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Making the traditional Home Smart

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Abstract. The forced PV generation sometimes produces surplus that can't be used. The Demand Side Management (DSM) has an important role in the balance realization of the load and generation in the power system. The small scale but large number household power management applications have reasonable effect on the national level power balance.
In this paper we introduce the wireless implementation of the Household Control Box function where the traditional household appliances (air conditioner, air heater, washing machine, hoover, PhotoVoltaic inverter are controlled by microcontroller board.
Although several compact smart home control solutions exist our approach is to make an universal open system available for all general, non- completely automated flats.

Keywords. Demand Side Management, microcontroller, household appliances, smart home, Raspberry Pi

1. Introduction

The rise of renewable energies sometimes goes beyond the original objectives. In Hungary, the amount of installed PV generation capacities (8000 MW) exceeds the system load (7000 MW) (see fig.1.). This creates regulatory and commercial situations that are difficult to manage. Excess production flows out of the country. All solutions that help to use the surplus PV production at the right time come to the fore. The goal is to shift more consumption into the PV production period. The solution presented below is the rescheduling of consumption in an average household. It is average, because intelligent devices are available everywhere today. If we can temporarily settle 1000 W in a household, then we can manage 1000 MW in 1 million households.

Beside the traditional centrally controlled power system structure occurred the distributed control strategies [2][3][4][5][6][7].

In recent years, due to technological development, significant changes have taken place in the operation of households. Smart home systems offer solutions that make everyday life more comfortable, safe and energy efficient. These systems connect home devices and enable remote control, automation and monitoring. Smart home technology isn't just part of luxury. It is increasingly driven by the need for sustainability and energy efficiency. Smart systems not only provide comfort but can also make a significant contribution to optimizing energy consumption, for example by using the energy produced by solar panels more efficiently or by regulating heating systems based on ambient temperature.

This project aims to put the smart home concept into practice, creating a system that is cost-effective, easy to install and widely accessible. The central unit, which uses Home Assistant software running on the Raspberry Pi 5 hardware, allows uniform control of devices from different manufacturers. This not only increases the convenience of users but also provides a solution to compatibility issues between different platforms.

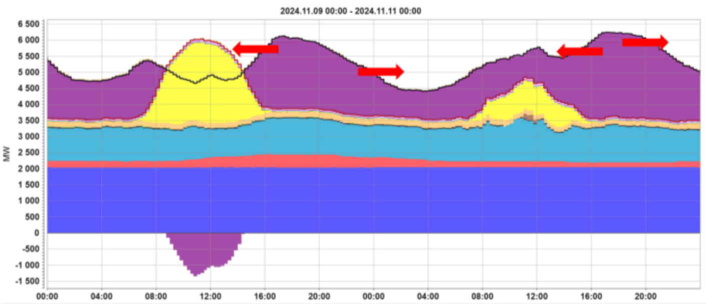

Fig. 1. The task is to pull the load to the right time [10]

2. Advantages of smart home systems

- Energy efficiency and cost savings: Smart systems can be used to optimize energy use, for example by automatically turning off lights in empty rooms or timing household appliances for lower-priced periods. By increasing energy efficiency, overhead costs can be reduced.
- Convenience and automation: Remote control of home devices via mobile apps or voice control simplifies everyday activities. Automations can be created, such as scheduled cleaning or heating control.
- Increase security: Smart security systems, such as cameras, motion sensors, and smart locks, constantly monitor the home. Notifications are sent to the owner when suspicious activity is detected.
- Sustainability and environmental protection: The integration of energy-conscious solutions and renewable energy sources such as solar panels contributes to reducing the ecological footprint. By optimizing local energy use, the loss associated with transporting energy is reduced.
- The uptake of smart home systems is currently hindered by a number of factors, such as high initial investment

costs and lack of compatibility between devices from different manufacturers. Our project offers a solution to these problems by creating a platform that is low budget, universal and easy to integrate.

- The ultimate goal of the project is to create a sample system that can be applied in practice and provide a basis for further development. This system can not only increase the energy efficiency of households, but also contribute to the wider application of smart technologies in Hungary and worldwide.

A. *Technology background*

The Home Assistant Software is an open source home automation platform that allows you to consistently control and automate smart devices from different manufacturers. The platform is especially popular due to:

- Universality: Compatible with almost all smart devices, be it lighting, thermostats, security cameras, or home appliances.
- Modularity: Offers over 2000 integrations that allow you to manage devices based on different protocols such as WiFi, Zigbee, or Z-Wave.
- User-friendly interface: It has an easy-to-understand, customizable interface that can display all tools and processes in a single control panel.
- Automation options: Many automation rules can be set in the system, for example based on events, timings, or sensor signals. In Home

B. *Home Assistant*

Home Assistant can be run on many platforms, such as: Raspberry Pi (4 or 5 models are recommended due to resource requirements). Virtual machine or Docker container on a PC. NAS systems such as Synology. In the present project, the Raspberry Pi 5 was selected because: Cost-effective (price around 50-80 USD). It provides Home Assistant with decent hardware performance, including a fast processor and expanded memory.

C. *Raspberry Pi 5 hardware introduction*

The Raspberry Pi 5 is a compact and versatile mini-computer that is ideal for smart home projects (see Fig.2.). Key features:

- Processor: Quad-core ARM Cortex-A76, 2.4 GHz, which provides fast computing power.
- Memory: Available in 4 GB or 8 GB RAM version, enough to control dozens of devices simultaneously.
- Storage: expandable with microSD card and support for M.2 SSDs is available.
- Connectivity: WiFi 6 support for fast and reliable wireless connection of devices. Gigabit Ethernet port that provides a stable network connection.
- Power consumption: Due to its low power consumption, it is ideal for continuously running systems. Technology details of WiFi communication: WiFi communication plays a key role in the operation of smart home systems, as it allows devices to be connected via the local network. The 2.4GHz and WiFi network is used in the project because: It has better wall permeability than the 5GHz network. It is widely supported among household WiFi devices.
- Pros: Easy integration: Most smart home devices natively support WiFi, eliminating the need for separate hubs (as is the case with Zigbee). Fast data transfer: Communication over WiFi ensures fast response times, especially for simple operations such as turning lights on and off.
- Cons: Interference: Other WiFi devices such as laptops or mobile phones can load your network. Security risks: WiFi-based devices must be protected with appropriate encryption (e.g. WPA3).

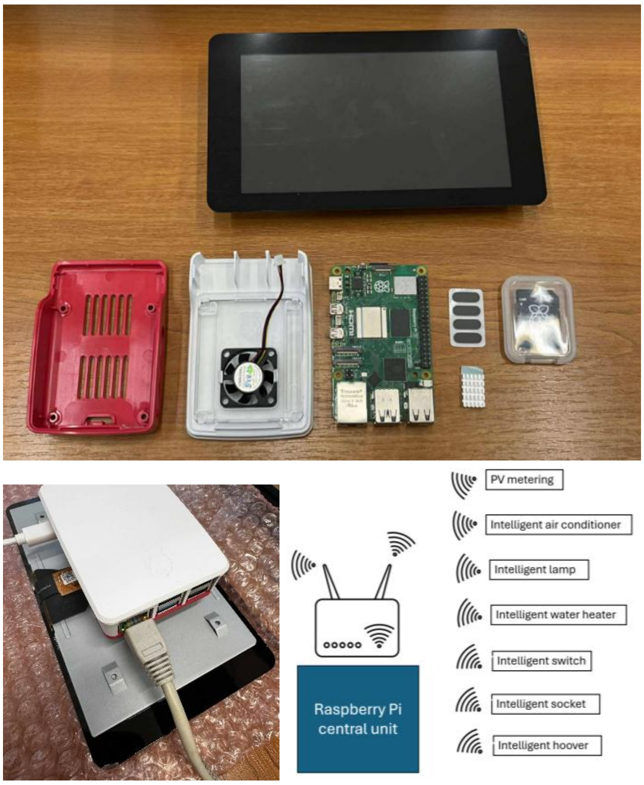

Fig. 2. The Raspberry Pi central unit

D. *Introduction of Sonoff devices*

The project uses Sonoff-branded devices that offer cost-effective, WiFi-enabled solutions. Most popular devices:

- Sonoff Basic: Easy on/off relay, for example to control lighting.
- Sonoff TH16: Relay combined with temperature and humidity sensor, ideal for heating systems.
- Sonoff POW R2: Used to monitor and control power consumption.

These devices are connected via WiFi and can be easily integrated into your Home Assistant system via the eWeLink app. Zigbee and Z-Wave protocol at a glance Although the project is currently WiFi-based, it is important to mention other common communication protocols.

Zigbee:

- Low power consumption.
- Mesh network capability that extends the range of the network.
- Ideal for battery-powered devices such as sensors.

Z-Wave:

- Very reliable communication, less interference.
- Support for long-range devices.

Both protocols are supported in Home Assistant, which gives you flexibility for future expansions.

The technological background presented here provides a stable basis for the implementation of smart home systems. The simplicity of WiFi communication combined with the flexibility of Home Assistant provides a cost-effective and reliable solution that meets the needs of most households.

3. The Household System's elements

In the laboratory of the university in frame of a student project, we set up a demonstrative Household, with several WiFi connected intelligent household appliances. The scalable and flexible system has the following elements:

- Solar feed in
- Mains feed-in: connection to local low-voltage distribution network
- Storage/battery
- Controller
- High power household devices as
  - washing machine
  - vacuum cleaner
  - air conditioner
  - refrigerator
  - tumble dryer
  - water heater
  - wall connector, etc.
- Low power and not reschedulable household devices as
  - lighting
  - ventilation
  - security function
  - background music, etc.

In this project, we build a smart home system in which we use Sonoff devices to control various household appliances via WiFi. The centerpiece of the system is the Raspberry Pi 5, which runs Home Assistant software. Our goal is that our everyday household appliances, such as washing machines, coffee machines or lamps, can be controlled and automated remotely, thus making our daily lives easier.

The Raspberry Pi 5 Central Unit is an excellent choice to run Home Assistant because its powerful processor and extended memory capacity allow you to control dozens of devices at once. Its price is about 50-80 USD The first step is to download the Home Assistant OS and then write it to a microSD card using the Raspberry Pi Imager. Once we insert the microSD card into the Raspberry Pi, we connect it to the network (Ethernet or WiFi) and then turn on the device. After the first settings, we access the Home Assistant interface (e.g. http://homeassistant.local:8123) through a browser, where we make further configurations. Sonoff devices are cost-effective and easy-to-use WiFi-compatible relay modules that can be used to control various household appliances.

- Sonoff Basic: This device can be used to turn simple household appliances such as lights and fans on and off. Its price is about 7-10 USD.
- Sonoff TH16: Module with temperature sensor, ideal for controlling heating or water heater.
- Sonoff POW R2: This device allows you to monitor and control power consumption, so it can be used, for example, to control washing machines or electric heaters.

Fig. 3. Intelligent sockets, switch, lamps and hoover

Fig. 4. Water boiler, 3 phase meter for PV metering and air conditioner

Sonoff devices are connected directly to the power supply of a particular household appliance. Once the devices are connected, they are connected to the WiFi network using the eWeLink app. The integration of devices into the Home Assistant is carried out using the eWeLink integration or perhaps using the Tasmota firmware if you want custom control.

Is it possible to control household appliances via WiFi

- Washing machine (e.g. LG ThinQ compatible models): LG ThinQ-compatible washing machines, such as LG F2WR709S2W, allow remote control. With the help of the application we can start, stop the washing process or monitor the washing cycle
- Coffee maker (e.g. Smarter Coffee 2nd generation: The Smarter Coffee coffee maker can be controlled via WiFi, which allows you to remotely schedule or start brewing coffee.
- air conditioner (e.g. Gree Pulse air conditioner): We connect the air conditioner to the WiFi network using the GREE+ app and integrate it into the Home Assistant with GREE integration.
- A smart vacuum cleaner (e.g. Tesla vacuum cleaner) can be controlled via WiFi, you can start cleaning remotely or schedule cleaning cycles, etc. See Fig.3. and 4.

4. Putting the system in operation

As practical implementation primarily, the vacuum cleaner unit was integrated into the network. Off course the energy/power consumption of this device is really low and not continuous. But controlling its State Of Charge (SOC) we can demonstrate the possible change of the spontaneous daily electricity schedule, and it works as a controllable load. The scheduling application can switch easily to 10 W or 10 kW power too. The device has been commissioned and added to the Home Assistant system. We start the installation of the robot vacuum cleaner by carefully opening the packaging: The correct positioning of the charging station is essential for smooth operation: Choose an accessible place for the charging station. Recommended placement rules: At least 1 meter of free space on each side of the charging station. At least 2 meters of free space in front of the charging station. All this so that the vacuum cleaner can dock easily. This is followed by the first charge of the vacuum cleaner, which usually takes 3 to 6 hours. The Smart Life app allows you to control the robot vacuum cleaner. After that, we install the Smart Life application. In the application we install the device type "Robot vacuum cleaner" using the "Add device" option. After connecting the vacuum cleaner to a local Wi-Fi network, it's time to customize Mapping and cleaning.

The objective to build the controllable household is to realize an intelligent and adaptive DSM (Demand Side Management) system [9]. After connecting the devices we are going to control that by the external energy conditions, e.g. PV generation excess of lack of midday energy. The control of the devices is made on the base a timetable/schedule (see Fig.5.). The schedule can be prescribed or dynamically adjusted.

In the following three different local control strategies are shown:

- the base case, when we have spontaneous operation of the different appliances without control (see Fig.6.)
- the proposed control for gloomy (non-sunny) days without huge PV generation. In this case we want to push more loads to the non-peak time that is towards the night deep load valley (see Fig.7.)
- on sunny day (de detect the strong PV generation) we pus more load to the midday PV generation peak (see Fig.8.)

After operation experiences the daily schedules can be generated by autonomous AI support.

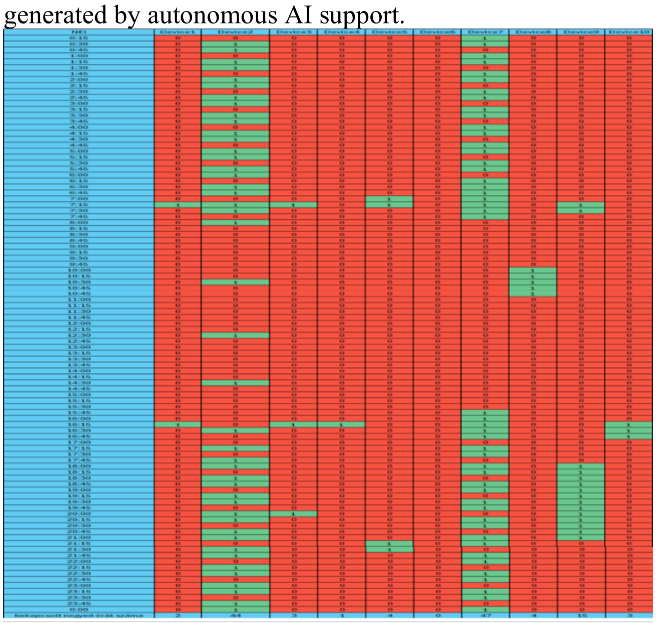

Fig. 5. Prescribed schedule for a gloomy day

5. Conclusion

The current model of our smart home provides a stable foundation for future expansion, the central element of which is the Home Assistant server installed on the Raspberry Pi. In the current configuration, the system successfully controls the robot vacuum cleaner, which is the first step towards building home automation. The flexibility and scalability of the Home Assistant platform allow us to integrate additional devices in the future, such as a Wi-Fi compatible air conditioner, dishwasher, coffee maker, and other smart devices and relays. The current state of the project provides an opportunity to test the performance and reliability of the system under less load, while paving the way for the integration of more complex functions. In future expansions, it's important to consider device compatibility, network security, and further fine-tuning automations and user experience. With this solution, the smart home is gradually becoming an intelligent system that makes everyday life not only more convenient, but also more energy efficient and sustainable.

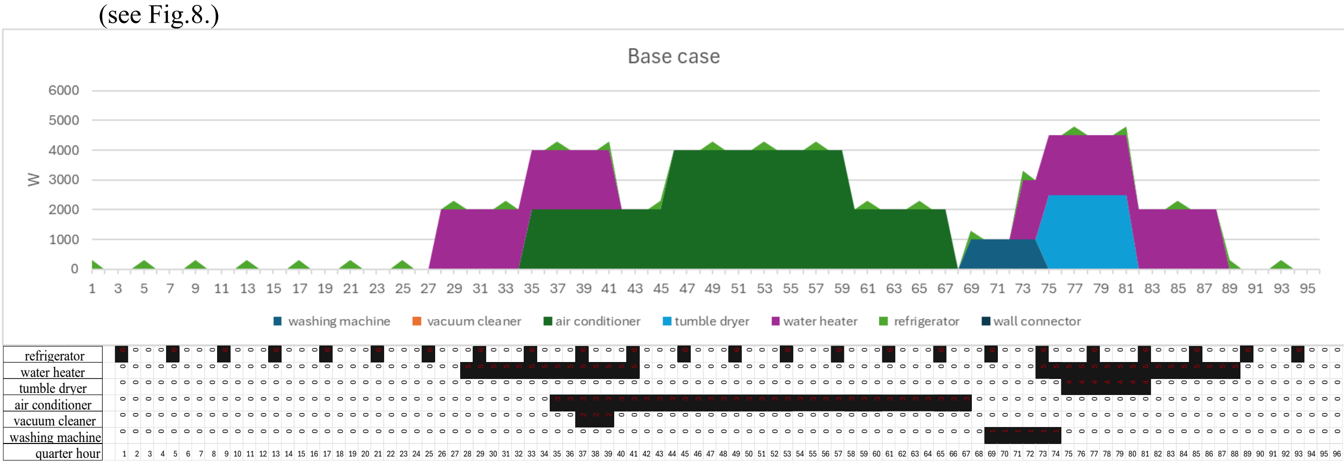

Fig. 6. The non controlled base situation

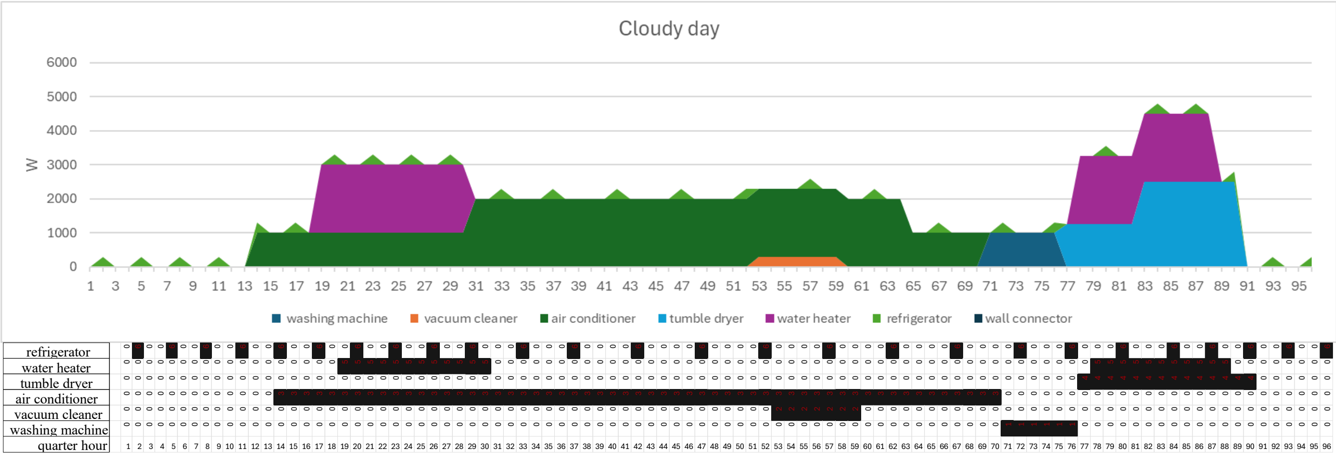

Fig. 7. The controlled load curve spread on whole day

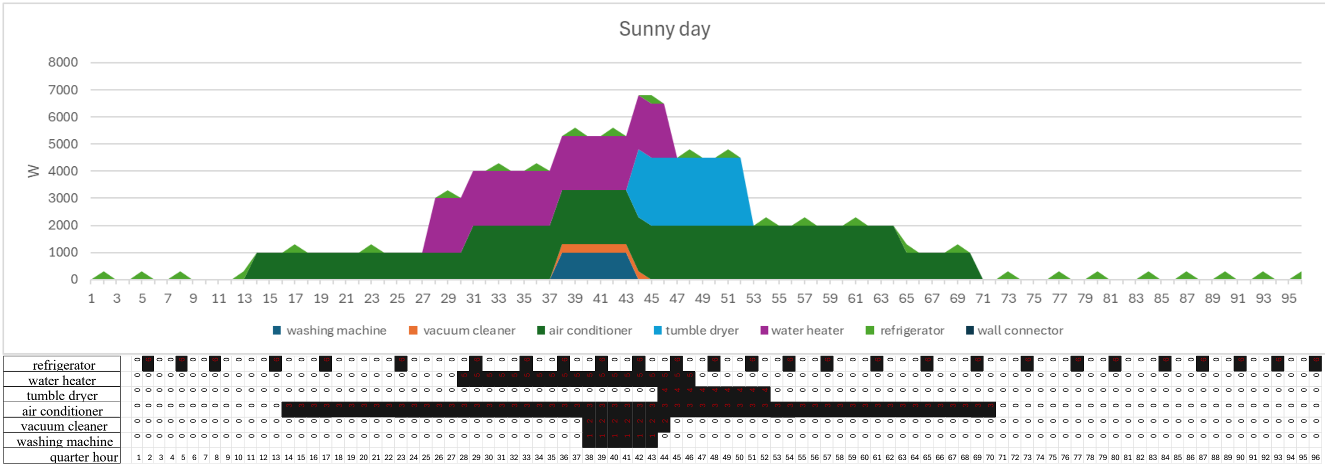

Fig. 8. Load concentrated on midday along the solar radiation

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