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INTERNATIONAL STANDARD

Information technology – Home Electronic System (HES) application model – Part 3: Model of an energy management system for HES

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CONTENTS

INFORMATION TECHNOLOGY – HOME ELECTRONIC SYSTEM (HES) APPLICATION MODEL –

Part 3: Model of an energy management system for HES

FOREWORD

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ISO/IEC 15067-3 has been prepared by subcommittee 25: Interconnection of information technology equipment, of ISO/IEC joint technical committee 1: Information technology. It is an International Standard.

This second edition cancels and replaces the first edition published in 2012. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) This edition revises ISO/IEC 15067-3:2012 by expanding beyond demand response to include a balance between multiple sources of power and appliance demands for this power.
b) This edition specifies a system framework that addresses the need for user-centric energy management by providing control options for consumers.

The text of this International Standard is based on the following documents:

Draft	Report on voting
JTC1-SC25/3201/CDV	JTC1-SC25/3254/RVC

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1, and the ISO/IEC Directives, JTC 1 Supplement available at www.iec.ch/members_experts/refdocs and www.iso.org/directives.

A list of all parts of the ISO/IEC 15067 series, published under the general title *Information technology – Home Electronic System (HES) application model*, can be found on the IEC and ISO websites.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Throughout most of the twentieth century, public policy and regulations encouraged utilities to expand the supply of electric power. This expansion of electricity systems world-wide has been a major achievement. However, technology developments and plans to mitigate climate change are having profound effects on the utility industry. Standards are being developed to provide an orderly transition for adapting to these changes.

Electricity generation is gradually shifting to the edge of the grid with local power generated from wind and solar at homes, buildings, and community sites. This is similar to the morphing of the central-office telephone-switching network to edge computing in our PCs, laptops, and smart phones for accessing Internet services such as Voice over IP (VoIP: telephone calls using the Internet), text messages, and email. These shifts in the power grid are motivated by technology changes and public demands to ensure that the essential role of electricity continues but from a diversity of sources that are

– more reliable,
– resilient to climate change,
– less polluting, and
– more affordable than depending on a single utility.

Public policy encouraging the expansion of electric power systems produced a world-wide proliferation of electricity generation and power grids including transmission and distribution lines. It was not until the late 1980s that policy makers in some developed nations started to worry about whether the supply of electricity would be able to continue increasing indefinitely to meet the demand anticipated primarily from industrial growth. Some regulators mandated integrated resource planning, where utilities were ordered to consider both supply and demand when preparing budgets to justify tariffs. The utility industry responded by offering programmes to manage customer demand for power called "demand-side management."

The introduction of local power generation from wind and solar is adding impetus to demand-side management because the power generated by wind turbines and solar-voltaic cells can fluctuate quickly with changing weather and the availability of sunlight. Local power sources including solar, wind, and storage are collectively called "distributed energy resources" (DER). Traditional demand-side management has been a centralized command-and-control system usually operated by a utility.

Adoption of demand-side management programmes varies widely by nation and by utility. The term "demand response" has been applied to customer equipment that responds to control signals by changing power consumption, called the "demand" for electricity. Typically, these signals are sent by a public utility for direct control of water heaters or air conditioners.

ISO/IEC 15067-3:2012 redefined the concept of demand response (DR) to include indirect incentives such as price changes or event notices that motivate customers to control demand locally by altering appliance usage. This reflected the transformation of demand response from utility-focused to consumer-focused. This document revises ISO/IEC 15067-3:2012 by expanding beyond demand response to include a balance between multiple sources of power and appliance demands for this power. Hence, this document addresses consumer energy management more generally, rather than just demand response. For this reason, "demand-response" has been removed from the title to de-emphasize a focus on demand for power supplied mostly from a public utility. This is part of a family of Home Electronic System (HES) standards addressing energy management, listed in the Bibliography.

This document focuses on energy management controlled by consumers. Effective energy management is tailored to user wishes and equipment that is responsive to fluctuating supplies. It provides performance and cost benefits without mandates and penalties. The growth of local power sources requires effective energy management equipment that is responsive to and managed by consumers, as specified in this and related documents.

This document specifies a system framework that addresses the need for user-centric energy management. This framework accommodates optimization of energy management across connected loads to balance consumer goals and constraints. It accommodates a diversity of internal and external power sources and was developed as options are proliferating for local DER equipment. This framework consists of a system model for equipment in homes and buildings that enables consumers to manage their usage of electricity in accordance with

– their activities requiring power for appliances, lights, electric vehicles, etc.;
– their budget; and
– other preferences related to power such as
  - using green sources, and
  - minimizing their environmental impact affecting climate change.

As the energy industry evolves, energy management will be enabled by on-premises control of power usage in response to fluctuations in power availability and cost from all sources, especially local sources on premises or in the neighbourhood. Energy management equipment (hardware and software) will be part of consumer electronics products from competitive suppliers rather than exclusively furnished for a utility programme. The goal of this document and related standards is to facilitate a marketplace where consumers have product choices for energy management.

The model in this document includes consumer equipment for energy management that is primarily located in homes and buildings. It consists of a system that

– interacts with occupants to determine user preferences for appliance operation, costs, and other factors influencing the consumer's use of energy, such as possible contributions to climate change;
– monitors power source availability and costs that are:
  - local (DER within the premises),
  - external (from a neighbourhood microgrid, transactive energy, an aggregator, or a public utility);
– maintains a database of power needs for appliances (including electric vehicle chargers) as a function of operating modes;
– measures power flows from local sources, storage, and appliance consumption for system performance and stability; and
– determines optimal power sourcing and allocation.

The energy management model specified in this document includes a controller that acts as an agent for the consumer to combine user preferences with power availability and power needs to meet the consumer's goals. Among these goals are convenience, comfort, health, and safety within budget constraints. Since this system controller is acting as an agent for the consumer, it is called the energy management agent (EMA). This model accommodates an EMA with features of artificial intelligence to facilitate energy management.

The EMA determines power allocation in part based on distributed energy measurement devices on premises. The system equipment can be stand alone, embedded in other consumer electronics, or hosted as an application in a gateway. This gateway can be a generic communications interface between a home network and an external network, an energy management gateway designed for handling energy-related data, or the HES gateway specified in the ISO/IEC 15045 series.

INFORMATION TECHNOLOGY –
HOME ELECTRONIC SYSTEM (HES) APPLICATION MODEL –

Part 3: Model of an energy management system for HES

1 Scope

This part of ISO/IEC 15067 focuses on a model of a system in homes and buildings that can manage energy consumption and generation of electricity by devices on premises dynamically in response to electricity availability from:

– sources within the home or building such as solar panels, wind turbines, or storage (stationary or mobile),
– neighbourhood microgrids,
– transactive energy,
– energy aggregators, and
– public utilities.

This document specifies a model including a framework and methods for energy management consisting of interconnected elements that can be configured to support various methods for a Home Electronic System (HES) energy management system. The methods specified are intended to be generic and representative of a wide range of situations. This document applies to the customer grid-edge portion of the electricity grid (within a home or building) and applies even if the consumer has sufficient local power generation to operate without connecting to a public utility.

This document includes an energy management model that balances power supplied from internal and external sources with demand from appliances and electric vehicle chargers. The model offers flexibility for locating the energy management equipment in a stand-alone product, embedded in consumer electronics, or hosted in a gateway. This gateway can be a generic communications interface between a home network and an external network, an energy management gateway designed for handling energy-related data, or the HES gateway specified in the ISO/IEC 15045 series.

This model specifies a local controller that achieves the allocation of power in accordance with available supplies, consumer preferences for appliance operation, and power requirements of these appliances within constraints set by the consumer. Such constraints are typically financial (a budget for electricity) but can also include goals such as using green sources and minimizing their impact on climate change. This controller is called the energy management agent (EMA) since it acts as an agent for the consumer. This model accommodates an EMA with technology of artificial intelligence to facilitate energy management.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 10192-3:2017, *Information technology – Home Electronic System (HES) interfaces – Part 3: Modular communications interface for energy management*

ISO/IEC 14543-2-1, *Information technology – Home Electronic System (HES) architecture – Part 2-1: Introduction and device modularity*

ISO/IEC 15045 (all parts), *Information technology – Home Electronic System (HES) gateway*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1.1
application cluster
logically related group of components that provides the functions of an application in a home or building

3.1.2
demand charge
total amount billed for demand in accordance with the relevant conditions of the tariff or supply agreement

Note 1 to entry: A demand charge for electricity is typically based on the peak power consumed during a specified interval of time, subject to a time-smoothing algorithm.

[SOURCE IEC 60050-691:1973, 691-03-05, modified – Note 1 to entry has been added.]

3.1.3
demand response
action resulting from management of the electricity demand in response to supply conditions

Note 1 to entry: "Demand response" includes a variety of methods for matching the demand for electricity to the available supply.

[SOURCE IEC 60050-617:2011, 617-04-16, modified – Note 1 to entry has been added.]

3.1.4
direct load control
demand response via remote control of one or more appliances by a utility or third-party service provider

Note 1 to entry: With direct control the utility uses a communications network or other signalling method (e.g. a signal embedded in the power service line) to control appliance operation remotely.

3.1.5
disaggregated bill
utility bill that shows energy consumption by major appliances

3.1.6
distributed load control
demand response based on dynamic price for electricity, event notices, or other information sent from the utility to smart appliances or to an energy management agent

3.1.7
DR supplier
utility or third-party supplier of demand response energy management services

3.1.8
electricity grid
electricity supply network

3.1.9
energy management agent
set of control functions that manage energy use, generation, and storage as an agent for the occupants

3.1.10
energy management gateway
residential gateway facilitating energy management agent services

3.1.11
energy reliability
enhanced availability of energy enabled for example by business and technical procedures

3.1.12
HAN device
device located in the home that can communicate via a home area network (HAN) wirelessly or via wires

Note 1 to entry: HAN is defined in ISO/IEC 15045-1. A wired HAN can use cabling specified in ISO/IEC 11801-4.

3.1.13
HES gateway
electronic device that transfers messages among wide area networks (WANs) and home area networks (HANs) providing interoperability, privacy, security, and safety in accordance with the requirements of the ISO/IEC 15045 series and the ISO/IEC 18012 series

Note 1 to entry: For an HES gateway, a WAN is a network outside the protected area and a HAN is a network within the protected area.

3.1.14
local load control
demand response via publication of time-of-use electricity rates

Note 1 to entry: With local load control the utility typically informs customers of the electricity rates by a notice sent with the electricity bill or via simple electrical signalling to a user interface such as various coloured lamps at the customer premises and does not directly control appliances. The customer would be able to use these rate data to select the times for an appliance to operate.

Note 2 to entry: In some implementations the utility sends a signal across the grid to a receiver at the premises that switches device operation between at least two different states in accordance with the electricity tariff.

3.1.15
major appliance
household device using large amounts of energy compared to other appliances

Note 1 to entry: Examples include an oven, microwave, refrigerator, cooking range, washing machine, and dryer, which are also called "white goods". Most of the appliances listed use relatively large amounts of power when operating in some modes. Therefore, these appliances are candidates for energy management.

Note 2 to entry: "White goods" is a term used in the appliance industry for major appliances because many such products are sold in white cabinets.

3.1.16
premises energy resources
PER
distributed energy resources located on premises

3.1.17
residential gateway
communications function that interconnects two or more networks using different communication protocols, with at least one network outside the premises and one or more networks inside the premises

3.1.18
smart appliance
home appliance that exchanges command and control data with other units on a home area network (HAN)

Note 1 to entry: Depending on the application, smart appliances can communicate via the HAN with other appliances, with an application controller, or with a utility for energy management. Smart appliance specifications are under development by appliance manufacturers and trade associations.

3.1.19
smart grid
electric power system that utilizes information exchange and control technologies, distributed computing and associated sensors and actuators, for purposes such as:

- to integrate the behaviour and actions of the network users and other stakeholders,
- to efficiently deliver sustainable, economic and secure electricity supplies

Note 1 to entry: Some smart grids integrate into the electric grid excess power generated locally from sun and wind-driven devices.

Note 2 to entry: Technically, a grid is a network. However, in common usage the term "smart grid" refers to the entire energy system, which includes generation, transmission, distribution, and customer systems.

[SOURCE: IEC 60050-617:2011, 617-04-13, modified – The notes to entry have been added.]

3.1.20
supply indication
static or dynamic signal or message related to electricity supply

3.1.21
transactive energy
system of economic and control mechanisms that allows the dynamic balance of supply and demand across the entire electrical infrastructure using value as a key operational parameter

[SOURCE: ISO/IEC TR 15067-3-8:2020, 3.28]

3.1.22
value-added services
optional services that can be related to energy offered by a utility, possibly for a fee

3.2 Abbreviated terms

CFL	compact fluorescent lamp
DER	distributed energy resources
DR	demand response
DRAM	Demand Response and Advanced Metering Coalition
DSL	digital subscriber line
DSM	demand-side management
EEMS	electrical energy measurement system
EMA	energy management agent
EPRI	Electric Power Research Institute
EV	electric vehicle
FC	fuel cell
FM	frequency modulation
HAN	home area network
HES	Home Electronic System
HVAC	heating, ventilation and air-conditioning
IoT	Internet of Things
LED	light emitting diode
PER	premises energy resources
PV	photo-voltaic
RTP	real-time pricing
SB	stationary battery
TOU	time-of-use
UPS	uninterruptible power supply
WAN	wide area network

4 Conformance

This document specifies a framework including a model, principles and methods for premises-based energy management that constitute an HES energy management system.

The framework for an HES energy management system specified in Clause 5 shall be implemented to support one or more of the methods for energy management specified in Clause 6. The chosen methods shall be based on one or more energy management use-case models in 7.2 and 7.3. Message exchanges among elements of the HES energy management model shall be based on the generic messages specified in 7.4. Message set formats (syntax and semantics) for energy management are specified in other HES standards such as the ISO/IEC 14543-3, ISO/IEC 14543-4 and ISO/IEC 14543-5 series.

The elements of the HES energy management framework shall include an energy management agent (EMA) specified in 5.3 and interfaces to some or all of the following equipment.

a) On-premises equipment:
   1) energy sources such as solar and wind power;
   2) energy storage (stationary or mobile);
   3) appliances and electric vehicle charging stations;
   4) HVAC equipment;
   5) energy measurement devices.

b) Off-premises equipment:
   1) energy service provider such as
      i) microgrid,
      ii) aggregator,
      iii) power utility;
   2) energy sources and storage at another home, building, or local facility.

These equipment interfaces enable the EMA to perform energy management for the user by exchanging data such as pricing, quantity of energy available during a specified time interval, and fuel type in order to determine how and when to control energy consumption.

NOTE 1 Which method of energy management is chosen is subject to local regulations and market conditions. In some countries, approvals from government regulators are needed for the implementation of energy management programmes such as demand response by public utilities.

NOTE 2 Access to energy sources and storage at another home or building enables users to engage in transactive energy markets by sharing or selling excess power, which can be facilitated by the EMA.

5 HES framework for energy management

5.1 HES energy management elements and model

The framework for energy management supports premises-based energy generation, storage, and consumption with options for exchanging energy with entities operating on an external grid. The external grid provides access to microgrids, aggregators, energy service providers including public utilities, and consumers offering to share or sell excess power through transactive energy.

This document accommodates consumers who choose to operate with grid connection, with limited grid connection or with no grid connection:

– islanded: no external grid connection, at least some of the time;
– prosumer: external grid connection to sell or buy power some of the time;
– consumer: external grid connection to buy power all the time.

The basis for choosing a grid connection depends on costs and consumer preferences regarding generation fuels and greenhouse gas emissions. For example, grid power sources can include fossil-fuel power generation plants, nuclear plants, wind turbines, hydro-electric power plants, or solar power farms. On-premises power generation sources are usually solar and wind powered.

According to IEC 60050-617:2017, 617-04-20, the term distributed energy resources (DER) means "generators (with their auxiliaries, protection, and connection equipment), including loads having a generating mode (such as electrical energy storage systems), connected to a low-voltage or a medium-voltage network". Most common usage of the term DER implies locally situated equipment. To add precision to the term DER and to avoid confusion, this document introduces the term PER for premises-based energy resources including local power generation and storage elements.

In this document power distribution on premises is carried by a "power bus", optionally connected directly to an external grid. In some cases the power bus and the grid do not use the same electrical parameters. For example, some power buses can carry DC power as generated by solar panels and stored in batteries.

Efficient interaction of energy management in premises (homes and buildings) with the power buses and PER requires a common model for

– the elements of an electrical power system,

– measurement points to manage the energy flow within the premises, and
– the interfaces between premises control systems, power bus systems, and PER.

Figure 1 depicts a generalized, logical, on-premises energy management framework model that shall be the basis for any implementation of an HES energy management system. It shows the system architecture and interrelationship among the elements. When applying this model to a specific home or building, the elements needed vary in accordance with the presence of devices such as smart appliances, local power generation, local energy storage, and sensors.

NOTE The HES energy management model is similar to the model of a building energy management system presented in Annex A.

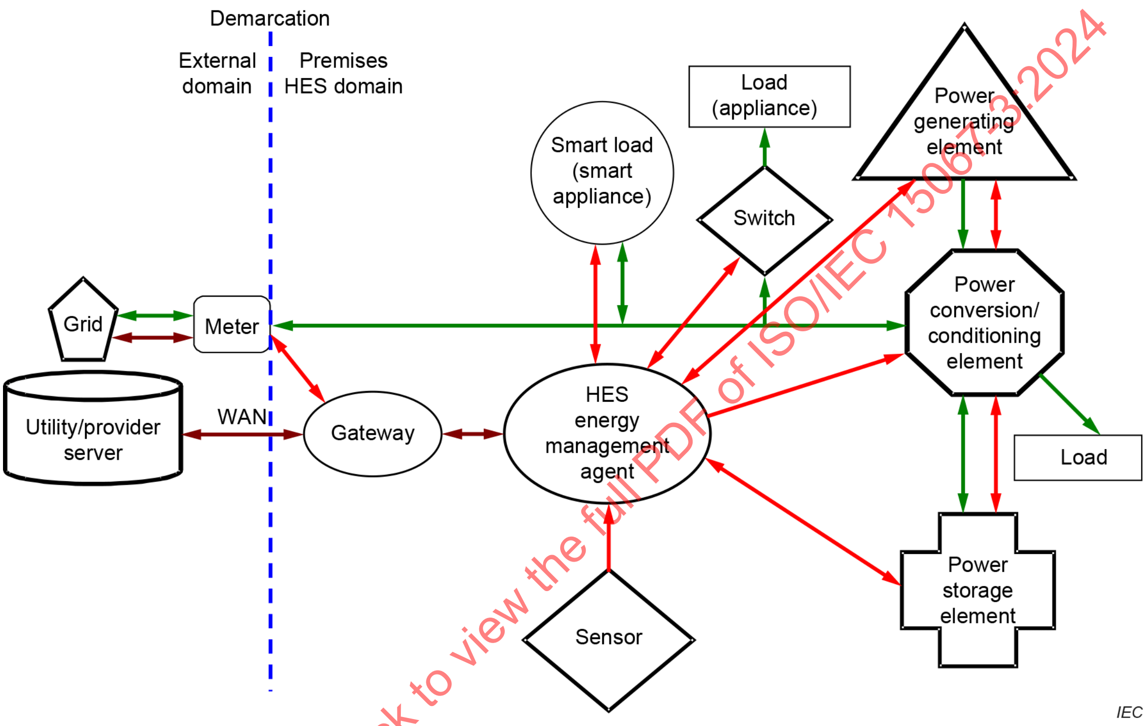


Figure 1 – HES energy management framework model

Each element is identified by one of the following unique graphical shapes:

Power using elements that communicate via a HAN:

– communicating appliances or other loads

Power using non-communicating elements:

– non-communicating appliances or other loads

Power controlling and sensor elements:

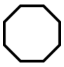
– sensors, switching actuators

Power generating elements:

– solar PV, wind turbines, generators, fuel cells, other PER

Power storage elements:

– batteries, flywheels, electric vehicles, other PER elements

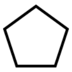


Power conditioning or power conversion device:

– inverters, chargers, power factor compensators, etc.

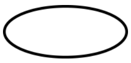
Utility elements – power exchange:

– utility meters, utility WANs, service entrance



Grid elements:

– generators (fossil fuel, nuclear, wind turbines, hydro-electric, solar power), transmission, and distribution



Communication network elements:

– gateways, energy management agents (EMAs)

HAN data

Power

WAN data

The green arrows represent electrical power paths, and the red and brown arrows represent communication paths. These paths can be two-way or one-way. The demarcation line is the boundary between the HES domain and the external domain. The optional WAN is any external access network (e.g. Internet access via fibre, cable, wireless, DSL, etc.). The optional utility-supplied meter provides the grid connection and premises service entrance for electricity. The grid communications network and home network do not usually use the same communications protocol. As explained in 5.6, the EMA can be designed as a separate device or reside inside consumer electronics or a gateway.

5.2 HES energy management protected environment

To protect consumer privacy, the EMA shall provide for the disclosure of the minimal amount of data in order to engage in a power transaction with grid entities. For example, a prosumer would disclose the amount and time of energy available to the grid in order to participate in transactive energy or in a programme where an energy service provider (typically a public utility) purchases consumer power usually with net-metering or a feed-in tariff. There shall be no requirement for the consumer to disclose details about locally-generated power that is consumed on premises. However, energy data disclosure requirements can be subject to government regulations and contractual obligations with energy service providers.

NOTE Messages and communication protocols within the HES domain are specified in various HES standards. WAN communications are specified by other protocols including ISO and IEC standards.

5.3 HES energy management agent (EMA)

The HES energy management agent (EMA) is an electronic controller that assists the user to manage energy. It is called an agent because it processes and executes the preferences of the user regarding which appliances to operate and when, subject to constraints the user imposes, such as limits on:

– expenditures for electricity;
– types of fuels and sources;
– greenhouse gas emissions.

An HES energy management system shall contain one or more EMAs in accordance with the operating environment including appliances, possible PER and EV charging stations, appliances presenting significant loads, and external electricity supplies from microgrids, aggregators, prosumers, and public utilities. ISO/IEC 15067-3-3 specifies multiple interconnected EMAs for HES energy management in an apartment complex consisting of a campus of buildings. The interaction procedures and messages between EMAs are specified in ISO/IEC 15067-3-31 for co-operation and co-ordination among EMAs.

5.4 Electrical energy measurement system (EEMS)

Integral to the HES energy management system is the ability to measure and modify system performance including premises use, generation and storage of electricity. Traditionally, electricity consumption is measured only at one point, namely, the electric meter. Electric utilities supply and manage electric meters at the demarcation point (e.g. at the service entrance to the premises where the electricity service line from the distribution grid is terminated). Electric meters with remote reading access are often known as "smart meters". The primary function of smart meters is customer billing using government-approved metrology methods and technologies. The sensor elements in the HES energy management model enable local power measurements at the point-of-use by selected appliances to facilitate the decisions made by the EMA for allocating power based on consumer service desires and goals. Locations where local power measurements are recommended and should be installed include:

– solar and wind power generation (at the input to an inverter);
– stationary batteries;
– mobile batteries in electric vehicles (EVs);
– appliances, EV charging stations, and other loads;
– utility or aggregator power via the grid;
– transactive energy using a private power feed.

These energy measurements are primarily intended to enable effective energy management by providing the EMA with electricity flow data and analysis of loads (application systems or specific appliances), local generation, and storage. Measurement techniques have advanced in accuracy with reduced costs to enable such on-premises measurements. A feature of the Internet of Things (IoT) is the proliferation of low-cost sensors. Power measuring devices proposed for supporting the EMA functions are examples of such IoT-sensor devices. These distributed measurement devices on premises constitute an electrical energy measurement system (EEMS).

5.5 EMA and EEMS functionality

This document specifies an energy management model with EMA and EEMS working effectively together. This model supports the shifting of generation resources in electricity infrastructure deployments from a public utility to locally-based renewable sources that fluctuate with the weather and time-of-day. Measurements of power consumption by major appliance loads are becoming increasingly important inputs so the EMA can allocate power to loads as local supplies fluctuate. These measurement features combined with the computation features of the EMA enable accurate automated energy management so users can balance appliance usage when desired against goals such as staying within a budget or limiting their environmental impact on climate change. If power supplies are constrained by events (such as weather) or too expensive with respect to the user's budgetary limit, the EMA can shift power to critical loads.

5.6 Location of an EMA

Manufacturers of elements of an HES energy management system have flexibility about the location and packaging of the EMA and related components. Figure 2 illustrates the EMA as a separate device. An EMA includes a processing engine and application software that can be located in a dedicated controller, in a personal computer, a cable TV set-top box, or a security system depending on the market development of home controllers and smart appliances.

Alternatively, the EMA can be hosted by the gateway.

6 Energy management methods for the EMA

6.1 Range of methods

Deployment of an HES energy management system is intended to enable consumers to decide among energy sources on-premises and off-premises, energy consumption by appliances and EV charging stations, and energy storage where available. Consumers make these decisions based on their individual mix of

a) local power sources and storage,
b) external power sources,
c) buyers for any excess power generated locally,
d) appliances,
e) EVs,
f) finances, and
g) values regarding their impact on the environment.

NOTE 1 A buyer for excess power can be a transactive energy customer or a utility offering a feed-in tariff.

This document does not limit consumer choice or impose any subjective values; rather it enables manufacturers to offer equipment that assists consumers to make their own decisions including no preference.

An HES energy management system shall be designed with computation functions that implement one or more energy management methods specified in this Clause 6. The methods for energy management can be broadly categorized as consumer-centric and utility-centric.

– Consumer-centric energy management is mediated by premises-based equipment that operates locally to fulfil the wishes of the consumer for electricity service using an EMA.

– Utility-centric energy management consists of programmes offered by public utilities.

As explained, this document specifies networks and equipment that shall provide consumer-centric energy management but can support utility-centric energy management when choices are limited or consumers prefer the utility programmes.

NOTE 2 This Clause 6 provides a framework and model for energy management methods. Implementation details are outside the scope of this document. Additional parts in the ISO/IEC 15067 series are planned for addressing issues of implementation.

6.2 Consumer-centric energy management

6.2.1 Framework for consumer-centric energy management

Figure 2 illustrates the architecture of an HES energy management system conforming to the HES energy management model in Clause 5. The components shown shall be interconnected via a home area network (HAN) in accordance with the architecture specified in ISO/IEC 14543-2-1, thereby constituting an HES network. Devices on the HES network can include home appliances, consumer electronics, sensors, actuators, user interfaces, controllers, EV charging stations, and PER. The HES network can be wired or wireless or a mixture.

NOTE Examples of devices typically involved with energy management include thermostats, HVAC (heating, ventilation and air-conditioning) equipment, displays, major appliances (defined in 3.1.15), EVs, and PER.

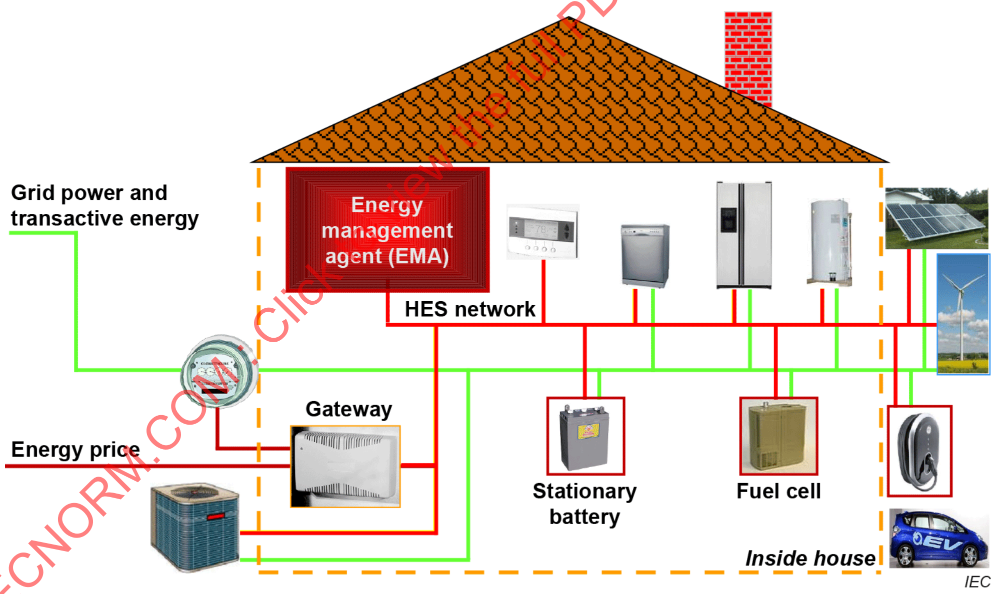


Figure 2 – HES energy management architecture

The EMA is a computing element that shall provide intelligent energy management in accordance with the wishes of the consumer. This is called "consumer-centric energy management" as opposed to energy management provisioned by and controlled by a utility. The benefits afforded by the EMA operating as part of the HES energy management system are explained in 6.2.8.

As the name implies, the EMA shall be programmed to function as an agent for the consumer. The EMA manages electricity from the following sources, as shown in Figure 2:

– locally generated power from solar, wind, etc.;

– locally stored power from batteries and fuel cells (stationary or mobile);

– external power from a grid provider (microgrid, an energy-service provider, or a public utility) or transactive energy from a prosumer (a consumer with excess power produced by local sources).

The specifications presented are intended for an EMA that manages a combination of local energy sources, local storage equipment, external energy sources, transactive energy, energy consuming appliances, EV charging stations, and an EEMS to gather power flow data. Energy management in an environment with fewer options for energy sources and storage can use an EMA with reduced capabilities.

6.2.2 Energy management agent (EMA) parameters

6.2.2.1 Source of EMA parameters

The EMA shall determine which energy sources to select and when to select them from among local generators, local storage batteries, and external sources as available, such as a microgrid, transactive energy, aggregator, and a public utility. Some of the data flows into and out from the EMA are illustrated in Figure 3. Data to inform EMA decisions shall be received by the EMA from the energy sources in real time and from local power measurements. Data to effect energy consumption, local generation, and local storage are issued by the EMA.

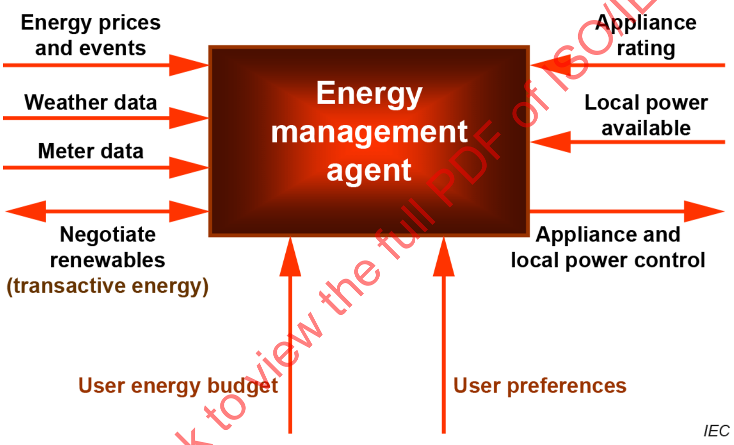


Figure 3 – Energy management agent (EMA) inputs and outputs

6.2.2.2 External EMA parameters

Data from external power sources including availability and pricing data are sent electronically to the EMA in real time over a WAN. Examples of such WANs are optical fibre, telephone, cable TV channels, and wireless (e.g. mobile data networks and FM radio station subcarriers).

These data shall enter the house through the gateway that interconnects a public network using telephone, cable TV, power lines, or radio with an HES network.

Older methods of energy management included direct control by utilities of selected appliances as specified in 6.3.3. The objective is to reduce energy consumption by the house during the period of control. Energy management by the EMA can be influenced indirectly by utility data, but no remote control is exercised. Instead, the utility issues a static or dynamic signal or message related to electricity supply (called the "supply indication") in order to influence customers to make choices about appliances and device operations. Customers can use local controllers to help in these choices. Such supply indications can include the following.

a) Price signals: A multi-level signal that indicates at least two different states corresponding to the electricity price.

b) Time-of-use pricing: A static rate structure (called a tariff) with specified rates that change at specified times in a repeating pattern.

c) Time-of-renewables availability: A notice to consumers about the fuel source for power including greenhouse gas emissions and when power is available from renewable sources.

d) Real-time pricing: Prices that change dynamically. The specific price, time duration of this price and amount of prior notification before this price level is in effect vary by utility practice. "Real-time" is determined by the service provider offering a dynamic pricing programme, a microgrid operator, or a prosumer participating in transactive energy. Real-time can include advanced notification of price changes, such as one or more hours up to one day ahead pricing. These are all called "real-time" in common usage by the electricity industry.

e) Event notices sent by the utility to customers about pending supply limitations that are usually temporary due to supply interruptions or public emergencies.

f) Event notices sent by the utility to customers about temporary rate changes.

NOTE 1 A typical time-of-use tariff can include a high rate during peak usage times (e.g. 07:00 to 10:00 and 16:00 to 19:00, a medium rate during the day (10:00 to 16:00) and a low rate for evenings and weekends. Time-of-use pricing can include a top tier called "critical peak pricing". Time-varying retail prices can respond to market forces as wholesale power prices fluctuate.

NOTE 2 The utility supplier specifies the format and encoding of real-time price and event messages, such as IEC 62746-10-1, which is part of a series under development that addresses utility demand-response programmes interfacing with customer equipment.

6.2.2.3 Internal EMA parameters

Power measurements shall be provided by an EEMS as specified in 5.4 when available. Methods for the EMA to participate in transactive energy are specified in 6.2.7.

The user enters preferences into the EMA for appliance operation, budget, and any other constraints for energy conservation. The user inputs should be primarily entering preferences for home activities that involve energy-consuming devices. The consumer can specify:

– appliance operating preferences (e.g. hot water for bathing at 08:00, air conditioning or heating at 18:00, dish-washing at 20:00, etc.);
– budget constraints;
– power from renewable sources whenever possible; and
– a limit on estimated greenhouse gas emissions that affect climate change.

The specifications of the user interface for the consumer to configure the EMA are outside the scope of this document. The user interface can be an educational tool to explain the relative energy consumption levels of various appliances and can display the actual consumption by major appliances.

6.2.3 EMA functions

The EMA shall process the external and internal parameters, and then shall issue signals that are distributed over the HES network to the relevant energy switches, appliances, and PER. A smart appliance that can operate in energy conserving modes shall react to such signals by altering the operating mode in accordance with the signal and to the capabilities of the appliance. The EMA shall offer the user the ability to override decisions of the EMA unless precluded by a prior agreement with an energy service provider.

The EMA shall allocate available power by determining

– when to operate appliances,
– when to draw power from PER, and
– when to store energy,

based on the data flows shown in Figure 3:

a) the availability of locally generated power and stored energy;

b) appliance power requirements;

c) the cost and availability of negotiated transactive energy;

d) the cost and availability of external power;

e) user preferences; and

f) user constraints, such as

   – budget,

   – greenhouse gas emissions, and

   – carbon footprint reduction.

The EMA acts an intelligent agent for the user to balance the user's goals for economy and emissions with the user's desires for comfort and convenience. The software in the EMA determines which appliances and PER to operate and when. The functional requirements for the EMA are specified in ISO/IEC 15067-3-30. An EMA with the functionality described for customer-centric energy management can be programmed with a sophisticated algorithm using artificial intelligence (AI) features as specified in ISO/IEC 15067-3-51 to optimize appliance performance while meeting user-imposed constraints. Smart appliances that can be programmed or commanded to operate in energy conserving modes can improve the effectiveness of the HES energy management system. With smart appliances the EMA shall have the option of switching these appliances into a conservation mode rather than curtailing them.

6.2.4 EMA control of appliances and PER

The EMA shall allocate power to appliances selected by the installer or the consumer in accordance with priorities established by the consumer, subject to the constraints imposed by the consumer. Power allocation means that the EMA sends messages to these selected appliances that cause them to:

– be enabled or disabled;

– increase or reduce power consumption.

Energy management would be simplified if all appliances were designed with internal controllers programmed for intelligent responses to energy management messages (called responsive appliances). However, the only remote control option for most appliances is to turn them on or off by controlling power flow to the appliance.

Smart appliances should be designed with controllable energy conserving operating, perhaps with reduced functionality. This would be preferable to turning off the appliance to save energy. In reality few appliances and HVAC systems are designed with built-in energy conservation modes that can be requested by the EMA. To accommodate these appliance limitations, the EMA shall be adapted to the local premises environment, which often includes a mix of appliances and application clusters with

– varying degrees of responsiveness to energy commands,

– EV charging stations, and

– local energy equipment (renewables and storage).

Appliances not designed with internal energy management features can be connected to power buses that are wired to a circuit-breaker panel designed for a level of priority services. In a typical residential house or apartment, the appliances are powered from one panel containing all the circuit breakers. It is possible that future electrical distribution configurations will include multiple circuit-breaker panels where at least one is assigned for critical loads. For example, appliances important for human welfare, such as a refrigerator or medical monitor, would be plugged into a high-priority circuit-breaker panel that connects to mains power plus local renewable power sources and energy storage for enhanced resiliency.

The HES family includes a standard interface for appliances that are switchable on/off or amenable to modulation of energy consumption (such as a thermostat adjustment). This is called the modular communications interface (MCI) and is specified in ISO/IEC 10192-3. Conventional appliances not designed for remote control of energy consumption would be plugged into special outlets that respond to remote commands for switching power flow on and off.

The EMA shall also control PER power generation and storage by sending messages that cause power generation and storage devices to

– turn-on or turn-off power generators,
– specify power-up level or power-down level for power generators, and
– specify charge or discharge level for storage devices.

The EMA can include a connection to an external energy supplier for reporting data such as consumption, PER availability, or inverter status. These data would be sent from the EMA via the gateway and a WAN to the supplier. The use of this upstream data link depends on the energy management method chosen by a consumer as part of an agreement with an energy service provider.

6.2.5 EMA protection of privacy

The consumer-centric HES energy management method focuses on managing local resources on premises. The grid becomes an alternative power source to be used primarily for storage – like a battery to be charged and discharged. With the widespread incorporation of PER such homes and buildings would become a generator, user, or store of energy. The HES energy management system enables this energy to be managed first locally (i.e. within the premises), and then within the community, and finally, within the overall grid – or as a part of a semi-autonomous "microgrid", or network of microgrids. Such a perspective greatly reduces the demands on the grid and simplifies the overall control problem.

The EMA shall be programmed to protect the user's privacy by limiting the sharing of energy consumption data. Where appropriate, the privacy policy chosen by the consumer would be able to be enforced by the gateway.

Privacy is enhanced by local power generation and storage. This perspective for energy management does not rely on the utility-fed electrical grid. In some situations, consumers choose not to utilize any external electrical grid connections, with their premises operating completely off-grid or "islanded". Alternatively, the home or building can operate in co-ordination with other premises on a neighbourhood electrical grid (or microgrid) to share resources in a community or to trade resources using transactive energy. This is done without necessarily revealing the user's private data about energy generation and consumption.

6.2.6 EMA and gateway

Figure 2 illustrates the EMA as a separate device for the model but does not indicate actual implementation. An EMA includes a processing engine and application software that can be located in a dedicated controller, in a personal computer, a cable TV set-top box, or a security system depending on the market development of home controllers and smart appliances. Alternatively, the EMA can be hosted by a generic gateway, a specialized energy management gateway, or the HES gateway. If the HES gateway is the host, this gateway shall conform to the specifications in the ISO/IEC 15045 series.

Communications between an external energy provider and the EMA comprise data about the cost of energy and any unusual events requiring a change in power consumption. These data are sent by the energy service provider via the gateway. The gateway should include cybersecurity protection for the premises to ensure that the data originated from the energy service provider. This level of security entails authentication to confirm that the data are from the real source and have not been altered during transmission. It is not usually necessary to encrypt such data since pricing and event data are often public.

NOTE 1 Cybersecurity is a term from information technology (IT) that refers to the availability of and protection of user data, as contrasted with protecting the body or environment of the user. The HES document ISO/IEC TR 15067-4 addresses physical security.

The customer and the utility should agree if and how frequently usage data in aggregate and usage by selected appliances are collected. Any customer usage data sent to an energy service provider should be encrypted by the gateway to establish a secure link so that the data cannot be intercepted by anyone for whom the data are not intended, such as a burglar or unauthorized commercial entity. A potential burglar can use such data to determine a customer's daily activities and occupancy. A commercial entity can use such data to market alternative products.

NOTE 2 The potential impact on customer privacy from the collection of usage data is discussed in C.4.5.

NOTE 3 Regulations can exist with regard to the frequency of data collection.

6.2.7 EMA and transactive energy

The functions of the EMA shall support transactive energy if available. Transactive energy, as described in ISO/IEC TR 15067-3-7 and ISO/IEC TR 15067-3-8, blurs the distinction between power producers and power consumers. Consumers with excess locally-generated power from solar panels and wind turbines can sell the excess to buyers who live in a nearby house or manage an office building in the community. There are many technology and business issues to be resolved before transactive energy becomes a reality. Among these are:

– a marketplace for buyers and sellers of power to find each other;
– a financial system to price electricity delivered now (spot market) or later (futures market);
– a delivery pathway from seller to buyer, such as using the existing distribution grid;
– a possible transport price for using the distribution grid or a private grid;
– a system with data security for settling or paying for transactions;
– a legal framework to allow transactive energy (generally not permitted now).

Consumers will probably not be involved in trading power like stocks and bonds. Automated equipment will act as agents for residential users and building managers. Such functions would be able to be built into the EMA, thereby expanding the options for locating power to meet customer preferences within the customer's budget and other constraints. As shown in Figure 3, transactive energy data are included as a source and sink of external power for the EMA allocation algorithm.

6.2.8 EMA benefits

The EMA concept and architecture are a consumer-centric approach to the generation and distribution of electricity. The EMA offers consumers personalized control of energy consumption, which is not practical from a centralized utility demand-management programme. The home or building is no longer just a utility rate-payer, but an autonomous entity that generates, uses, and stores energy – like a recreational vehicle or a boat. EMA-based premises can be interconnected to form a microgrid, which in turn would be able to be interconnected to form a community web of microgrids that provide mutual support through transactive energy.

Some consumers co-operate with utility programmes for conservation and load shifting in the short run if they perceive there is a crisis. However, in the long run effective energy management should be an automatic daily activity that integrates with appliance operation. To reach this goal with a high level of adoption requires an operating scenario that is almost invisible so it does not interfere with consumer comfort and convenience. The EMA provides the intelligence in the HES energy management system that enables this functionality.

The EMA is intended to relieve the user of learning technical details. Instead of engineering parameters such as kilowatt-hours (kWh) and market tenders for transactive energy, consumers are presented with a few choices. Whether these choices resulted from a simple demand response programme or a complex market-based transactive energy programme is not important to the consumer. The EMA shall be programmed to hide complex technology from users by delivering useful functions without the user being aware of the complexity. The EMA offers consumers a simple system for energy management even with the advent of price fluctuations and transactive energy.

Energy management tailored to the needs, values, and budget of the consumer is the reason for embedding the EMA in the HES energy management model. A system based on this model seamlessly blends energy supply data from local and public sources with automation embedded in appliances or appliance agents, and a simple user interface. The objective is to hide the complexity while making the operation transparent so the user understands the options and the outcomes, without needing to know how the functions are accomplished.

The consumer benefits by attaining maximum convenience for appliance operation while controlling electricity costs and greenhouse gas emissions. There is no need for the consumer to know details about time-of-use or demand-based electricity rates. The customer can override the EMA and be informed of the cost impact. Thus, the consumer is insulated from technical issues while making simple economic decisions.

The user decisions are simple, while consumer privacy and convenience are not compromised. As a result, buying energy becomes no more complex than shopping at a store. The following scenario is an example of how a user can interact with a system that incorporates an EMA for energy management. It is 16:00 and the user is about to run the dishwasher. The options in Figure 4 can appear on an appliance display panel.

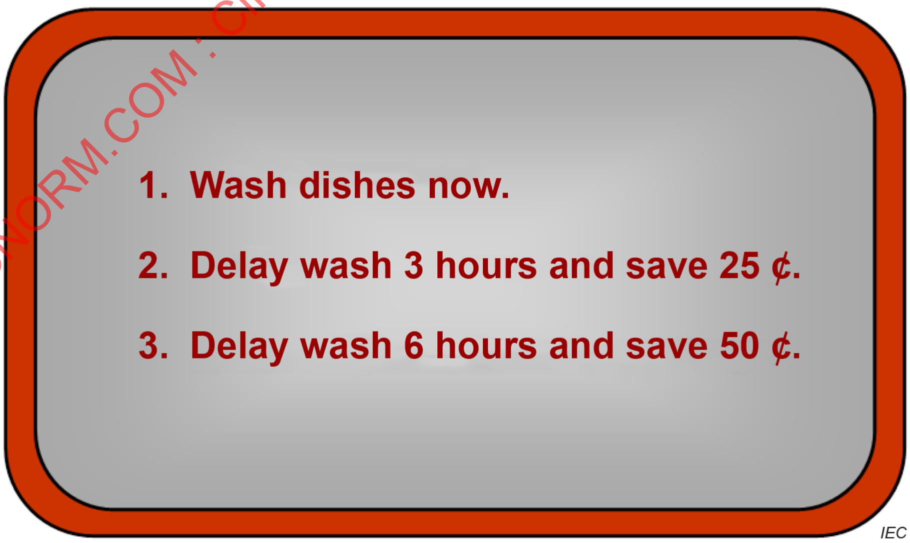


Figure 4 – Simple consumer choices

The user makes a simple decision based on criteria that are understandable: "Do I need the dishes cleaned in the next three hours (perhaps for a dinner party at 19:00), or can I wait and save some money?" This makes buying energy as simple as shopping at a retail store.

6.2.9 Additional EMA services

6.2.9.1 EMA and grid stability using PER

Annex B describes additional EMA functions that would enable an HES energy management system to participate in maintaining external grid stability. Some energy service providers such as public utilities offer a programme for remote management of PER and power conditioning or power conversion subsystems in the house. Participation in such programmes can be voluntary or mandated by local regulations.

6.2.9.2 Value-added services

External EMA communications and automated meter reading require two-way communications between customers and a utility or a third-party energy service provider. Some utility or third-party service providers use the same communications pathway to offer optional additional services to benefit consumers. Services that are not essential for power delivery are called value-added services. Examples of value-added services are presented in Annex D.

NOTE The choice of value-added service and revenue arrangements depends on the utility, the market, and local regulations.

6.3 Accommodating legacy energy management

6.3.1 Utility-centric energy management

The electricity industry involves a massive investment in capital and equipment. This industry has deployed one of largest engineering systems in history with much success. Therefore, the changes proposed for shifting to customer-centric energy management are being approached cautiously by the industry. Utility-centric energy management is included in this document to accommodate existing customer programmes as a prelude and transition stage to consumer-centric energy management.

For most of the twentieth century public utilities tried to maintain electricity supplies to meet all customer demands. Some utilities developed demand-side management (DSM) and later demand response (DR) programmes to achieve grid balance when supplies were strained due to fuel shortages, generation limitations, or grid capacity. In the twenty-first century DSM and DR are being replaced with DER, PER, and islanded energy management systems. Nevertheless, if the consumer has choices limited to DSM or DR, or prefers one of these energy management programmes, a system based on the HES energy management model shall be capable of supporting such programmes.

Demand response (DR) is a form of demand-side management (DSM). DSM is described in Annex C. DR uses incentive-based and indirect methods for controlling how much electricity is consumed during a specified time interval by end-devices such as water heaters, air-conditioners and appliances. The more innovative methods of load control depend on market forces for exerting control by varying the price of electricity at the retail level in accordance with market conditions with limited or no advanced notice to customers.

One or more demand response (DR) methods shall be implemented when an electric utility determines that DR would address a mismatch between the supply and demand for power and a customer agrees to participate. An electric utility or other provider (also called "third-party supplier") of energy management services shall choose one or more of the methods described in the following list to design a demand response system in order to influence the customer's use of power. The methods include (starting from the simplest)

– local load control,
– direct load control,
– prices-to-devices, and
– distributed load control.

The term "distributed load control" was introduced in ISO/IEC 15067-3:2012 and is replaced by "consumer-centric energy management", as specified in 6.2.

Some customers can implement multiple demand response systems in parallel depending on the capabilities of the appliances, the communications networks and the availability of auxiliary equipment such as an EMA. Separate communication channels (logical connections) can be implemented for each demand response programme.

6.3.2 Local load control

Utility suppliers choosing local load control shall issue supply indications using price signals (6.2.2.2 a)) or time-of-use pricing (6.2.2.2 b)).

NOTE 1 For price signal indication the utility sends a signal across the grid to a receiver at the premises. The user decides how to direct this signal to end-devices. These devices can switch device operation between at least two different states in accordance with the electricity tariff indicated by the price signal. This signal can be delivered via an interface in an electric meter.

NOTE 2 For time-of-use (TOU) pricing the TOU tariff rates are usually published for customers prior to implementation of the TOU rates and prior to any changes of the TOU rates. The method for publishing TOU can vary by utility. Utilities typically deliver TOU pricing data to the customers via a mailed letter or electronically to a user interface for display or to a residential gateway. The purpose of publishing such pricing is to motivate customers to alter or shift the demand for electricity. Customers often need guidance to help them select which appliances to operate and when, in order to avoid peak power charges, or have such functions done automatically.

6.3.3 Direct load control

To implement direct load control (described in C.4.1), the utility or third-party supplier of demand-response energy management services (collectively called the DR supplier) shall send control signals to interrupt the operation of selected devices such as air conditioners and water heaters remotely from outside the house.

NOTE 1 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 min to 15 min each half-hour for up to six hours each day. Water heaters are generally turned off entirely for 2 h to 6 h.

Appliances and devices such as thermostats that participate in direct load control shall include internal or external communication interfaces to receive and execute electronic commands sent by the utility. Figure 5 illustrates the architecture of direct load control. Not all appliances participate in direct load control, such as the television and the kitchen appliances shown in Figure 5. The utility is usually responsible for installing connections to those appliances under direct load control. These connections are labelled "home network" in Figure 5. This home network is used exclusively for direct load control. Such a network possibly consists of separate wires from the gateway to each controlled appliance. The gateway for direct load control converts control signals from the grid to on/off signals for appliance actuators.

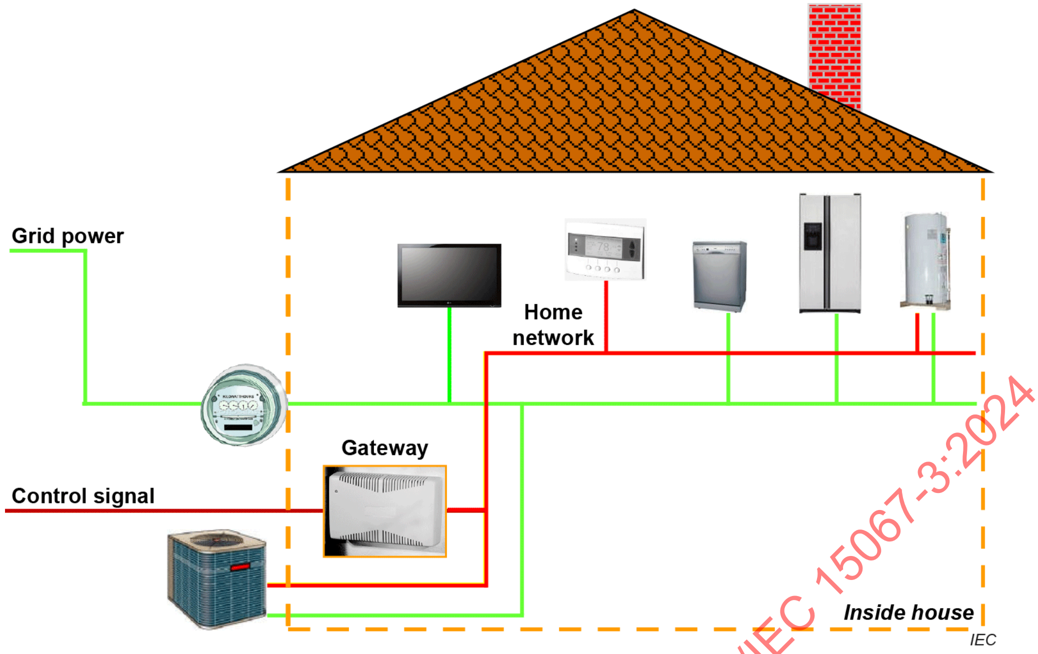


Figure 5 – Direct load control

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 document. If the customer denies permission for direct load control, the customer can opt out of a direct load control programme.

NOTE 2 Direct load control is subject to agreements or contracts between utilities or service providers and customers.

The elements to generate, encode, transmit, decode and execute direct load control data for the purpose of energy management include communication interfaces and a communications network. These elements are outside the scope of the framework in this document and are usually selected by the utility to be the same for all customers. Nevertheless, within the home, the HES gateway (ISO/IEC 15045 series), HES networks (ISO/IEC 14543 series) and interfaces (ISO/IEC 10192 series) are recommended if accommodated by the direct load control programme.

6.3.4 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. Figure 6 illustrates the architecture of distributed load control using prices-to-devices. The gateway provides protocol translation between the utility WAN and the HAN. If the customer denies permission for prices-to-devices, the customer can opt out of the programme or configure connected appliances or the gateway to ignore pricing data.

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

– load reduction in a limited number of levels;

  NOTE The number of energy reduction levels is determined by the appliance manufacturer after considering the design, usability, functionality, and market condition of the appliance. For example, four or five possible power consumption levels would be able to be specified.

– adjusting the operating temperature of an appliance or the set point of a temperature-controlling appliance.

EXAMPLE 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 to resort to full power usage or different energy consumption modes.

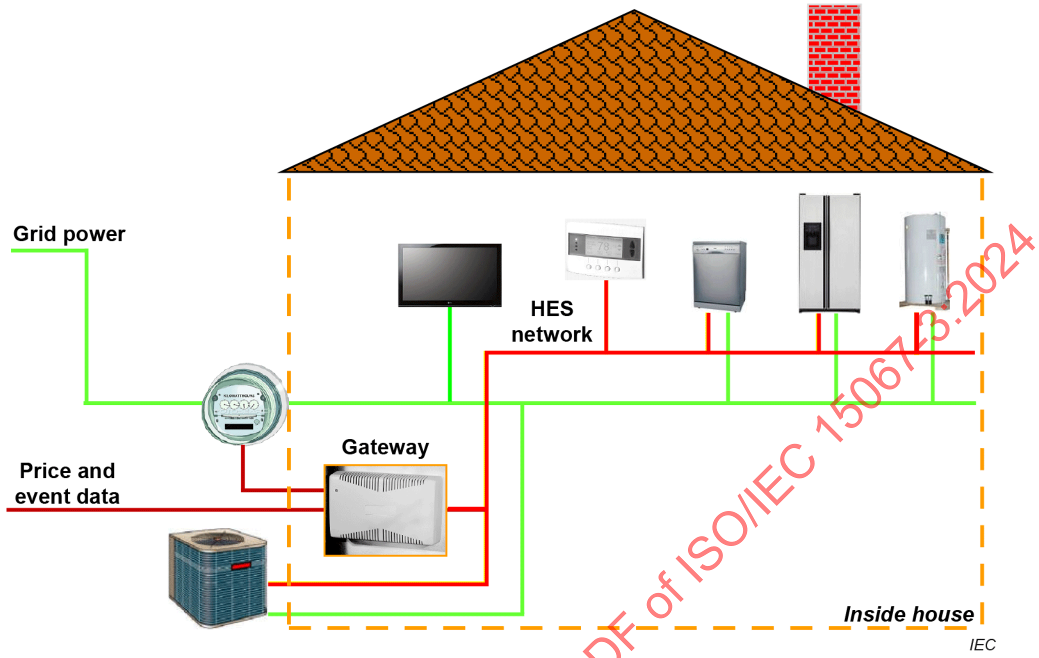


Figure 6 – Price-to-devices

The absence of the EMA precludes allocating limited energy among the smart appliances involved in prices-to-devices. Instead, each appliance responds independently to utility price data. Therefore, the energy management effectiveness of prices-to-devices is limited by

– the capabilities of algorithms designed into smart appliances, and

– the lack of a whole-home management of energy provided by an EMA to allocate power among the appliances.

7 HES energy management use-case models and messages

7.1 Introduction to energy management use-case models and messages

The methods for energy management using the HES energy management framework in 5.1 are described in Clause 6. In this Clause 7, each application method is explained in words and illustrated with physical and logical models. These models are based on the elements of the HES energy management model. The logical models in this document are intended to show the relationship among these elements without implying a particular design or installation.

Since the consumer-centric model builds upon and expands the utility-centric models, the utility-centric models are presented first. Information flows to support these models are included. Use-case models of the utility-centric HES energy management options described in 6.3.1 are specified in 7.2. 7.3 specifies generic logical and physical models for the consumer-centric HES energy management system described in 6.2.1. Generic messages exchanged between the elements of the HES energy management models supporting the use cases are specified in 7.4.

In the following cases, reference is made to power and kilowatts. 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). The materials presented here constitute a framework for energy management and are not specific to a particular HAN communications protocol. A formal lexicon for energy management elements will be specified in a future standard (ISO/IEC 18012-3).

7.2 Logical and physical models for utility-centric HES energy management

7.2.1 Structure of utility-centric management models

Models for utility-centric methods introduced in 6.3.1 are presented here. In these use cases, the EMA is not present because the utility can send information

– non-electronically to the customer,
– electronically to a utility-supplied user interface, or
– electronically by a direct signal to appliances as agreed by the customer (including appliance actuators, such as thermostats).

7.2.2 Case 1: local control

Local control is illustrated in Figure 7 and Figure 8.

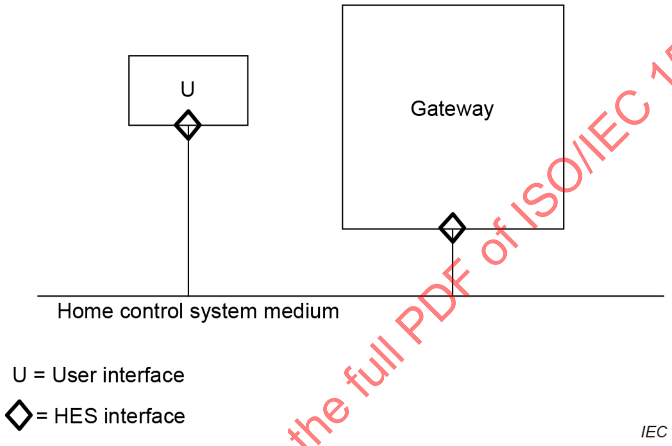


Figure 7 – Case 1: local control, physical model

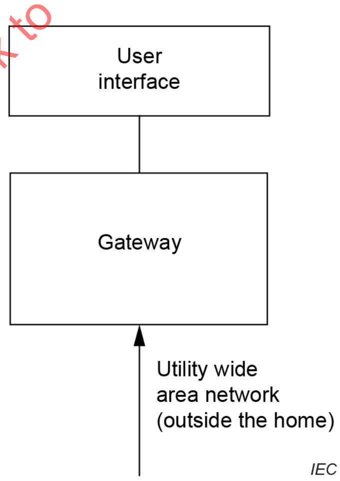


Figure 8 – Case 1: local control, logical model

Some local control schemes involve no electronic 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 can 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. It is possible for the latter rate to be unusually high in order 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 real-time pricing associated with distributed control.

In all of these variations of local control, the possible communication messages, if there are any, between the utility and the customer consist of an indication of which price level is in effect. Therefore, signals flow in one direction from the utility via the gateway to a user interface, as illustrated in the physical and logical models. The user interface, typically supplied by the utility, can consist of indicator lamps on a special unit with markings to indicate whether peak or off-peak or any intermediate rates are in effect. The signals controlling this user interface are usually not available for customer equipment such as an EMA.

7.2.3 Case 2: direct control without supervision

Direct control without supervision is illustrated in Figure 9 and Figure 10. Some direct-control programmes use proprietary communications from the utility to the appliances being controlled, thereby bypassing the gateway, HES network, and HES interfaces.

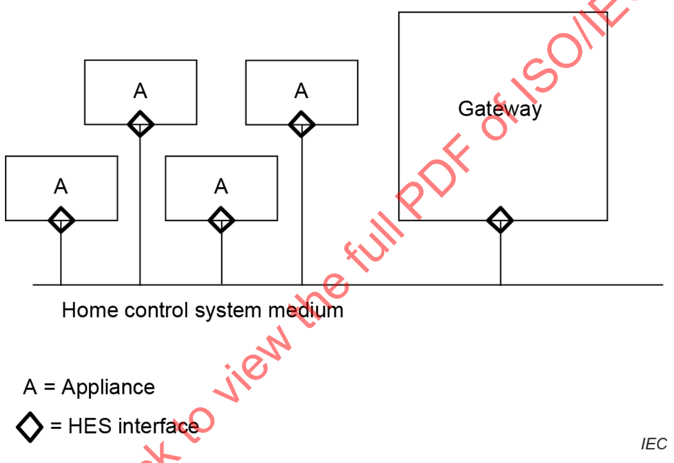


Figure 9 – Case 2: direct control, physical model

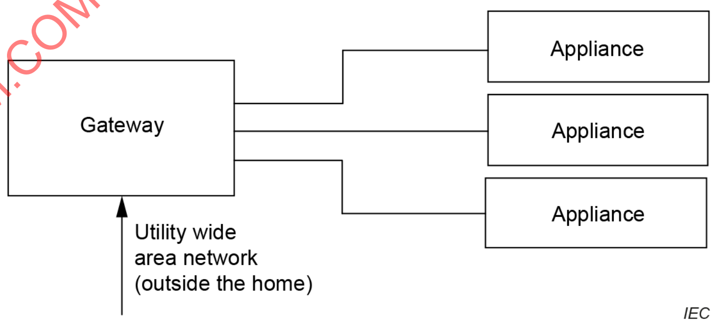


Figure 10 – Case 2: direct control, logical model

The utility enables or disables the operation of specific appliances. This case is representative of direct load control. Many direct-control programmes consist of one-way communications from the utility to the customer appliances, as illustrated in Figure 10. The utility messages are usually limited to specifying which appliance is to be turned-off or to be restored to operating status. The utility does not know if the control signal actually reached the appliance or if the appliance was operating. An improved option for direct load control schemes includes acknowledgement that the control signal was received.

7.2.4 Case 3: direct control with supervision

7.2.4.1 Case 3: physical and logical models

Direct control with supervision is illustrated in Figure 11 and Figure 12.

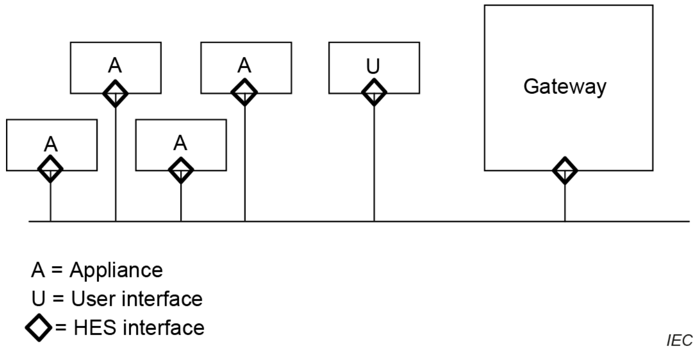


Figure 11 – Case 3: direct control with supervision, physical model

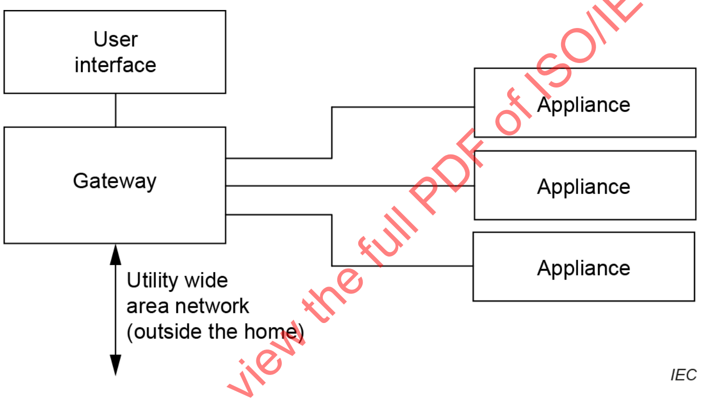


Figure 12 – Case 3: direct control with supervision, logical model

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": 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 power during a specified interval. The following expanded set of messages supports Case 3. A user interface is included because some implementations allow the user to override a direct load control signal. A cost penalty is usually assessed for overrides.

7.2.4.2 Utility information flows for supervised direct control

The following messages are sent from the utility for enhanced methods of direct load control.

- 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 can indicate the maximum level of operation (e.g. temperature) allowed instead of sending a turn-off signal. This can consist of a specified reduction in the power 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 can be told when the next control time is likely after the present one is being announced.
– The priority level of the control. The customer should always have the option of overriding the control.
– The approximate cost consequence if the customer overrides the control. The customer is not expected to have an EMA. Appliance interaction is conducted by the utility via a sophisticated gateway. This gateway also controls any display device involved in direct load control.

7.2.4.3 Customer information flows for supervised direct control

The following messages are sent from the customer or from customer equipment.

– 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 min, or should 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).

NOTE The typical power consumption would be able to change with time. The amount of power that can be shed by load control is an average value. This set of values depends on the appliance design and demand response programme.

– 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. An unpowered (off) device can or cannot respond with this message.
– Customer acceptance or rejection of utility plans to control a specific appliance. A reason for rejecting direct load control can be provided: customer choice, life-safety device, device out of service, etc.

7.2.5 Case 4: utility telemetry services

Utility telemetry services are illustrated in Figure 13 and Figure 14.

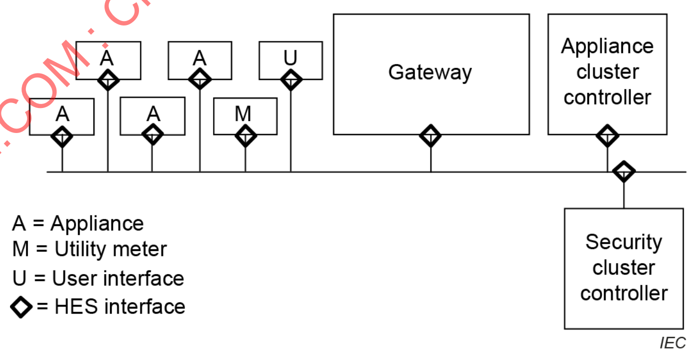


Figure 13 – Case 4: utility telemetry services, physical model

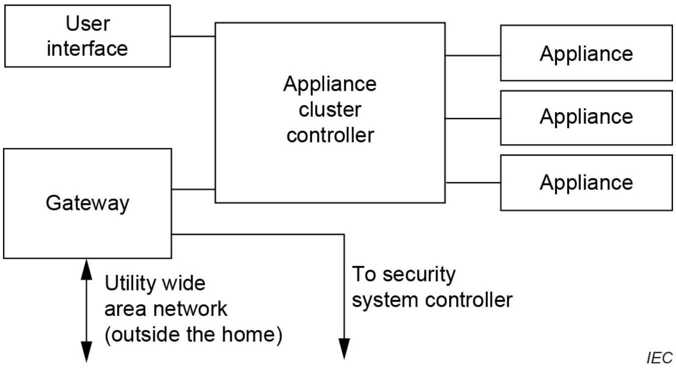


Figure 14 – Case 4: utility telemetry services, logical model

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 gateway and one or more local application cluster controllers, similar to the EMA. The local controllers, shown in Figure 13 and Figure 14 as an appliance cluster controller and a security controller, exchange messages with specific appliances or an application cluster controller, as specified in ISO/IEC 10192-4-1.

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 will possibly allow the utility to download special test sequences into the appliance or into the EMA. 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, is the quantity of data to be communicated between the utility and the customer. The control channel (Class 1) of HES is not intended for large volumes of data. It is important to allocate an information channel, defined in the HES architecture, for this purpose.

7.3 Logical and physical models for consumer-centric HES energy management

7.3.1 Structure of consumer-centric management models

The typical components for energy management are shown as the physical model of components sharing an HES HAN in Figure 15. The logical relationship among the components of an HES energy management system is illustrated in Figure 16. The gateway is the logical boundary between the WAN outside the home, which can be used for energy management data and the HAN inside. The HES interface shall be the modular communications interface specified in ISO/IEC 10192-3.

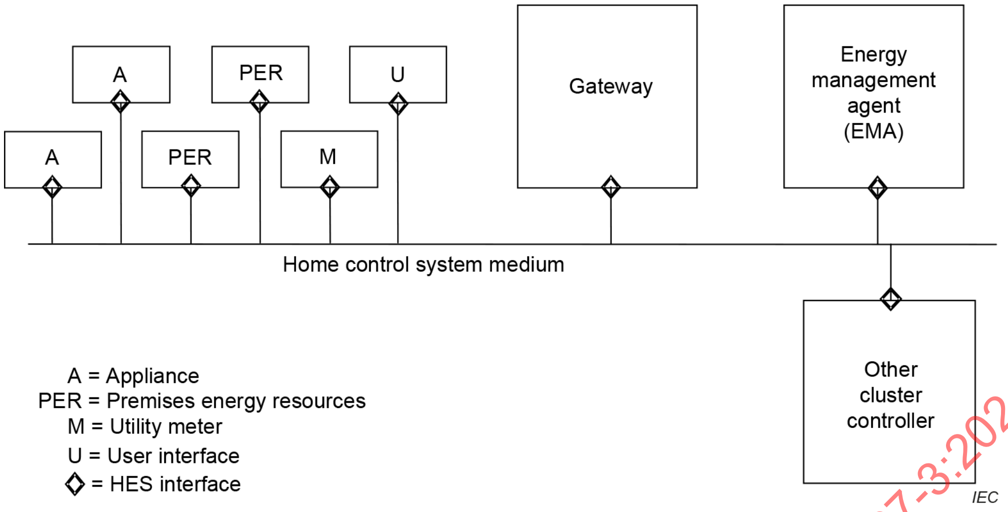


Figure 15 – Customer-centric HES energy management, physical model

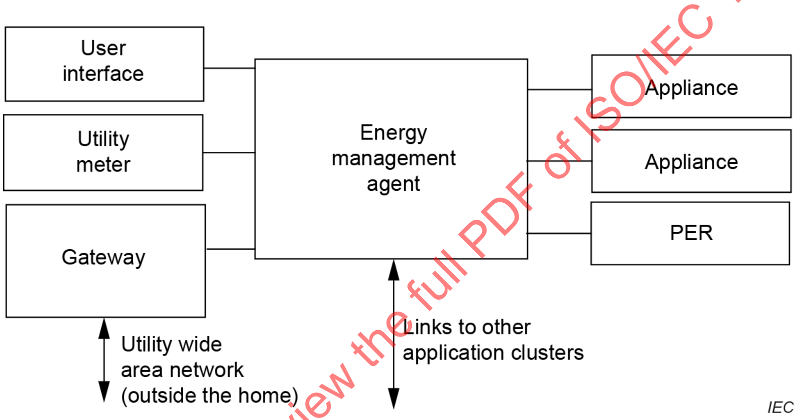


Figure 16 – Customer-centric HES energy management, logical model

Energy management is one of many application clusters possible in HES. As shown in Figure 16, the EMA can be linked to other HES application clusters including a master common user interface that can co-ordinate HES applications. Examples of co-ordination include scheduling and application-cluster interaction. The co-ordination function is specified in ISO/IEC 10192-4-1. This function can be located in an application, as a separate device, or hosted in the gateway.

7.3.2 EMA information flows

EMA information flows to appliances and PER depend on the capabilities of these devices. For example, some appliances can be designed to respond to on and off messages while more advanced appliances can allow the EMA to designate an operating mode that draws a specified amount of power. Also, messages can flow from the appliance to the EMA.

The signals between the EMA and appliances 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 EMA can calculate the cost consequences of appliance and PER operation.

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

The same set of messages between the EMA and appliances is required as defined in Case 3 in 7.2.4.2. The following additional messages are needed.

a) From the EMA:
   1) data about the cost of operating the appliance in the operating mode requested by the user;
   2) data suggesting operating modes and costs that will save money;
   3) a request to reduce average power 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 to stop operating completely. Others would be able to operate in specified modes, as directed by the EMA;
   4) which PER will be controlled (turned-on, charge or discharge), when, how long and how much;
   5) for PERs that have multiple levels of power generation, such as FCs, the EMA can indicate power-up or power-down.
b) From appliances connected to the EMA:
   1) confirmation of the mode of operation set by the user;
   2) manual operation of the appliance or the PER by the user;
   3) user request to override control of the EMA;
   4) power being consumed by the appliance, being stored by the battery, being generated by the PER or power being provided by the battery. This information can be compiled for bill disaggregation: a bill that shows how much power each major load is consuming. Also, the utility can request that these data be uploaded for a load survey.
c) Automatic adaptation to real-time pricing
   1) It is possible that some appliances will eventually be able to adapt energy consumption in accordance with the price of electricity directly. This means that part of the algorithm planned for the EMA will possibly be built into future appliances.
   2) The messages between the EMA and the appliance convey the current price and the anticipated duration of this price level.
d) Emergency load control
   1) The utility issues an emergency notice that supplies are limited and a specific level of power consumption should not be exceeded. The EMA would be able to 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.
   2) It is possible that an intelligent appliance is 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.
   3) The utility commands to the EMA specify the maximum power availability and the time allowed to shed loads. The EMA should confirm acceptance of the power reduction within the specified time or the customer can be disconnected from the grid.

e) Power consumption:

1) 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 should be outfitted with power meters. It is possible that current meters are adequate if the appliances are primarily resistive loads.

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

3) The utility can choose to communicate with the EMA to request power recording and to upload data accumulated by the EMA. The controller would be responsible for gathering and averaging the data and producing a summary report.

7.4 Messages for HES energy management

7.4.1 Overview of HES energy management messages

The following messages are specified 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 shall support the features of each message. Messages shall be chosen in accordance with the needs of a specific implementation. These messages represent a variety of functionality, not necessarily implemented in any one system.

The objective of this message set is to provide a bounded set of choices for HES energy management messages to facilitate interoperability. This document specifies choices from a bounded set. A developer of an interoperability framework based on ISO/IEC 18012 can write XML schema with a manageable data set. A future standard that will include a lexicon of these messages is under development (ISO/IEC 18012-3).

7.4.2 HES message list

7.4.2.1 General

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

7.4.2.2 Gateway ←→ user interface

The user interface can indicate one of a set of predefined price levels for energy. Alternatively, the user interface can display price data, changes in the price tiers and applicable times.

NOTE 1 Predefined price levels would be able to be indicated by multiple lamps, each corresponding to a level. Price data, changes in price tiers and applicable times would be able to be displayed in characters or graphical images sent by the utility via the gateway.

Messages sent to the user interface contain the following data:

a) on or off

1) Turn on the addressed indicator lamp in the user interface.

2) Turn off the addressed indicator lamp in the user interface;

b) rate tiers, or unusual conditions;

c) cost of override.

NOTE 2 The intent is to inform consumers of the cost of overriding a direct load control signal.

NOTE 3 Manufacturers have flexibility to choose user interfaces for displaying pricing data. Such data can be presented in a text string or using graphical icons.

7.4.2.3 Gateway ←→ appliances

Messages sent between a gateway and appliances:

a) on/off messages
   1) Turn off the addressed appliance for a specified duration.
   2) Turn on the addressed appliance.

   NOTE 1 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.

b) Level of consumption
   1) Limit the addressed appliance operation to a specified maximum power for a specific duration.
   2) Remove any power restriction from the addressed appliance.

c) Time of restriction
   1) Notify the addressed appliance of the start time of a specified restriction and the anticipated duration.
   2) Notify the addressed appliance how often a specified restriction will be instituted.
   3) Notify the addressed appliance about the start time of a specified restriction after the present restriction ends.

d) Priority of restriction
   1) Assign a priority level to the addressed appliance for future on/off or restriction messages.

   NOTE 2 It is assumed that there is prior agreement on the number and meaning of priority levels.

e) Appliance report
   1) Request specified report from addressed appliance.
   2) Provide requested report from addressed appliance to the gateway.
   3) 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 in 7.2.4.

   NOTE 3 The format of the reports consists of parameters that can be identified by field position or by keyword.

7.4.2.4 Gateway ←→ HES EMA

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

a) Rate data update
   1) The EMA queries the gateway for the availability of new rate data.
   2) The gateway responds with the time and date of the last rate update.

b) Rate data
   1) The EMA queries the gateway for a download of rate data.
   2) The gateway downloads the rate data.

NOTE 1 The format of the data will be defined. It would be able to follow the format used for wide area communications between the utility and the gateway.

NOTE 2 The rate data can include fuel type and time-of-renewables availability.

7.4.2.5 EMA ←→ appliances, PER

The following messages between an EMA and appliances or PER equipment depend on device capabilities.

a) Appliance or PER capabilities

   1) The EMA queries an addressed appliance or PER about device information and energy requirements.

   2) An appliance responds to a query from the EMA with static information (see Case 3 in 7.2.4) 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 can indicate that the appliance is in a critical mode that should not be interrupted or involved with life-safety operations.

   3) A PER responds to a query from the EMA with rating information including data about nominal energy generation (W), maximum energy generation (W), minimum energy generation (W), remaining electric power (kWh, %) and momentary charge or discharge electric power (W), current (A), voltage (V).

b) Appliance control

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

   2) The EMA requests the addressed appliance to resume operating without any mode or power restriction.

   3) The addressed appliance responds with acceptance and confirmation or rejection of the request from the EMA or indicates that it is turned off, out-of-service, or under manual control.

   4) The EMA informs an addressed appliance about the cost of rejecting the previous request for energy consumption reduction.

   5) The EMA informs an addressed appliance about recommended operating modes with various degrees of conservation.

c) PER control

   1) The EMA requests the addressed PER to turn-on, discharge and power-up to switch the electricity source of some loads from the grid to the PER.

   2) The EMA requests the addressed PER to turn-off, standby and power-down to switch the electricity source of some loads from PER to the grid.

   3) The EMA requests the addressed PER to charge in order to have the PER store electricity.

   4) The addressed PER responds with acceptance and confirmation or rejection of the request from the EMA with a reason (out-of-service, user override, etc.).

   5) The EMA informs an addressed PER about the cost of rejecting the previous request for energy generation.

d) Appliance energy consumption

   1) The EMA requests that an addressed appliance report energy consumption for the previous specified time interval.

   2) The addressed appliance responds with the energy used (kWh) or indicates that it was off or out-of-service.

e) PER energy generation

   1) The EMA requests an addressed PER to report energy generation for the previous specified time interval.

   2) The addressed PER responds to a query from the EMA with

      i) static information including data about measured cumulative generated power (Wh),

      ii) measured cumulative exported power (Wh),

      iii) a history of momentarily measured generated power (W),

      iv) measured momentary exported power (W),

v) measured cumulative charge or discharge electric power (Wh), and

vi) a history of momentarily measured charge or discharge electric power (W), current (A) and voltage (V).

7.4.2.6 EMA ←→ user interface

The following messages specify user interactions with the EMA.

a) User inputs
   1) Numerical data providing a monthly energy budget.
   2) Appliance operating preferences by appliance name, mode of operation, times of operation and priority relative to other appliances.

b) Displays for user
   1) Numerical data about monthly energy consumption with optional bill disaggregation by major appliance.
   2) Numerical data about the present and projected energy tariff.
   3) Optional displays for energy management system configuration.

NOTE Interactive menus would be able to configure the energy management system as appliances are added and deleted. A future network management computer would be able to handle automatic configurations.

7.4.2.7 EMA ←→ meter

The following commands apply to electronic meters with communications capabilities.

NOTE It is possible in some installations that the meter functions as the gateway. Therefore, commands defined for the gateway would be able to be appropriate here.

a) From EMA
   1) EMA requests consumption data from the meter for a specified period and peak usage (the demand), if available.
   2) Additional parameters can be requested depending on the meter functionality.[1]

b) To EMA
   1) The meter responds with consumption data, demand data and applicable time period.
   2) Additional data can be returned depending on meter capabilities and requests from the EMA.

7.4.2.8 EMA ←→ other controllers

Controllers can communicate messages for co-ordination or to announce unusual conditions requiring action by other controllers.

NOTE For example, the EMA would be able to request that an HVAC unit reduce energy consumption. If the home automation network includes an HVAC applications controller, the EMA message would 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.

1. In the United States, ANSI C12.19 specifies a set of tables with parameters that define meter capabilities. A meter manufacturer selects 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.

Annex A
(informative)

Building energy management

To facilitate the comprehension of the HES energy management model, an example of a building energy management system is presented in Figure A.1. The functions are very similar to the HES model using typical equipment icons. The grid communications network and building network do not usually use the same communications protocol.

The building control system manages the power source and power sink entities in the building in accordance with rules set by the building operator. The operator considers the availability of locally-generated power and information provided by the utility via the data associated with the power exchange entity.

The HES energy management model does not assume the presence of a building operator. In the HES environment, one or a combination of the following entities participates in performing energy management:

– locally-generated and stored power;
– a local microgrid or aggregator or utility;
– devices in the home such as the energy management agent (EMA);
– electrical energy measuring system (EEMS);
– smart appliances; and
– the user.

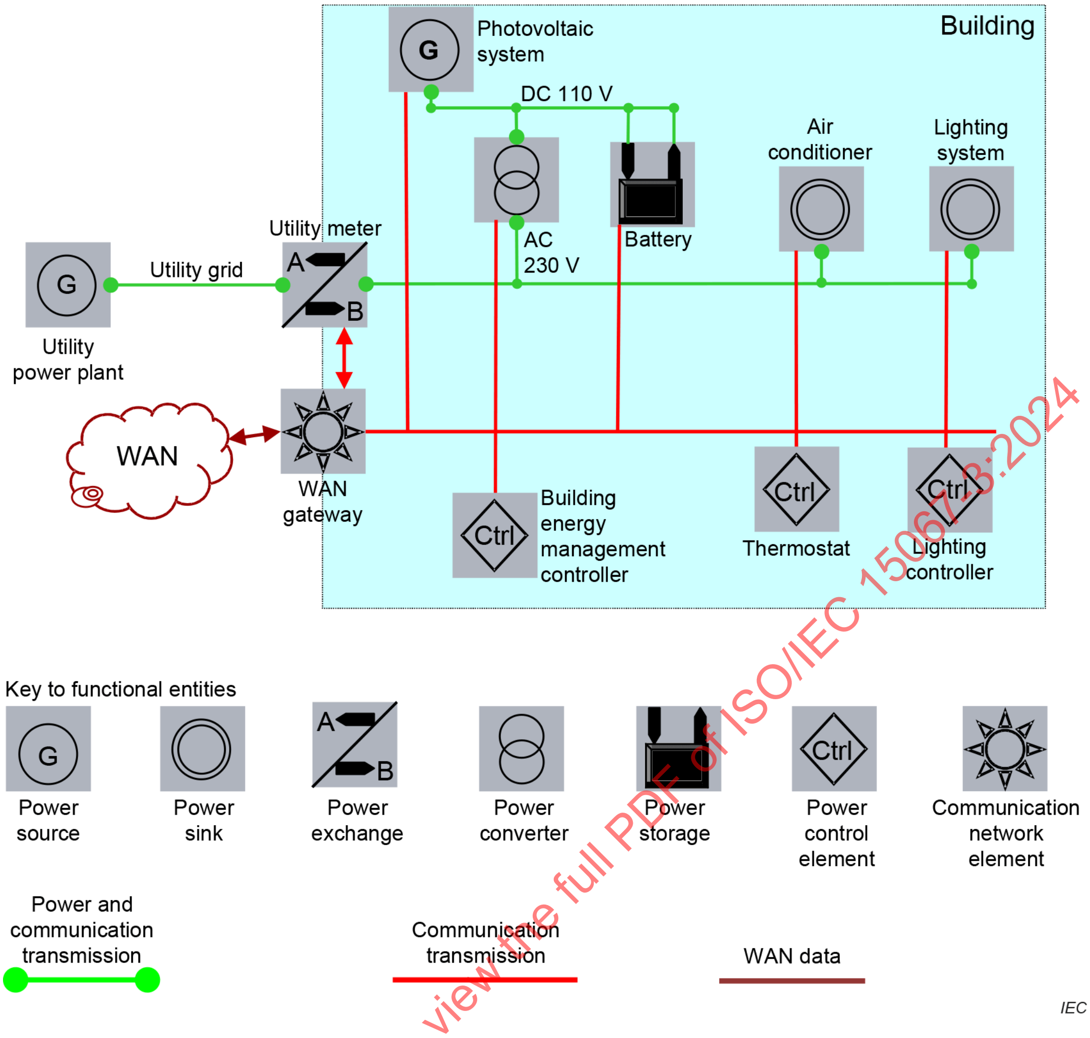


Figure A.1 – Example of building energy management