Building Energy resilience: the role of energy management systems, smart devices and optimal energy control techniques

By G.Chantzis, A.M.Papadopoulos

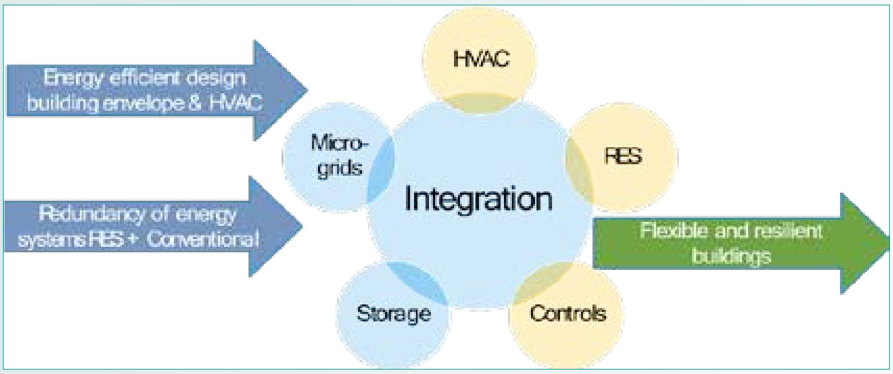

Fig. 1 - Features and technologies of flexible and resilient buildings [1].

This contribution describes the creation of a support system for the operational activities of detailed perimeter of wooded areas attacked by insects/pathogens and/or forest fires, by means of a SAPR (Airborne System with Remote Piloting) with definition of the trajectory in automation via real-time recognition assisted by an airborne sensor and satellite system.

Energy Management Systems

The first step on the road to energy resilience is the selection of the appropriate energy management system. There are two main types of energy management systems the Centralized Energy Management systems and the Decentralized Energy Management systems. The Centralized Energy Management systems present advantages considering economic and political aspects. They are also found to have better response during lockdown in urban areas and in islanding modes. Still, they come with low levels of flexibility and usually require high levels of organization to operate. On the other hand, the Decentralized Energy Management systems are characterized by increased flexibility and enhanced environmental management capabilities. They are also considered to respond better in areas with frequent extreme weather events. When permissible constraints allow, a centralized energy system is chosen to better deal with crisis scenarios, such as pandemic conditions. [1]

Flexible and resilient built environment

Resilient buildings characteristics

Resilient buildings have some special characteristics. They have installed HVAC systems that adapt to the needs of users and indoor and ambient conditions. They are capable of exploiting the streams of data flowing through them in real time. They are efficient, smart and flexible.

A two-way communication between the grid and building-HVAC systems-occupants is established. They are ready for disruptions to power and water services (energy efficiency, energy and water harvesting). They manage use of services with the target of energy consumption, cost and CO_2 emissions reduction, while at the same time maintaining comfort conditions.

On the road to smart, flexible and resilient buildings there is a need of implementing smart metering, IOT and building automation and control technologies. Metering technologies will help harvesting historical weather, energy consumption and RES production data. Then those data are fed to the core IT modules that undertake to utilize the historical data and to produce demand, production and weather forecasts. At the same time by utilizing data of energy prices or carbon dioxide intensity they manage to produce the optimal control strategy which will be applied to the building energy systems through the Building Automation Control system.

Smart metering
As we mentioned above, a vital step on the road to smart and resilient buildings is the collection of historical data. The data is collected by smart meters that are installed in the buildings and their systems.

Energy metering solutions

To receive data about energy consumption we use energy meters. There are DIN Rail energy meters can be installed in the electrical panels of buildings and can measure various parameters such as voltage, current, power and energy. Some meters such as pulse meters require also the installation of a pulse reader which is responsible for translating and sending the measured data via Wi-Fi or other communication protocols. Some meters of this type have the ability to measure multiple loads and multiple parameters. The communication and data sending methods vary (WIFI, Ethernet, GSM/GPRS, etc.). In addition, there are plug energy meters which can only measure plug loads and are non-configurable. Finally, there are central smart meters which most utilities plan to install in new but also existing electrical installations. Those meters are capable of measuring multiple electrical properties, support most communication protocols and have configurable parameters.

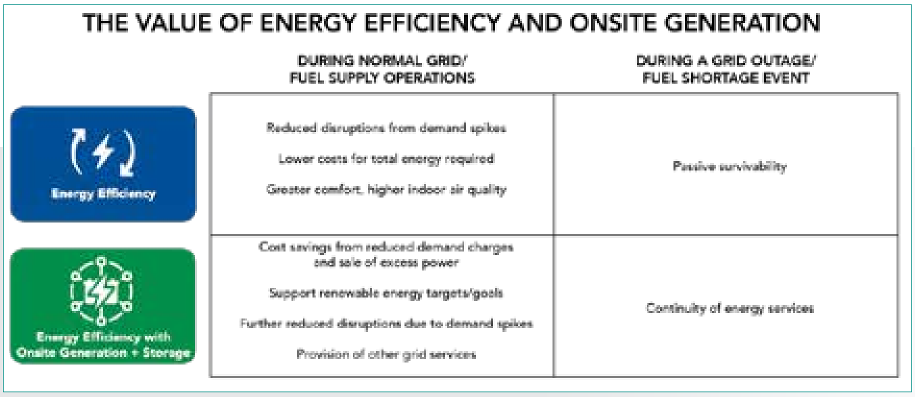

Fig. 2 - Energy efficiency – Resilience Nexus [2].

Indoor conditions & Weather metering

There are mainly two types of sensors for indoor environment, temperature sensors with probe (a) and indoor air quality sensors (b) which are capable of measuring multiple parameters (temperature, humidity, CO2, etc.). To harvest ambient weather data, smart weather stations are used (c). Measured parameters include wind direction and speed, outdoor temperature and humidity, rainfall, solar and UV radiation.

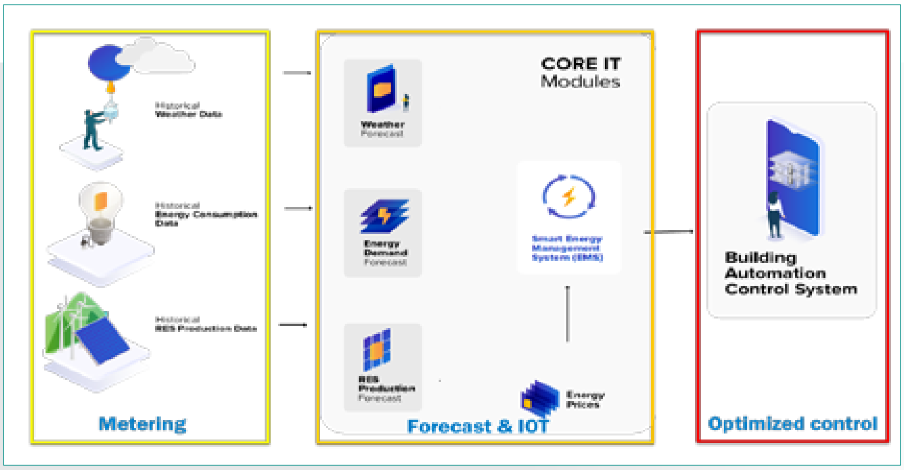

Fig. 3 - The roadmap to smart, flexible and resilient buildings [3].

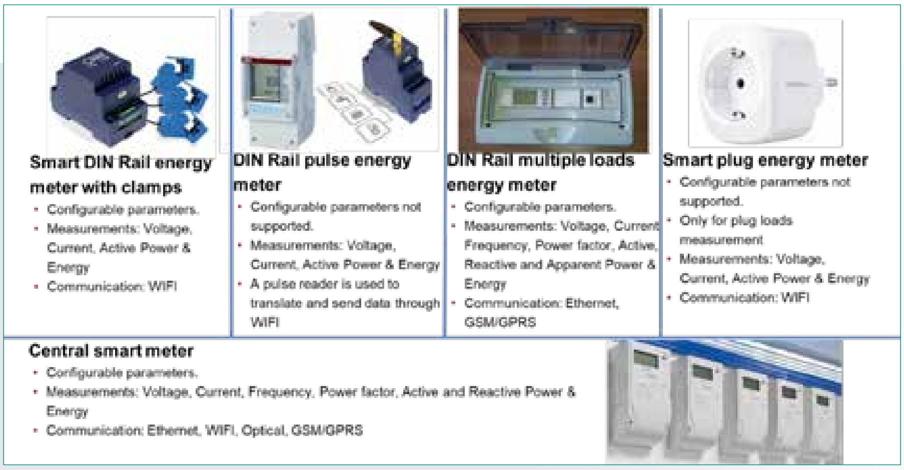

Fig. 4 - Energy metering solutions.

Fig. 5 - Indoor conditions and weather metering solutions.

The sensors support sending the collected data, at a configurable frequency, through LORA, Bluetooth, Wi-Fi, etc. Special attention should be given while selecting the number and position of smart sensors to ensure proper HVAC operation, and indoor comfort.

Control techniques

There are two main types of control Rule-Based Control and Model Predictive control. Rule-Based Control is a heuristic technique that monitors the status of a parameter, for example temperature, and sets value limitations for it. The controlled system responds changing its function according to a predefined strategy [4], [5].
Model Predictive Control is a more complex method. It requires modelling a building and forecasting its energy behavior. The most efficient energy management strategy, results from solving an optimization problem [4], [5].
The existence of controllers installed in the energy system that we wish to control is required. The output of the control strategy is used as input of the controller. The final control is done through temperature or power regulation or by changing the operating profile of the system.

Fig. 6 - The conservatory in Thessaloniki.

Resilient building example

The conservatory in Thessaloniki dates to the 1980's. It was refurbished for climate adaptation, to deal mainly with increasing cooling demands in the summer and heating demands in the winter. The installed PVs contribute to further reduction of electricity consumption and CO2 emissions.
Energy efficiency measures include:

- External thermal insulation for heating loads reduction.
- Installation of ventilated facades to further reduced energy consumption for heating, but mainly to reduce cooling loads.
- Phase change materials in ventilated façade to further reduce electricity consumption for cooling.

The contribution of photovoltaics was significant, covering up to 10% of total electricity consumption of the building.
Temperature and air quality sensors are installed to monitor thermal comfort conditions.
Sensors in the façade cavity

Control type	Example of sensors used for control	Measured data implementation
Rule-based control	Zone temperature sensors, zone humidity sensors, energy meters	• identifying energy efficiency opportunities • maintaining thermal comfort • energy consumption and cost observation
Model predictive control, reinforcement learning control, Demand response control	Zone temperature sensors, zone humidity sensor, CO_2 sensors, energy meters	• learning or validating the building model • direct feedback in advanced control • response to dynamic electricity prices and/or other grid signals • frequency regulation and ramping controls • thermal comfort optimization
Occupancy-based control	Occupancy sensor, CO_2 sensors, energy meters	• direct control of lighting and ventilation • HVAC temperature set points adaptation • energy consumption and cost observation

Tab. 1 - Control types, sensors and measured data implementation.

Fig. 7 - Installation of temperature sensor probes inside the ventilated façade cavity.

enable monitoring the thermal behavior of the facades and automation and control of the installed mechanical ventilation in the cavity.

Figure 7 depicts the installation of sensors inside the façade cavity. The measured temperatures in each layer of the ventilated façade are shown in figure 8. The effect of the ventilated façade is evident for both the gypsum board and the PCM section. In the gypsum board section it is observed that for an external temperature of 32°C the temperature inside the cavity reaches 30°C and the indoor temperature is kept at 27°C. We notice that a significant improvement is achieved in the indoor conditions on a typical summer day, especially if we compare to the previous situation, where for an outdoor temperature of 30.5°C, the indoor temperature reaches 29°C. The PCM seems to further improve the situation since for an ambient temperature of 33°C the indoor temperature is kept at 26°C. Another measure to further improve the function of the ventilated façades is the installation of mechanical ventilation in some air cavities. Thus, some zones of natural and some zones of mechanical ventilation are created. The mechanical ventilation is controlled by automation and control systems illustrated in figure 9. The automation utilizes the measured temperature at various points of the façade and differentially controls the operation of the installed crossflow fans.

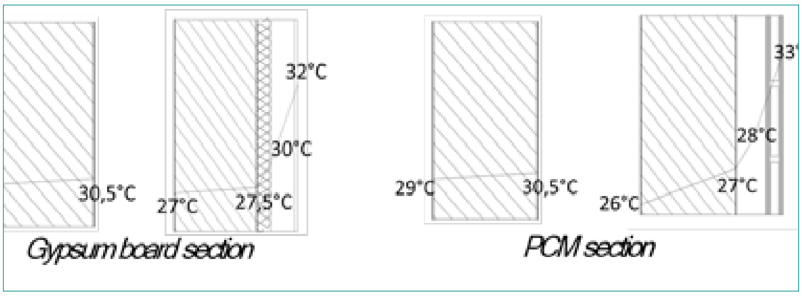

Fig. 8 - Temperature distribution of ventilated façade sections.

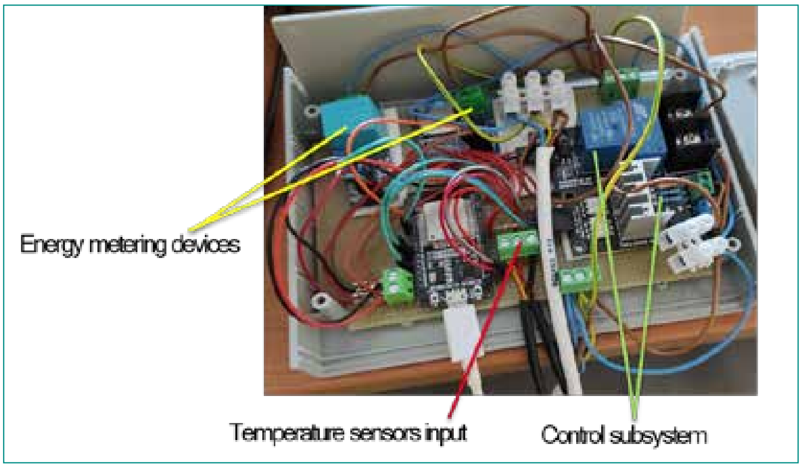

Fig. 9 - Mechanical ventilation automation and control system.

In the case of ventilated facades, the short-term comparison of the results between natural and mechanical ventilation from the recorded temperature difference is relatively small. However mechanical ventilation was found to provide better temperature stabilization.

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KEYWORDS

Energy resilience; management systems; smart device; optimal energy control techniques

ABSTRACT

This contribution describes the creation of a support system for the operational activities of detailed perimeter of wooded areas attacked by insects/pathogens and/or forest fires, by means of a SAPR (Airborne System with Remote Piloting) with definition of the trajectory in automation via real-time recognition assisted by an airborne sensor and satellite system.

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