Research on Energy Management System for Home Microgrid Applications

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I. Research Background and Goal

As the penetration rate of renewable energy increases, with the integration and application of heterogeneous energy sources, the construction of home microgrids and the planning and design of user-side power management systems play an important role. In light of this, this study has analyzed and researched the establishment of household microgrids and energy management systems. In addition to building energy management systems, our research also connects energy creation, energy storage, and smart appliances to establish household microgrids. It introduces automatic demand response (OpenADR communication protocol) and domestic home appliance TaiSEIA communication protocol to realize various system function applications.

This study selected the company's Fengshan dormitory area display house and Shulin District test site to complete the construction of smart home microgrids. The details of both demo sites are explained as follows. (1) Fengshan dormitory area display house focuses on low-carbon energy saving and completes the development of a smart energy management system. In addition to monitoring the power consumption data from the smart meter AMI and each circuit of the switchboard, users can also remotely control smart home appliances on the platform. It combines solar energy and energy storage and adopts optimal power dispatching logic to replace the electricity from the grid when solar power generation is sufficient. With that, users can achieve net-zero energy consumption. The smart energy management system can also automatically transition to island mode, where the power supply is continued by energy storage and solar energy when the power is off-grid to achieve smart power dispatching and provide more comprehensive home smart microgrid applications. In addition, the platform also integrates the voice control function of home appliances, significantly improving the convenience of smart homes. (2) In the test site of Shulin District, in addition to completing the construction of the energy management system to realize the aforementioned functional applications, it also completed implementing the OpenADR communication model developed by TPRI. Integrating the energy management system and the OpenADR module has successfully established the communication path between the user and the electricity industry side, allowing users to participate in different low-voltage user demand-side management measures with energy storage equipment to provide various demand response execution strategies. The facilitation of smart home applications that balance energy saving and comfort can help the development of low-voltage demand-side management measures in the future.

II. Experimental Results

This study completed various household microgrid and energy management system platform functions (as shown in Figure 1), including:

1. AMI real-time monitoring: The show house is equipped with an AMI smart meter. Through the Route B communication module, users can obtain minute-by-minute electricity consumption data through the web page and mobile APP and conduct electricity consumption self-management.

2. Home IoT integration: The show house is equipped with household solar energy, energy storage equipment, AMI smart meters, and various smart home appliances that support the TaiSEIA 101 communication protocol to create a home Internet of Things (IoT) and apply energy management strategies.

3. Electricity usage visualization: The show house's HEMS website can instantly display power information, such as power consumption data from each circuit of AMI smart meters and switchboards, solar power generation curves, and energy storage charge and discharge curves.

4. Low energy consumption management (lower electricity bills) strategy: To improve energy efficiency, the show house adopts an automated low-energy management strategy with "solar energy as the main component, energy storage as a supplement" to reduce the system load peak at night and save electricity bills.

5. Islanding/grid-connected test: The show house automatically activates the island operation mechanism when the main power is off-grid. The emergency/important loads will be supplied by solar energy first, followed by energy batteries.

6. Smart speaker integration: The show house is equipped with Google nest mini 2 smart speakers integrated with smart home appliances. Users can perform function settings such as turning on and off home appliances or switching operating modes through voice.

7. Smart life scenario: Through the mobile APP, users can experience smart home functions

(1) Before users return home in summer, the air conditioner and related smart appliances are automatically turned on, allowing the users to enjoy a comfortable environment.

(2) Automatically detect environmental humidity, air quality, and other factors, and turn on home appliances such as dehumidifiers and air purifiers.

(3) View the energy storage and real-time power consumption of each circuit through the power overview.

8. Automatic demand response: Using the OpenADR 2.0b communication protocol, the energy management system allows users to choose any solution such as air conditioning control, energy storage power supply, air conditioning and energy storage joint execution, etc., and then displays the ADR execution process in real time through dynamic visualization, which can be synchronized in real-time. It also calculates and updates information, such as the energy storage system and the current unloading power.

Source: Taiwan Power Research Institute, TPRI

Figure 1. Home energy management system (HEMS) information platform