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Development of a smart energy management system based on Plus-Energy-Houses

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ABSTRACT

Rising energy prices, the finiteness of resources and harmful effects on the environment require a more efficient use of energy in the future. In the construction and housing sector, the technology of the so-called "plus-energy house" can make a major contribution to more efficient energy use. As part of an educational project, different partners from industry and craftsmanship create a sustainable school building which meets the demands of a plus-energy-house. The building produces a majority of its required energy by using a PV system. An intelligent energy management system monitors all consumers and distributes the energy so that a minimum of energy is used from the energy provider's grid. A special control system ensures good air quality and comfortable temperatures in the building. In the future, the building shall prove its concept in everyday school life and not only fulfill the required climatic conditions, but also set standards in terms of energy efficiency.

1. Introduction

Recent years have shown that the current way of energy production and energy use cannot be fit for the future. This requires a fundamental change of thinking. Due to the finiteness of resources and the impact burning fossil fuels has on the environment, it is necessary to work towards a more efficient use of energy. (Mertens, 2011) To realize this, available capabilities to save energy have to be used effectively. The construction and housing sector plays a major role here. The so-called plus-energy house, an example which is discussed in more detail in the following paper, makes a major contribution. It generates in average more energy than is needed for heating and the total household electricity annually (Warnke, 2014). This can be accomplished by modern energy recovery techniques in conjunction with energy storage devices which are connected with innovative bus systems.

2. Application

To set new standards in the field of energy-plus houses, a new multifunctional school building was created in cooperation with a manufacturer of prefabricated houses and numerous partners from industry and crafts. The building (Fig. 1) is located on the campus of the Wernher-von-Braun-school at Neuhof (Germany) and conforms to innovative technologies. The University Applied Sciences of Fulda is using this building as a research object and has taken over the design and implementation of an intelligent energy management system with various control strategies. The modern and energy-saving building contains many systems which produce, store and intelligently distribute the energy required for the operation of the building. For example, a photovoltaic system on the roof generates energy which can be used to power the building, be stored in a battery storage or fed into the grid. To ensure the lowest possible power consumption for the entire building, only high efficient and energy-saving systems, such as LED lighting, are used. A ventilation system with heat recovery ensures optimal air quality. To heat the building, an infrared heating is deployed.

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Fig. 1: front view of the school building

3. Bus system technology

The control of actuators such as lighting, blinds, electrical outlets and the evaluation of some sensors such as temperature, CO2, brightness or motion detectors operates via a wireless bus system which is designed according to the EnOcean standard (ISO / IEC 14543-3-10). The basic idea for the innovative EnOcean technology is based on a simple observation: Where sensors record measured values, there is also a shift in energy state involved (EnOcean, 2013). When a switch is pressed, the temperature changes or the light intensity varies. These processes contain enough energy to transmit wireless signals. The self-powered wireless technology takes the required energy directly from the environment. This energy, like linear motion/pressure, light and temperature difference, is transformed into electrical energy and used to send wireless telegrams. By using the EnOcean technology, the wiring of sensors and switches is dropped completely. This means that domestic installations require fewer expenses in wiring and costs. Only the actuators require a power supply. The sensors and switches can be easily installed in a desired location after interior construction has been finished, an additional point which makes the system very flexible in terms to any subsequent amendments. For the control of temperature and CO2 and the management of loads inside the building, a PLC (Programmable Logic Controller) is used which can communicate with a special communication module of the PLC by using a bidirectional connection to the wireless bus system (Fig. 2).

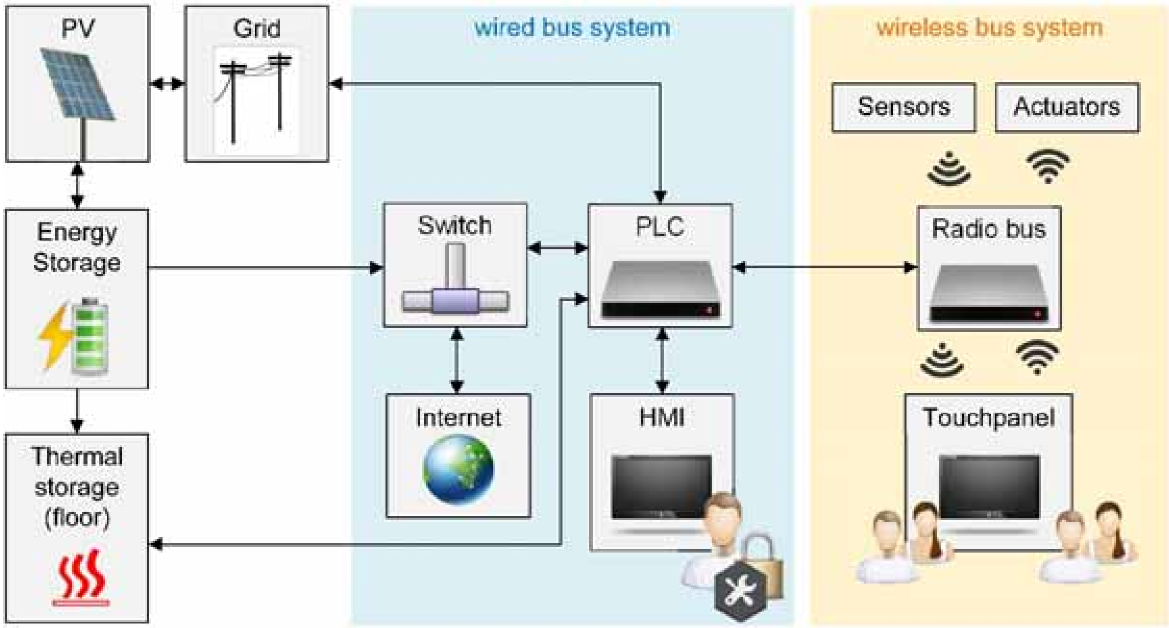

Fig. 2: front view of the school building

4. Hardware components in detail

Fig. 2 shows the major hardware components which contribute to an energy-efficient operation of the whole building. Fans are used to keep ambient air quality in the classroom below the regulatory limits. The deployed fans operate on the principle of regenerative heat exchange. A heat-retaining ceramic body is sitting in the middle of the air stream generated by the axial fan. By means of a reversing air flow which is caused by specific changes in the direction of the fan, the ceramic body is charged with the thermal energy of the ambient air and returns it to the provided outdoor air. The ventilation system ensures that the limits of carbon dioxide concentration are not exceeded and that the air quality is within the specified set points. Room temperature control is provided by using a low-temperature heating which is installed under the screed of the building and emits only radiant heat. The heating transforms electrical energy into heat and, with a certain time delay, transfers it via the surface of the floor at the room's environment. The "heating up" of the screed is ideally done with power from either the photovoltaic array or the energy storage. For more information, please refer to (Fischer and Köhler, 2014).

5. Energy management

The aim of the energy management system is to regulate the power so that as little as possible energy has to be received from the grid. To ensure this, the system is based on three fundamental pillars, as the following figure shows:

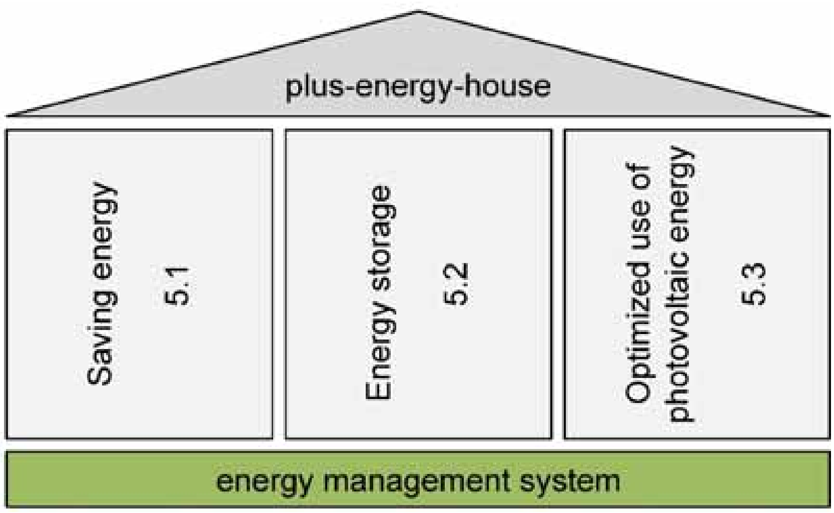

Fig. 3: front view of the school building

5.1. Saving energy

Parallel to the modern, optimally thermally insulated, energy-saving efficiency-house architecture of the school building, it is also necessary to reduce the internal energy consumption to a minimum. On the one hand, this is done by energy-saving systems such as LED lighting, on the other hand the energy management system ensures that energy is only consumed when needed. By using various sensors (such as locking cylinder contacts or motion sensors) the system always knows if the building is currently occupied or. Accordingly, the energy flow to unneeded systems is interrupted. This reduces energy consumption and ensures that only the essential loads inside the unoccupied room receive energy.

3.1. Energy storage

The problem of the photovoltaic system is that it can only be used at daytime. This creates two significant disadvantages for consumers: If no sun is available, the total energy has to covered by the grid. On sunny days, it is also possible that more energy is produced than needed. The excess energy is fed into the grid and cannot be used for self-consumption. Both disadvantages can be compensated by use of a battery system. The battery system stores excess energy instead of feeding it into the grid. This energy is then available when the energy of the photovoltaic system is not sufficient. This increases internal consumption of self-generated energy and has a decisive influence on self-sufficiency of the building.

3.1. Optimized use of photovoltaic energy

To increase self-sufficiency, it is important to use the generated energy optimally. The idea for achieving this is as simple as effective: the energy is to be used proactively where it is needed in the foreseeable future anyway. The used battery storage system only has a certain capacity to store energy for later use. In spring, summer and autumn, the available storage space is almost sufficient. Only during long periods of bad weather energy must be obtained from the grid. In winter months, though, because of the need for a large amount of energy by the heating system, storage space is usually not sufficient. And that’s the moment when optimization of energy use is deployed. Even in winter there are occasional sunny days when the photovoltaic system provides enough energy. Excess energy that is normally fed into the grid should be used effectively inside the building to preventively reduce energy consumption at a later date. For this purpose, in order to store the energy in form of heat by infrared heating, the temperature in the screed is raised. The stored heat is then transferred to the room and heats the school building.

6. Conclusion and prospects

The multifunctional school building shows that effective thermal insulation can produce comfortable air conditions and that efficient energy management coupled with intelligent control systems can lead to an energy-efficient operation of a building. Considering the total consumption of the building one year (in the period from 08/01/2013 to 08/01/2014) after commissioning, it can be seen that more energy has been produced than consumed. The energy balance over this period is shown in figure 4.

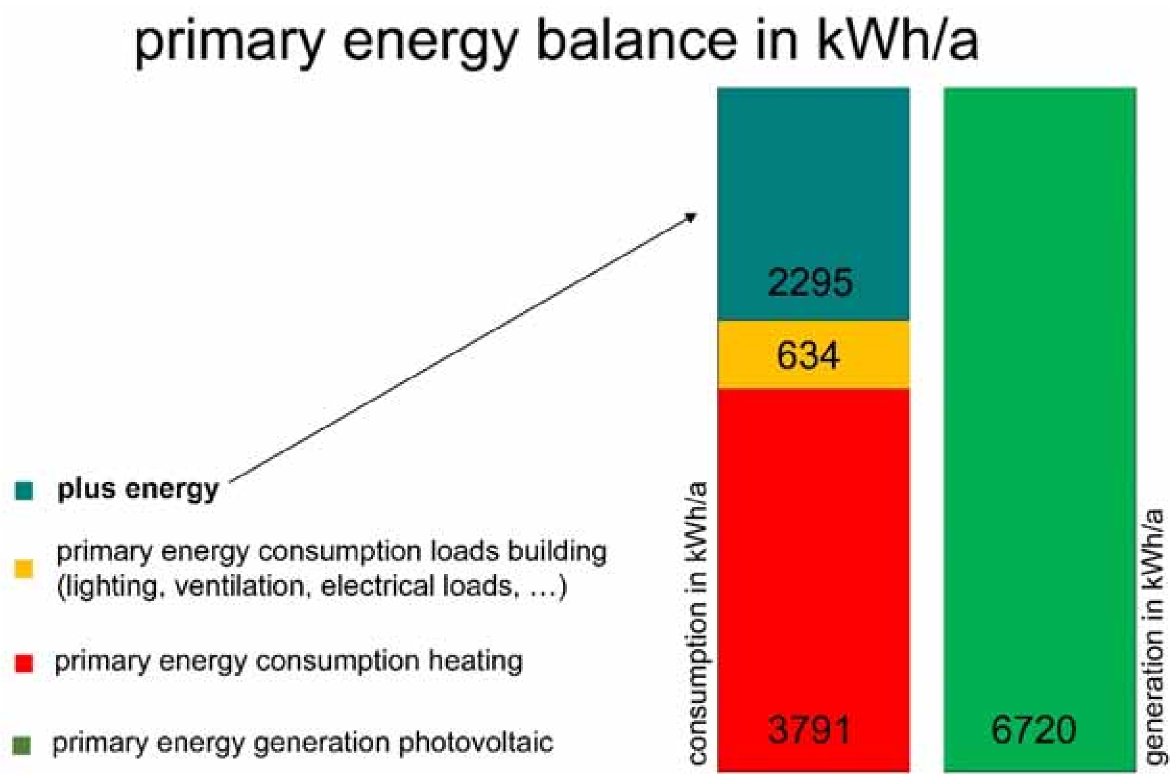

Fig. 4: energy balance

For the future, it is useful to optimize the energy management further more to become even more efficient. For example, in order to be able to schedule the use of sun energy more flexibly, a weather forecast could be integrated into the temperature control. Furthermore, it is reasonable to include a char of occupancy of rooms into the energy management system to initiate predictive energy-saving measures when the building is not in use (e.g. on holiday). Because the photovoltaic system cannot provide enough energy in the winter months, the installation of a wind turbine (such as a savonius-rotor) on the roof of the building could be a solution to further improve self-sufficiency.

7. References

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