |
| DSM | Demand-Side Management |
| EPRI | Electric Power Research Institute (Palo Alto, California, U.S.A.) |
| HAN | Home Area Network |
| PV | Photo-Voltaic |
| RTP | Real-Time Pricing |
| TOU | Time-of-Use |

## 4 Conformance

This standard specifies methods for demand response that may be implemented by an electric utility or by a third-party supplier of energy management services. For compliance with this standard one or more of the demand response profiles in Section 6 must be implemented.

For those utilities choosing distributed load control for demand response, Section 7 is required.

Utilities may offer value-added services in conjunction with demand response, as listed in Section 8, which is optional.

Section 9 defines the taxonomy and lexicon corresponding to the options for demand response according to the HES energy management model. These include a combination of control signals, pricing data, and event notices. An implementation of a demand response use case shall conform to the taxonomy and lexicon specified in this section for that use case.

NOTE: In some countries approvals from government regulators are required for the implementation of demand response.

## 5 Energy management using demand response

One or more demand response (DR) profiles shall be implemented when an electric utility determines that DR would address a mismatch between the supply and demand for power.

Electricity consumption patterns have peaks daily and seasonally. During weather extremes of heat and cold the demand for electricity rises sharply. To meet these occasional peak demands, some utilities need to keep relatively expensive generators running or must build new plants.

Some laws mandate that utilities maintain the supply of electricity sufficient to meet any demand. However, this is becoming less practical because of the cost of new electricity plants, public resistance to new plants, and government rules controlling environmental pollution. The pressure for plants to meet peak demands could be reduced if customers evened out their power consumption so the peaks are flattened.

Utilities have developed specific programs to influence the customer demand for power in order to align with the available supply. Such utility programs are called demand-side management (DSM).

DSM programs and associated tools enable utilities to modify the cumulative demand for energy, known as the load shape when plotted over a one-day interval. Utilities have developed a variety of DSM programs to manipulate the load shape. Different programs have different load shape goals, with the majority intended for peak clipping.

When the goal of DSM is peak clipping is typical target is to reduce peak demands for electricity by about 5% up to 100 hours per year, according to a December 2005 report of the Demand Response and Advanced Metering Coalition (DRAM).

NOTE: Demand Response and Advanced Metering Coalition (DRAM), comments filed in Docket AD06-2, December 19, 2005, 5. Reported in FERC (U.S. Federal Energy Regulatory Commission), Assessment of Demand Response and Advanced Metering Staff Report, Docket AD06-2-000, August 2006.

The Electric Power Research Institute (EPRI) estimated in 2001 that “… a 2.5% reduction in electricity demand state-wide could reduce wholesale spot prices in California by as much as 24%; a 10% reduction in demand might slash wholesale price spikes by half.”

NOTE: Taylor Moore, “Energizing Customer Demand Response in California,” EPRI Journal, Summer 2001, p. 8.

DSM programs initially focused on providing incentives for using electricity more efficiently. Customer co-operation may be obtained by offering a financial incentive, such as an up-front rebate, a loan guarantee, a lower rate for electricity, or free energy efficient planning and evaluation services. Some programs offer rebates for switching from tungsten to compact fluorescent lamps (CFL), for adding building insulation, and for purchasing energy efficient appliances.

Utilities have developed more deterministic methods for influencing the demand through DSM. Since DSM programs may not involve explicit management by the utility, the term demand response (DR) is being widely used in the industry. DR uses incentive-based and indirect methods for controlling how much electricity is consumed during a specified time interval by water heaters, air-conditioners, and industrial equipment. The more innovative methods of load control depend on market forces for exerting control by varying the price of electricity.

# 6 Demand response profiles

## 6.1 Choice of profile

An electric utility shall choose one of more the profiles described in this section for designing a demand response system to influence customer use of power. The profiles include

- Direct load control (Section 6.2)
- Local load control (Section 6.3.2)
- Distributed load control (Section 6.3.3)

## 6.2 Direct load control

Some large industrial customers volunteer for lower electric rates in exchange for deliberate service interruption. When utilities are facing a supply limitation, perhaps on a hot summer day, they order these volunteers to reduce or to curtail some energy consuming equipment. The analogous program for residential customers is “direct load control.” This program may be offered by utilities or by third-party suppliers.

To implement direct load control, utilities or third-party suppliers of energy management services shall send control signals to interrupt the operation of selected devices such as air-conditioners and water heaters remotely from outside the house. In a typical version of direct load control the utility sends a signal via the power line, radio, telephone line, Internet, or cable television channel to a switch that limits the run time of air-conditioners to 0-15 minutes each half-hour for up to six hours each day. Water heaters are generally turned off entirely for 2-6 hours.

Appliances and devices such as thermostats that participate in direct load control shall include internal or external communications interfaces to receive and execute electronic commands sent by the utility. Figure 1 illustrates the architecture of direct load control.

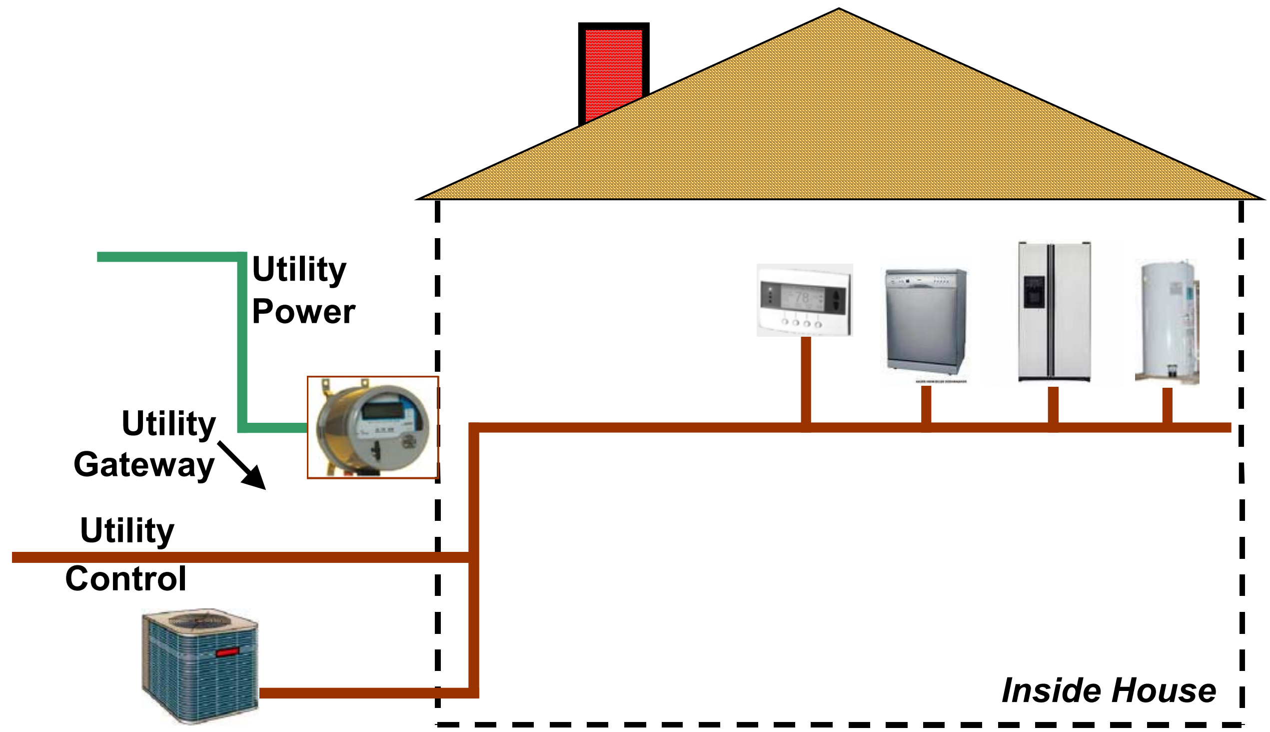


Figure 1 – Direct Load Control

Direct Load Control requires prior arrangements with customers for permission and equipment installation. The signalling method, choice of communications channel, and appliance interfaces are outside the scope of this standard. Figure 1 illustrates a uniform path to deliver the utility control signal to the selected appliances. The utility may interpose a communications gateway between the utility network and the network within the home if different communications protocols are implemented outside and inside the home. If a gateway is involved, it shall conform to ISO/IEC 15045-1.

Note: Many customers in the U.S. are offered rebates of up to $10 a month for participating in Direct Load Control. Of the 5% of U.S. customers under load control, most are participating in Direct Control.

### 6.3 Demand response via pricing and event notification

#### 6.3.1 Indirect control of customer demand

An indirect method of load control is based on electric rates that vary over time or a notice to customers of a pending event, such as a partial supply interruption, requiring consumption reductions.

Time-of-use rates vary the price according to the time of day. Typically, on-peak and off-peak rates are announced. The hours for each rate are fixed for each day, or at least for work days, similar to telephone rates. Rates that change dynamically with one-day or even no advanced notice constitute real-time pricing.

Note: In many countries electricity traditionally was sold at a flat rate or a volume-sensitive rate. New pricing schemes are adding time as a factor.

#### 6.3.2 Local load control

Utilities choosing local load control shall publish time-of-use (TOU) pricing for electricity. The published rates shall be provided to customers prior to implementation or changes to the TOU rates. Utilities may deliver TOU to a user interface via a communications network and optionally via a residential gateway to the customers. If a gateway is involved, it shall conform to ISO/IEC 15045-1. Utilities should educate customers to help them select which appliances to operate when in order to avoid peak power charges.

TOU pricing typically involves pricing electricity higher during specified hours, such as 4-6 PM when the wholesale cost of power is higher. Some utilities set the ratio of on-to-off peak pricing high enough to motivate customers to defer heavy power-consuming appliance usage to the off-peak times.

In some countries, TOU pricing also includes a demand charge. The consumer pays a special charge called a demand charge if the total electricity consumed during a short interval (typically 15 or 30 minutes) exceeds a pre-set limit. The penalty may be higher charges or even interruption of power flow.

As with telephone tariffs, customers are notified of the TOU rates and are expected to adjust consumption accordingly. For this technique, called *local control*, to be effective the customer must:

- Remember the time period for off-peak pricing of power.
- Know which appliances consume relatively large amounts of energy.
- Know which combination of appliances may result in a demand charge if imposed by the utility.
- Not be significantly inconvenienced by deferring appliance operation to off-peak times.

### 6.3.3 Distributed load control

Utilities can better match electricity supply with customer demand by dynamically varying the price of electricity as market conditions change, a method known as real-time pricing (RTP). Eventually, utility policy makers would like to adjust prices according to the wholesale market price of electricity to reflect actual utility costs. The utility has the opportunity to change prices when a peak demand is expected.

Note: In some countries regulation do not presently permit residential users to be offered fully flexible real-time pricing. Utilities may be permitted tariffs with two or more price tiers to reflect their costs of energy generation and distribution. In countries with a competitive market, third-party suppliers may set the retail rates.

Some utilities are capable of accurately forecasting the cost of energy in the near future, typically 24 hours in advance, and supplying this information to the residential consumer. The prediction of such forecast pricing enables peaks in demand to be smoothed both forward and backward in time, thereby reducing the impact of such measures on consumer comfort and convenience. As these innovative pricing schemes lower the peak demand, utility costs are reduced.

Distributed control enables users to respond effectively to utility price variations and event notices involvement or inconvenience by using computer-based agents and smart appliances, as described in Section 7.3. Forecasted pricing enables the consumer, or an intelligent energy management system, to “draw forward” on consumption in anticipation of peak pricing. This may involve comparatively simple measures such as ensuring that heat storage devices, water heaters, and similar appliances are fully charged when the peak-price period starts.

Distributed load control combines local and direct load control with much increased flexibility and customer control. Utilities choosing distributed load control shall publish time-varying electricity prices and optionally notices of critical events regarding the supply of electricity. Utilities shall make these data available via a communications pathway to each customer with connections to a home area network (HAN). The connection to a HAN may be via a residential gateway that shall conform to ISO/IEC 15045-1. The architectural choices for distributed control are specified in Section 7.

# 7 Architecture for distributed control

## 7.1 Smart appliances

There are two important problems for effective use of the changing cost of power. First, the price data must be delivered to the customer in a timely fashion. Second, the customer must interpret the data and apply it to appliance operation. Since most customers do not understand electricity measures, such as kilowatt-hours, they are not likely to use these data correctly. Here is where home control technology can benefit the consumer and the utility by insulating the customer from the complexity of dynamic energy management by enabling distributed load control.

Demand response via distributed load control shall link a utility communications network to a home area network (HAN) as specified in ISO/IEC 14543-2. Devices on a HAN may be home appliances, consumer electronics, sensors, actuators, user interfaces, or controllers. Examples of such devices typically involved with energy management include thermostats, HVAC (heating, ventilation, and air-conditioning) equipment, displays, and major appliances (called white goods by the appliance industry). The HAN may be wired or wireless.

Appliances that function as HAN devices are sometimes called “smart appliances.” Smart appliances can communicate via the HAN with other appliances, with a HAN controller, or with the utility, depending on the application. For distributed control, the HAN is linked to a utility network, possibly via a residential gateway.

Distributed load control shall be implemented by using the prices-to-devices method of Section 7.2 or by using the agent for energy management method of Section 7.3. Utility pricing or event data are sent directly to smart appliances with prices-to-devices. In this case the smart appliance may modify operation upon receiving a price signal according to the algorithms designed into the appliance. The agent for energy management is a specialised controller that co-ordinates energy consumption among multiple smart appliances.

## 7.2 Prices-to-devices

In the prices-to-devices method of distributed load control utility prices and any event notifications shall be communicated directly from the utility to smart appliances. A gateway may be interposed if needed for protocol translation between the utility wide area network and the HAN. If a gateway is used, it shall conform to ISO/IEC 15045-1.

Such smart appliances shall be programmed to understand the price or event messages and to respond accordingly with reduced consumption where appropriate. Smart appliances may respond to price or event from the utility in one of the following ways or in other ways to be developed by appliance manufacturers in consultation with utilities:

- Shedding load in a limited number of levels (for example, four or five possible power consumption levels).
- Adjusting the temperature setting of a thermostat controlling a heater or air-conditioner during a period of higher priced electricity.

The customer shall always have the option to override these actions and resort to full power usage or different energy consumption modes.

Figure 2 illustrates the architecture of distributed load control using prices-to-devices.

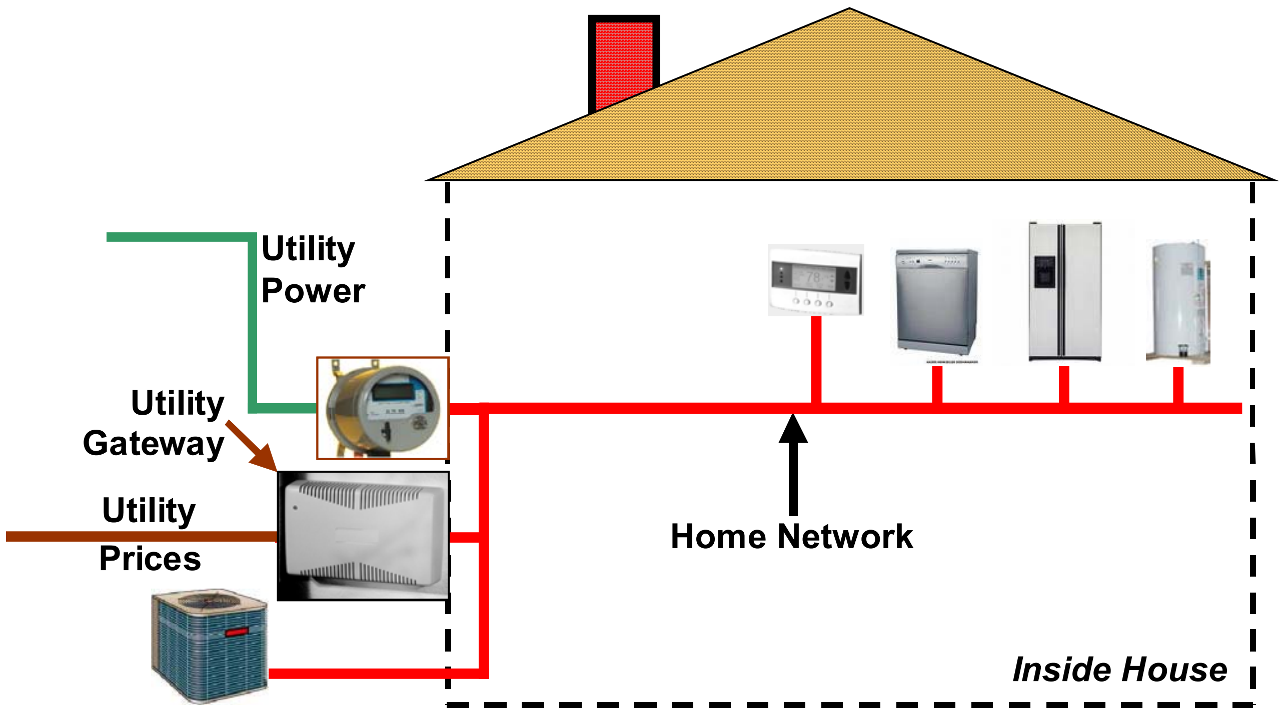


Figure 2 – Prices to Devices

### 7.3 Agent for energy management

The smart appliances involved in prices-to-devices (Section 7.2) respond independently to utility price data. The introduction of an Energy Management Controller (EMC) adds functionality to distributed load control by enabling the allocation of limited energy (or a limited budget for energy) among appliances according to consumer preferences. Figure 3 shows a feasible Distributed Load Control residential implementation. The EMC acts as an agent for the consumer.

The utility shall send pricing data electronically to all houses in real-time over a network such as the Internet. This pricing signal shall enter the house through a utility gateway, a version of a residential gateway conforming to ISO/IEC 15045-1. This gateway interconnects a public network using telephone, cable TV, power lines, or radio with a home network. The gateway may be a separate device, as shown in Figure 3, or could be integrated with other gateways, controllers, or even inside an electric meter.

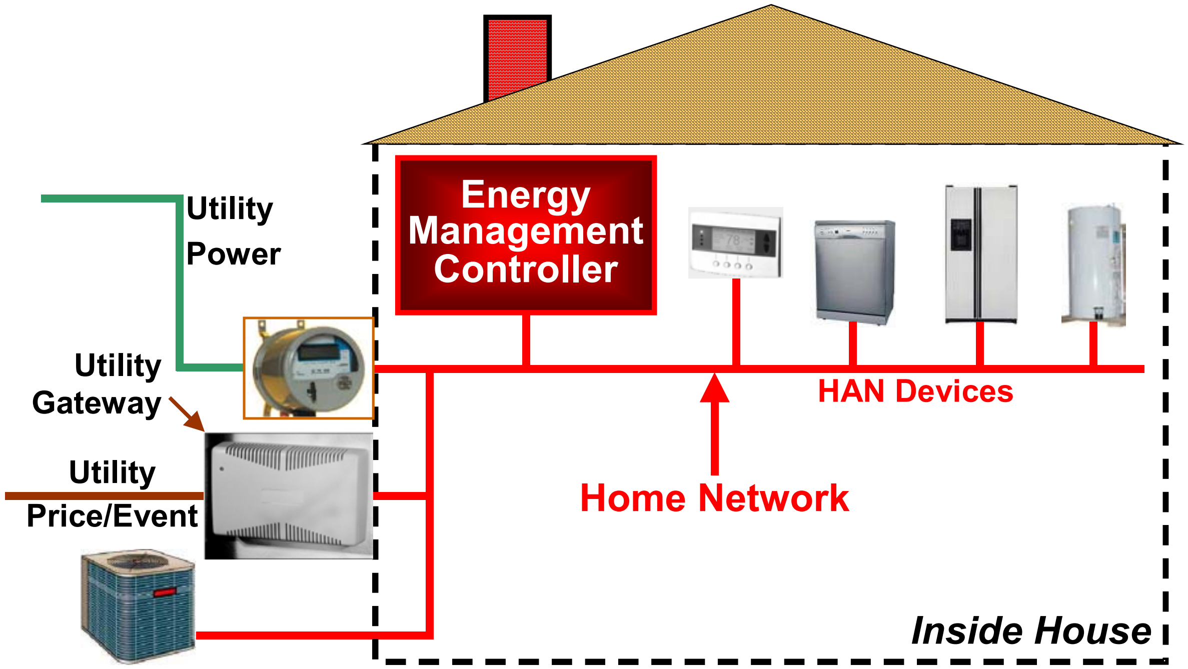


Figure 3 – Distributed Load Control System

The EMC is responsible for regulating energy consumption. Options for the implementation of an EMC depend on the market development of home controllers and smart appliance. Some possible embodiments of an EMC include:

- A discrete physical unit.
- Embedding the EMC functions in a smart appliance, a cable set-top box, a residential gateway, etc.

The EMC performs specialised computing functions by receiving the electricity rate data from the residential gateway and applying sophisticated software algorithms to determine which appliances to operate and when. The functions of the EMC are illustrated in Figure 4.

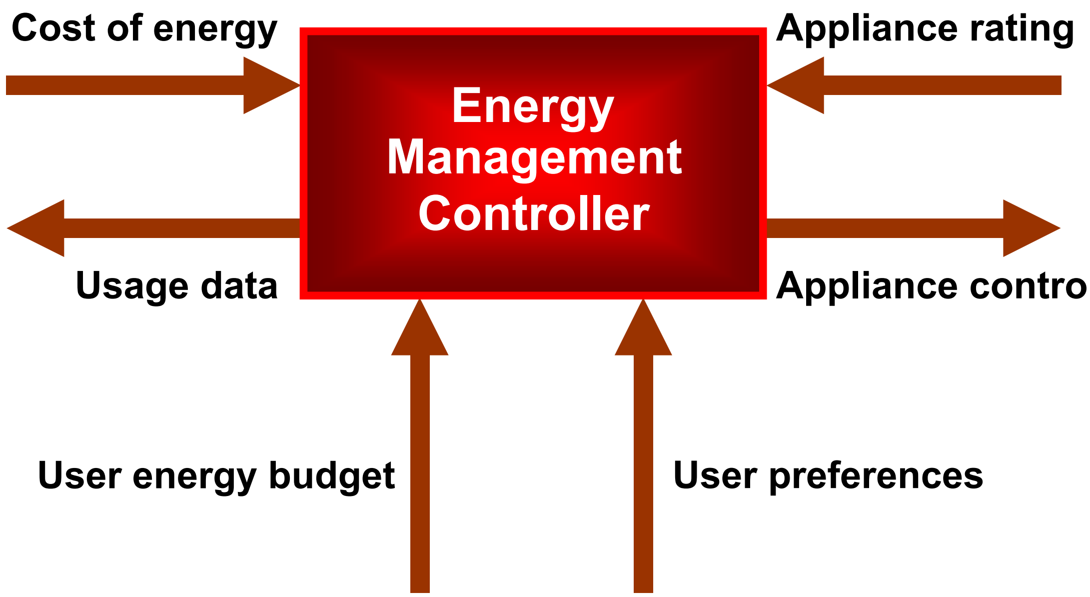


Figure 4 – Energy Management Controller

The EMC shall be programmed to determine how and when to operate appliances based on the cost of energy, the energy requirements of the appliances, and user inputs. The user might specify a monthly energy budget and preferences (shower at 8 AM, air conditioning at 6 PM, pool at 8 PM, etc.). The customer shall always be able to override decisions of the EMC. After processing these data, the controller shall issue signals that are distributed over a home network to the relevant appliances. Smart appliances that can operate in energy conserving modes can improve the effectiveness of a distributed load control system.

The details of the user interface for configuring the EMC are left to market development. Recommended guidelines for such a user interface are simple, non-intrusive, and adaptable by language and physical impairment, as specified in ISO/IEC 24752-1. The user interface may be an education tools to explain the relative energy consumption levels of various appliances and could display the actual consumption by major appliances. However, the EMC system shall provide automated demand response so customers should not need interaction with the EMC multiple times per day.

Communications between the utility and the Energy Management Controller shall include the two data flows shown on the left side of Figure 4. The cost of energy data shall be sent by the utility or a demand response service provider using a secure link that ensures the data originated from the utility or the service provider. This level of security entails authentication to confirm that the data is from the real source and has not been altered during transmission. It is not necessary to encrypt such data since it is public. However, the customer usage data shall be encrypted so that, if intercepted, a potential burglar could not determine customer daily activities and occupancy.

The customer and the utility shall agree how frequently usage data are collected. The more frequently the usage data are sent, the more detailed a record of household activities and preferences can be accumulated, thereby impacting customer privacy. Aggregated energy consumption data, weighted by the price when consumed, are the only required data to be sent to the utility for billing. The customer shall decide how often the total consumption data and any detailed data are sent to the utility based on the tariffs offered by the utility. Detailed usage data by appliance (such as HVAC, refrigerator, water heater, etc.) are called disaggregated data. Consumers may choose to share such data with utilities or service providers for enhanced energy management or ancillary services such as appliance diagnostics.

# 8 Value-added services

Demand response and automated meter reading require two-way communications between customers and the utility or a third-party energy-management service provider. This pathway enables the supplier to offer additional services to benefit consumers. In a competitive market for energy, utilities are considering such additional services in order to retain customers and to generate additional revenue with offerings ancillary to power. Collectively, these are known as value-added services. Some governments have mandated that utilities, which traditionally were granted monopolies, start planning for competition. Therefore, utilities are seeking value-added services to make their products more attractive to customers. Utilities and third-party suppliers that implement demand response in compliance with this standard may implement one or more of these value-added services.

Potential value-added services for electric utilities beyond load control are listed. The services preceded by a check mark (✓) may be sold for additional revenue beyond the usual energy charges.

- Automatic meter reading
- Remote connect/disconnect
- ✓ Offer disaggregated bills with details about consumption by major appliances
- Monitor power delivery
- ✓ Monitor power quality
- ✓ Offer load profiles
- Control customer access when customers move or don't pay bills
- Stagger power restoration in a neighbourhood after a power failure
- Detect tampering
- ✓ Diagnose appliances problems and notify the customer
- ✓ Offer information and telemetry services
- Compute the environmental impact of customer energy consumption

# 9 The HES energy management model

## 9.1 Energy management taxonomy and lexicon

The architecture of the energy management model and options for demand response have been described in the previous sections of this standard. Section 9.2 specifies generic logical and physical models for HES energy management. The taxonomy for specific use cases of the HES energy management model is specified in Section 9.3. The lexicon of the messages for demand response are presented in Section 9.4

## 9.2 Logical and physical models

The typical components for demand response are shown in Figure 5. The logical relationship among the components for demand response systems is illustrated in Figure 6. To accommodate prevalent practices of direct control, a logical model with minimal functionality is proposed in Figure 7. In this case, the energy management controller has been eliminated because the utility controls appliances (including appliance actuators, such as thermostats) by a direct signal. A user interface is included because some implementations allow the user to over-ride a direct load control signal. A cost penalty is usually assessed for over-rides. Furthermore, when the utility installs and manages the link to the appliances, the gateway may be eliminated if the utility uses the same signalling inside and outside the house, possibly via a virtual private network.

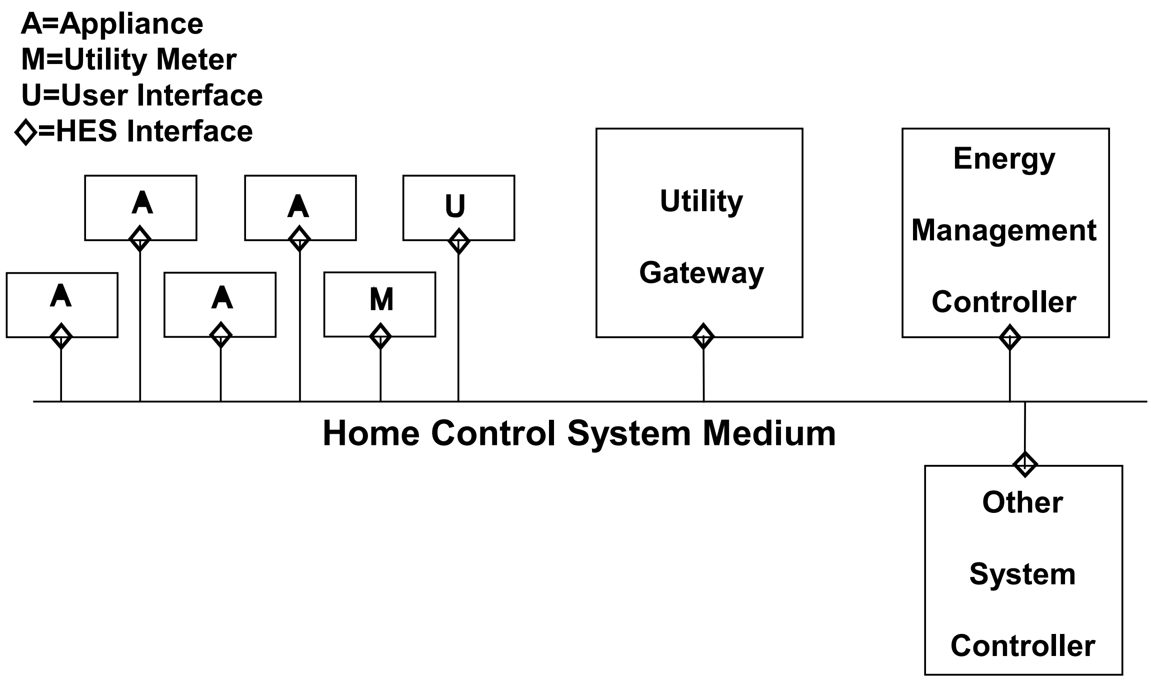


Figure 5 – Typical HES energy management model component

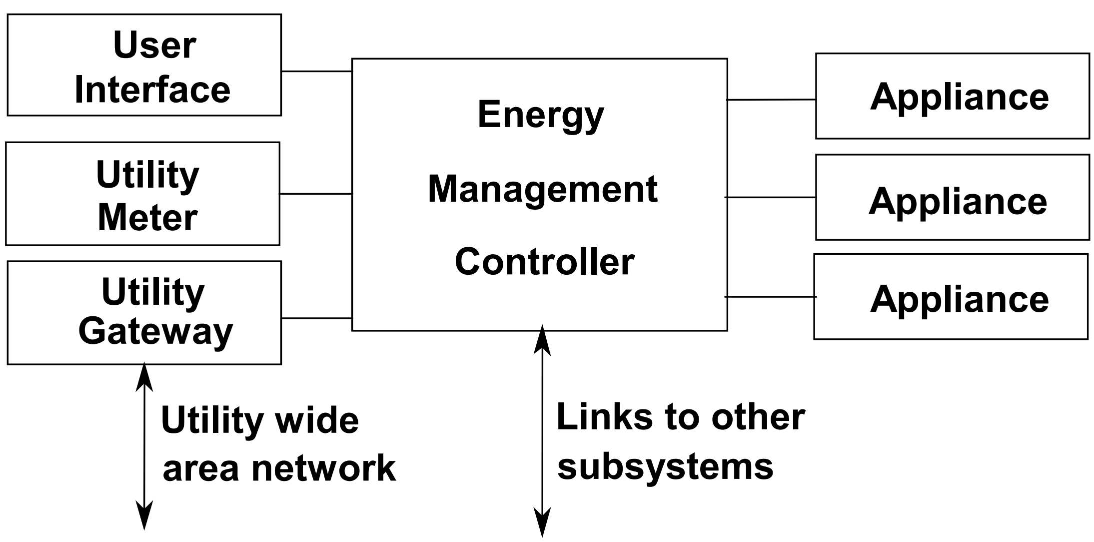


Figure 6 – Logical model for HES energy management

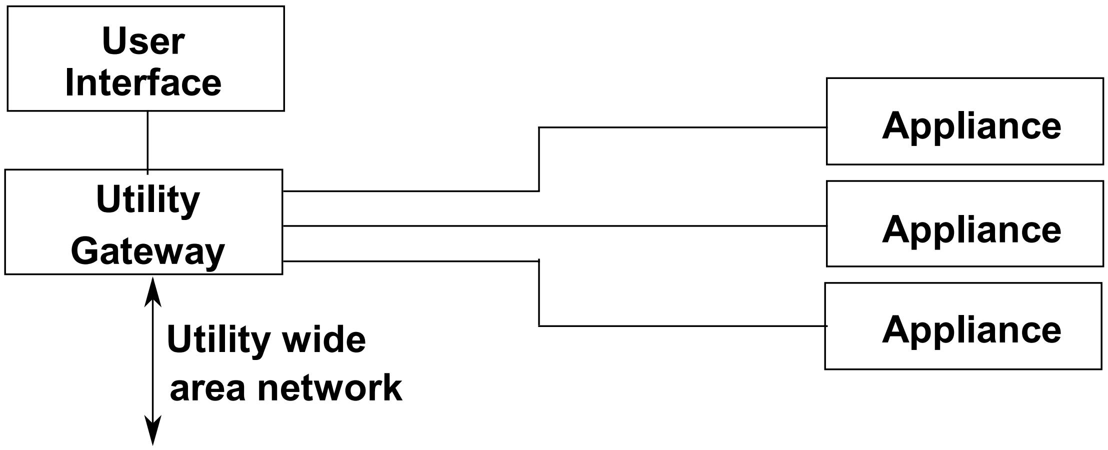


Figure 7– Logical model of minimal HES energy management

Energy management is one of many subsystems possible in a home control network. As shown in Figure 6 the energy management controller may be linked to other home control systems or to a home control co-ordinator. The co-ordinator might be responsible for providing common scheduling and subsystem interaction. This co-ordination function may be distributed among the system controllers through sophisticated software, thereby eliminating the co-ordinating controller.

## 9.3 Taxonomy of HES energy management use cases

### 9.3.1 Structure of use cases

This section presents examples of energy management applications. Each application is explained in words and illustrated with physical and logical models. These models are based on the components of the HES Energy Management Model. In the following cases, reference is made to power and kW. With a change of terminology, these cases can apply to other utilities, such as gas, water, fuel oil, or heat flow (for district or central heating).

### 9.3.2 Case 1: Local control

(Illustrated in Figure 8 and Figure 9.)

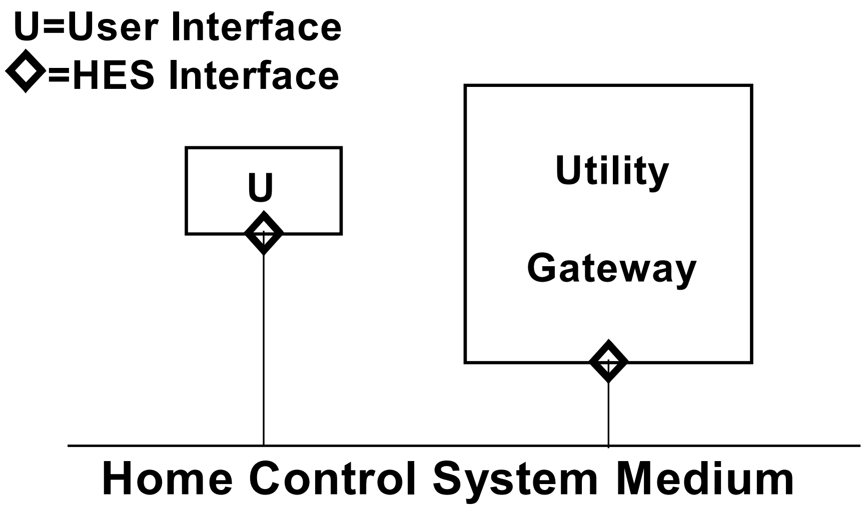


Figure 8 – Case 1 — Physical model

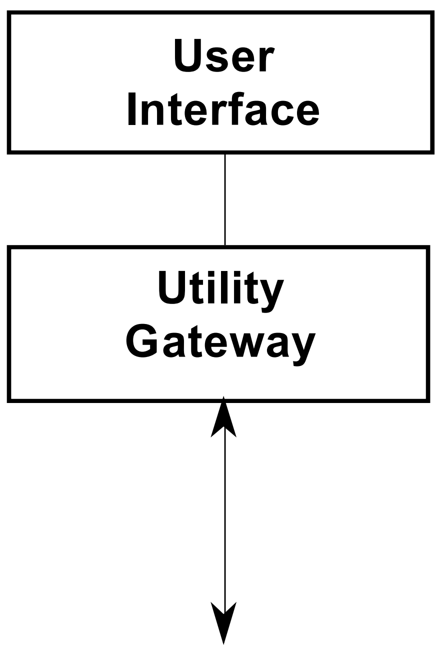


Figure 9– Case 1 — Logical model

Most local control schemes currently involve no communications to the customer, in which case the models in these figures do not apply. Typically, a static two-tier rate is announced by the utility to customers. In more sophisticated local control the utility may establish:

- Peak and off peak rates that change with appropriate notice.
- The times for peak and off-peak rates.
- Multiple-rate levels, such as time periods for low rates, medium rates, high rates, and emergency rates. The latter rate may be unusually high to indicate an emergency condition.

NOTE: As the number of pricing tiers grows and the time of transition becomes variable, local control pricing becomes similar to the pricing associated with distributed control.

In all of these variations of local control, the possible communications messages, if there are any, between the utility and the customer consists of an indication of which price level is in effect.

Therefore, signals flow from the utility via the gateway to a user interface as illustrated in the physical and logical models. The user interface may consist of indicator lamps on a special unit with markings to indicate whether peak or off-peak or any intermediate rates are in effect.

### 9.3.3 Case 2: Direct control

(Illustrated in Figure 10 and Figure 11.)

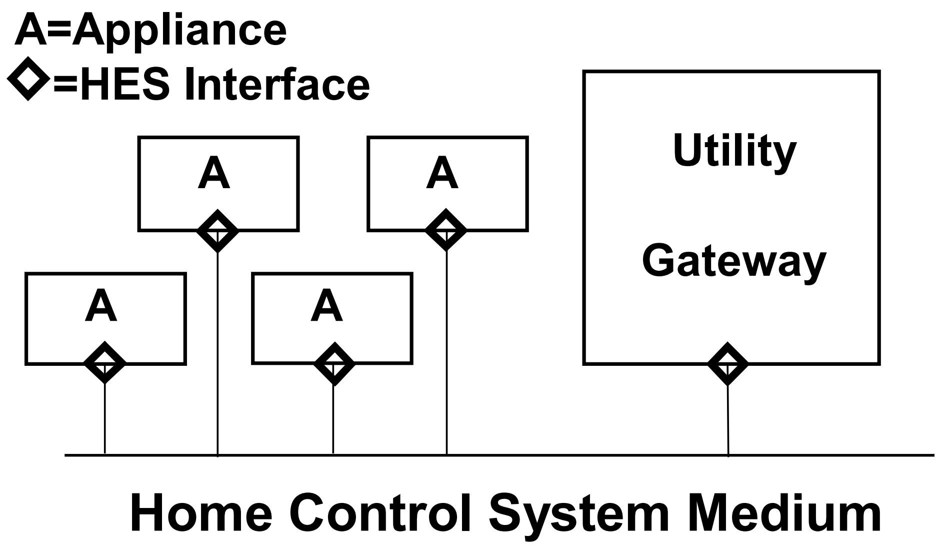


Figure 10 – Case 2 — Physical model

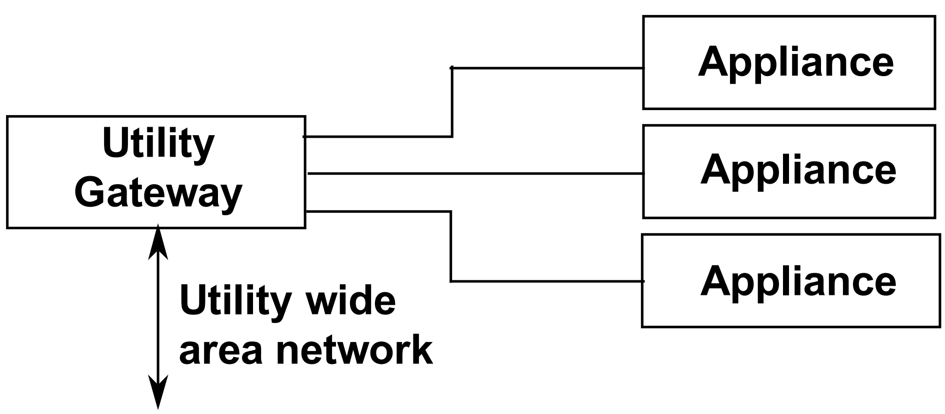


Figure 11 – Case 2 — Logical model

The utility enables or disables the operation of specific appliances. These case is representative of direct load control. Most present direct control consists of one-way communications from the utility to the customer appliances. The utility does not know if the control signal actually reached the appliance or if the appliance was operating. Newer direct load control schemes include acknowledgement that the control signal was received.

The utility messages are usually limited to specifying which appliance is to be turn-off or to be restored to operating status. When the utility installs and manages the link to the appliances, the gateway may be eliminated if the utility uses the same signalling inside and outside the house, possibly via a virtual private network.

### 9.3.4 Case 3: Direct control with supervision

(Illustrated in Figure 12 and Figure 13.)

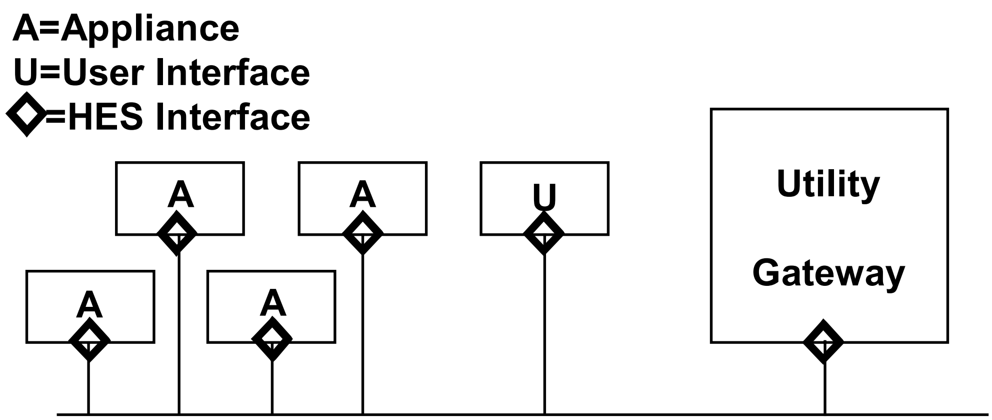


Figure 12 – Case 3 — Physical model

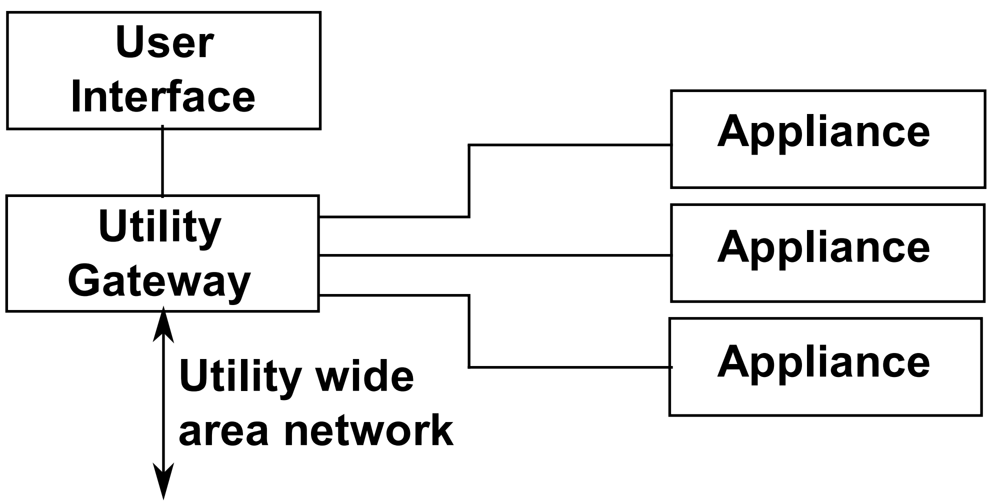


Figure 13 – Case 3 — Logical model

Case 3 accommodates more advanced direct control with two-way communications. This case allows the utility to verify that specific appliances are responding to control. Also, the utility can determine the effectiveness of load shedding and, therefore, can detect “free-riders.” These are customers where the controlled load never attempts to use energy during the controlled time period. Typically, these customers are not home and the appliances are not operating during the controlled period.

Case 3 also allows the utility to institute control over the demand for power by setting a limit on kW during a specified interval. The following expanded set of messages supports Case 3.

#### 9.3.4.1 Utility messages

- Which appliance will be controlled (turned-off) and for how long.

- For appliances that have multiple levels of power consumption, such as a heater, the utility may indicate the maximum level of operation allowed instead of sending a turn-off signal. This may consists of a specified reduction in the kW demand of the appliance.
- When a specific appliance will be controlled and for how long.
- How often an appliance is likely to be controlled. Alternatively, the customer may be told when the next control time is likely after the present one being announced.
- The priority level of the control. This may indicate whether the customer has the option of over-riding the control.
- The approximate cost consequence if the customer over-rides the control. The customer is not expected to have an energy management controller. Appliance interaction is conducted by the utility via a sophisticated gateway. This gateway also controls any display device involved in direct load control.

#### 9.3.4.2 Customer messages

- Static information about the controlled device: name and type of device, location of device, name of customer, typical power consumption, maximum power demand in an interval (typically 15 minutes, or must be specified), amount of power that can be shed by load control, maximum duty cycle (to indicate how often the device can be safely controlled)
- Historical information about the controlled device: Date and time the last control command was received and whether it was accepted (whether the customer allowed the device to be controlled), number of control commands and acceptances during a specified period, amount of load shed during the most recently accepted control command, average load shed during a specified period, reduction in power demand during a specified period.
- Device operating status: On, off, operating level (if appropriate), out-of-service, under direct load control.
- Customer acceptance or rejection of utility plans to control a specific appliance. A reason for rejecting direct load control may be provided: customer choice, life-safety device, device out of service, etc.

### 9.3.5 Case 4: Distributed control

The logical and physical arrangements contain all the elements in the generalised diagrams, Figure 5 and Figure 6. An energy management controller accesses real-time pricing data. This controller disables selected appliances or causes them to reduce power consumption to meet the user's programmed goals of budget versus convenience. Figure 4 illustrates the signal flows into and out of the energy management controller. The utility pricing data may be provided in real-time indicating an immediate rate change. In a more realistic scenario, the utility broadcasts the rates one-day in advance. These rates may change hour-by-hour.

The energy management controller receives the electricity rate information from the utility gateway via a home automation communications network. The controller combines this information with stored data about appliance power requirements and customer information. The customer can enter preferences for appliance operation and budget limitations for electricity expenditures. For example, the customer may indicate a preference for hot water in the morning (for bathing) and heat in the early evening. Also, the customer might attempt to set a limit of monthly expenditures for energy. The energy management controller uses these inputs to allow or disallow appliance operation.

The software in the energy management controller determines which appliances to operate and when. Such software may be complex to balance economy with the user's desires for comfort and convenience. Elements of artificial intelligence are frequently required for effective operation.

The consumer benefits by attaining maximum convenience for appliance operation while controlling electricity costs. The consumer does not need to know details about time-of-use or demand-based electric rates. The customer can over-ride the energy management controller and be informed of the cost impact. Thus, the consumer is insulated from technical issues while making simple economic decisions.

### 9.3.6 Case 5: Advanced distributed control

The logical and physical arrangements contain all the elements in the generalised diagrams, Figure 5 and Figure 6. Case 5 extends Case 4 with the additional ability of the energy management controller to monitor appliance operation and restrict the operating modes of selected appliances. Thus, the control signals to appliances are extended from on and off to operating mode or demand level (as appropriate for the appliance). Also, messages may flow from the appliance to the energy management controller.

The signals between the energy management controller and the appliance are similar to those defined for Case 3, Direct control with Supervision. The fundamental difference is that all decisions about appliance control are made locally based on real-time price data. The energy management controller can calculate the cost consequences of appliance operation.

Appliances may include indicators and controls for energy management. For example, the energy management controller may determine that an appliance should not be operated. If the user attempts to run that appliance, a lamp on the appliance may indicate that operation is deferred by the energy management controller. Furthermore, the user may be allowed to over-ride this decision by pressing a special key on the appliance. A display on the appliance or on a nearby home automation control panel may tell the user the cost consequences of over-riding the energy management controller. The user is now making an informed decision on spending money for energy.

The same set of messages between the energy management controller and appliances is required as defined in Case 3. The following additional messages are needed:

- From the energy management controller:
  - — Data about the cost of operating the appliance in the operating mode requested by the user.
  - — Data suggesting operating modes and costs that will save money.
  - — A request to reduce average kW consumption by a stated percentage. Note that this command is intended for appliances with intelligent controls. Most appliances will not be able to respond to such a request. Most will be able either to operate normally or stop operating completely. Others may be able to operate in specified modes, as directed by the energy management controller.
- From appliances connected to the energy management controller:
  - — Confirmation of the mode of operation set by the user.
  - — Manual operation of the appliance by the user.
  - — User request to over-ride control of the energy management controller.
  - — Power being consumed by the appliance. This information may be compiled for bill desegregation: a bill that shows how much power each major load is consuming. Also, the utility may request this data be uploaded for a load survey.

### 9.3.7 Case 6: Distributed control for intelligent appliances

The logical and physical arrangements contain all the elements in the generalised diagrams, Figure 5 and Figure 6. Additional energy services are possible with intelligent appliances. For example:

- Automatic adaptation to real-time pricing

  — Some appliances might eventually be able to adapt energy consumption according to the price of electricity directly. This means that part of the algorithm planned for the energy management controller might be built into future appliances.

  — The messages between the energy management controller and the appliance convey the current price and the anticipated duration of this price level.

- Emergency load control

  — The utility issues an emergency notice that supplies are limited and a specific level of power consumption must not be exceeded. The energy management controller could calculate the demands of all operating appliances to achieve this limitation. Some networked appliances have been marketed that interleave operating cycles among major appliances to limit the demand peak.

  — An intelligent appliance might be able to control demand to a desired level automatically. The command sent to such an appliance would simply indicate the maximum energy consumption for a specified period of time.

  — The utility commands to the energy management controller specify the maximum power availability and the time allowed to shed loads. The energy management controller must confirm acceptance of the power reduction within the specified time or the customer may be disconnected from the grid.

- Power consumption

  — Some utilities gather power consumption statistics from major appliances for load planning purposes. Others offer these data to customers in a scheme called "bill disaggregation." This shows the customer consumption by major appliance to explain the bill and encourage conservation. Such appliances must be out-fitted with power meters. Current meters may be adequate if the appliances are primarily resistive loads.

  — Commands to support power consumption consist of polling the appliances by the energy management controller. Each appliance returns the energy consumed since the last poll. Ancillary commands to initialise or reset power measurement in the appliance may be provided. The energy management controller may also communicate with the electric meter to gather whole-house consumption data.

  — The utility may communicate with the energy management controller to request power recording and to upload data accumulated by the energy management controller. The controller would be responsible for gathering and averaging the data and producing a summary report.

### 9.3.8 Case 7: Utility telemetry services

(Illustrated in Figure 14 and Figure 15.)

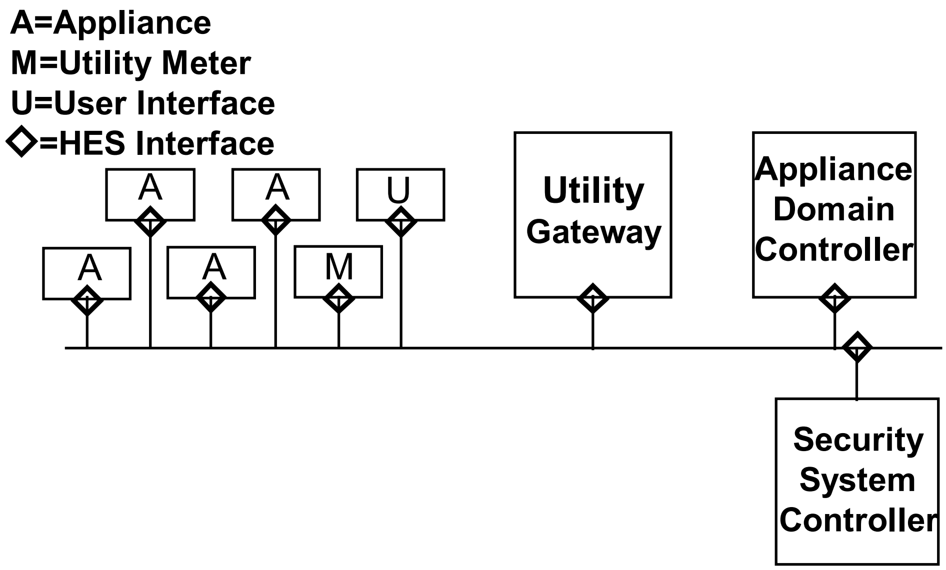


Figure 14 – Case 7 — Physical model

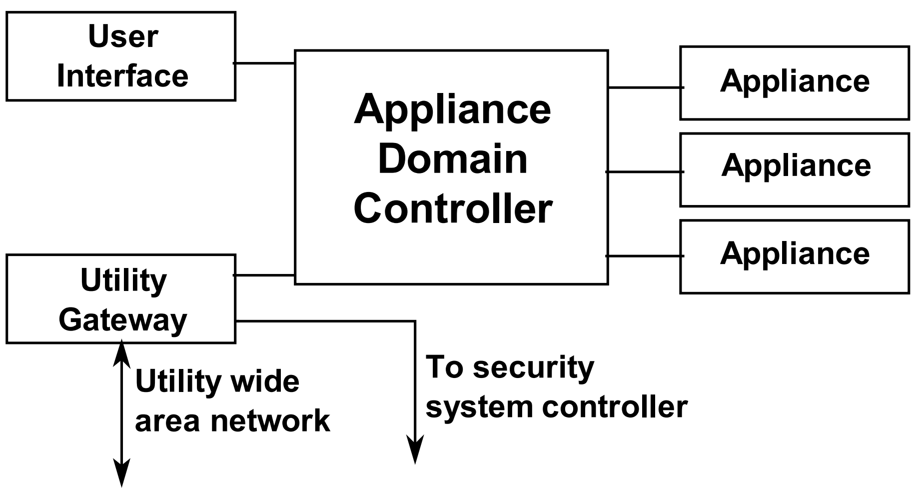


Figure 15 – Case 7 — Logical model

This case accommodates a variety of new value-added services being considered by some utilities. It is not possible to anticipate all messages necessary to support services to be defined. Nevertheless, the pathways for such messages will likely be between a utility gateway and one or more local Application Domain Controllers[1], similar to the energy management controller. The local controllers, shown in Figure 14 and Figure 15 as an Appliance Domain Controller and a Security Controller, exchange messages with specific appliances or subsystems to be controlled.

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[1] Application Domain – A logically related group of components that provides the functions of an application in a home or building. Typical components include sensors, actuators, user-interface devices, and controllers. Examples of Application Domains are lighting, security, energy management, and HVAC (heating, ventilating, and air-conditioning).

Application Domain Controller – A controller responsible for managing the operation of an Application Domain. An Application Domain Controller may be a physical device, or the application control functions may be distributed in related devices such as a sensors, actuators, and appliances.

Please note that an explicit controller may not be present. In that case, control functions are distributed among the network components comprising a Fully Distributed System.[2]

An example of a utility telemetry service is appliance monitoring and diagnosis. A customer would subscribe to this service where the utility periodically tests the operation of a specific appliance. The utility initiates a built-in test sequence in the appliance and reads the result. Any problem requiring customer notification is presented on a local user interface.

Message sets to accommodate remote appliance diagnosis contain the test sequence identification code. The appliance responds with the result code of the test procedure. Future appliances might allow the utility to download special test sequences into the appliance or into the energy management controller. In the latter case, the controller is acting as a test instrument for the appliance.

An important factor to consider as value-added services, including remote testing, are designed is the quantity of data to be communicated between the utility and the customer. The control channel planned for HES is not intended for large volumes of data. An information channel, defined in the HES architecture, needs to allocated for this purpose.

## 9.4 Lexicon for HES energy management

### 9.4.1 HES message lexicon overview

The following messages are proposed for commands, status reports, or data to be exchanged among the logical components in the HES energy management system model. This message set does not imply that all energy management components can or must support the features of each message. Messages will be chosen to support a specific implementation. These messages represent a variety of functionality, not necessarily implemented in any one system.

The purpose of this generic message lexicon is to facilitate interoperability among demand response systems that may be developed by competing equipment suppliers to the utility and home system industries. These messages are provided in the XML format specified in ISO/IEC 18012-2, and introduced in ISO/IEC 18012-1.

### 9.4.2 HES message list

Each message may be sent to a single device, to all devices (broadcast), or to a predefined group of devices.

#### 9.4.2.1 Gateway ←→ user interface

The user interface may consist of lamps indicating predefined price levels for energy. Alternatively, the user interface may display character data or graphical images sent by the utility via the gateway. An expanded character display would accommodate data about changes in the price tiers and applicable times.

- ON/OFF messages
  - Turn on the addressed indicator lamp in the user interface.
  - Turn off the addressed indicator lamp in the user interface.

[2] Fully Distributed System – A system comprising multiple Application Domains where the functionality of Application Domain management is distributed over related devices. In such a system the presence of Application Domain Controllers as physical devices is optional.

- Messages about rate tiers, or unusual conditions
  - — A string of characters to be displayed on a suitable user interface. A string length of about 40 characters should be sufficient. For multiple line displays, multiple messages may be sent.
  - — Future displays might support graphical (or icon) display, requiring appropriate coded messages in place of plain text.
- Cost of over-ride
  - — This may be implemented using the method above for message display.
  - — The intent is to inform consumers of cost of over-riding a direct load control signal.

#### 9.4.2.2 Gateway ←→ appliances

- ON/OFF messages
  - — Turn off the addressed appliance for a specified duration.
  - — Turn on the addressed appliance.
  - — (This message is sent either to the appliance or to a power module that controls the flow of power into the appliance. The specified duration parameter is optional.)
- Level of consumption
  - — Limit the addressed appliance operation to a specified maximum kW for a specific duration.
  - — Remove any kW restriction from the addressed appliance.
- Time of restriction
  - — Notify the addressed appliance of the start time a specified restriction and the anticipated duration.
  - — Notify the addressed appliance how often a specified restriction will be instituted.
  - — Notify the addressed appliance about the start time of a specified restriction after the present restriction ends.
- Priority of restriction
  - — Assign a priority level to the addressed appliance for future on/off or restriction messages.
  - — (It is assumed there is prior agreement on the number and meaning of priority levels.)
- Appliance report
  - — Request specified report from addressed appliance.
  - — Provide requested report from addressed appliance to the gateway.
  - — Specified reports include: static information, historical information, device operating status, customer acceptance or rejection of load control, and the reason, if available. The contents of these reports are described in Case 3 above. The format of the reports consists of parameters identified by field position or by keyword.

#### 9.4.2.3 Gateway ←→ energy management controller

The following commands involve the exchange of data in character format.

- Rate data update
  - — The Energy Management Controller queries the Gateway for the availability of new rate data.
  - — The Gateway responds with the time and date of the last rate update.

- Rate data

  — The Energy Management Controller queries the Gateway for a download of rate data.

  — The Gateway downloads the rate data. The format of the data is to be defined. It may follow the format used for wide area communications between the utility and the gateway.

#### 9.4.2.4 Energy management controller ←→ appliances

- Appliance capabilities

  — The Energy Management Controller queries an addressed appliance about device information and energy requirements.

  — An appliance responds to a query from the Energy Management Controller with static information (per Case 3 above) including data about nominal energy consumption, and, if available, data about peak consumption, consumption by operating mode, and ability to reduce energy consumption upon request. The latter parameter may indicate that the appliance is in a critical mode that should not be interrupted, or involved with life safety operations.

- Appliance control

  — The Energy Management Controller requests the addressed appliance turn off or limit operating modes or limit power consumption to a specified level or percentage of peak usage within a specified time interval and with a specified urgency.

  — The Energy Management Controller requests the addressed appliance resume operating without any mode or power restriction.

  — The addressed appliance responds with acceptance and confirmation or rejection of the request from the Energy Management Controller or indicates it is turned off, out-of-service, or under manual control.

  — The Energy Management Controller informs an addressed appliance the cost of rejecting the previous request for energy consumption reduction.

  — The Energy Management Controller informs an addressed appliance about recommended operating modes with various degrees of conservation.

- Appliance energy consumption

  — The Energy Management Controller requests an addressed appliance report power consumption for the previous specified time interval.

  — The addressed appliance responds with the kW used or indicates it was off or out-of-service.

#### 9.4.2.5 Energy management controller ←→ user interface

- User inputs

  — Numerical data providing a monthly energy budget.

  — Appliance operating preferences by appliance name, mode of operation, times of operation, and priority relative to other appliances.

- Displays for user

  — Numerical data about monthly energy consumption with optional bill disaggregation by major appliance.

  — Numerical data about the present and projected energy tariff.

  — In addition, a series of interactive menus are needed to configure the energy management system as appliances are added and deleted. A future network management computer may handle automatic configuration.

#### 9.4.2.6 Energy management controller ←→ meter

These commands apply to electronic meters with communications capabilities. It is possible in some installations that the meter functions as the gateway. Therefore, commands defined for the gateway may be appropriate here.

- From Energy Management Controller
  - — Energy Management Controller requests consumption data from the meter for a specified period and peak usage (the demand), if available.
  - — Additional parameters may be requested depending on the meter functionality[3].
- To Energy Management Controller
  - — The meter responds with consumption data, demand data, and applicable time period.
  - — Additional data may be returned depending on meter capabilities and requests from the Energy Management Controller.

#### 9.4.2.7 Energy management controller ←→ other controllers

Controllers may communicate messages for co-ordination or to announce unusual conditions requiring action by the other controllers. For example, the Energy Management Controller might request an HVAC unit reduce energy consumption. If the home automation network includes an HVAC applications controller, the Energy Management Controller message might be sent to the HVAC controller rather than to the appliance. This routing would be appropriate if the HVAC controller contains algorithms for managing the operating characteristics of the HVAC equipment.

3. In the United States, ANSI standard C12.19 specifies a set of tables with parameters that define meter capabilities. A meter manufacturer will choose a subset of features to incorporate in a particular meter model. The first table in a meter identifies which features are available in that meter and defined in subsequent tables.