Self-sufficient with the wind and the sun

Smart Home

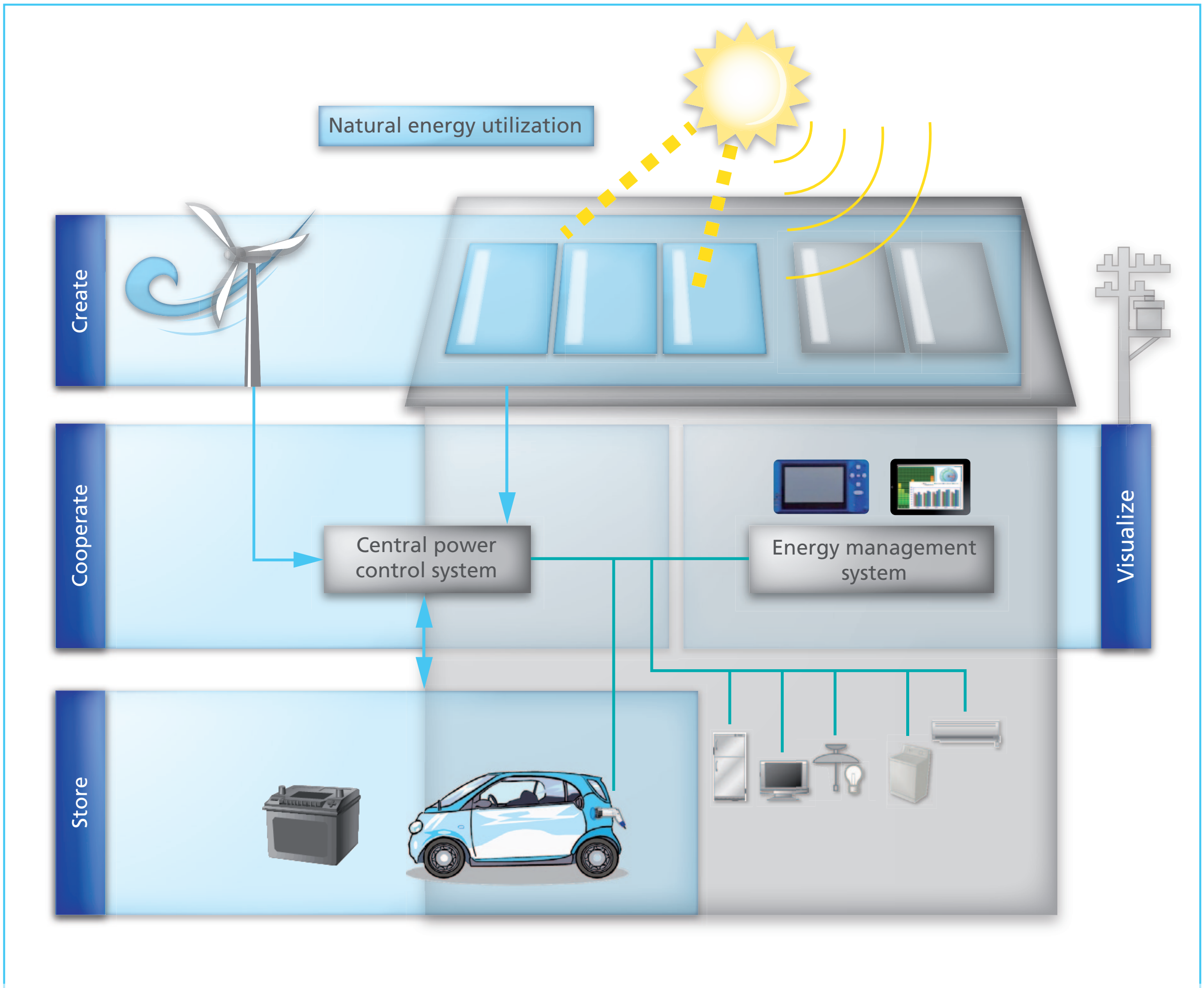
In the face of prospective fossil fuel shortages and environmental concerns, energy generated by wind power or solar power is a strong alternative. Numerous pilot projects are being conducted worldwide to efficiently research, develop and generate renewable energy sources. In Japan, in the wake of the nuclear power plant accident accompanying the Tohoku earthquake on March 11, 2011, people's expectations of renewable energy sources have soared. dSPACE Japan K.K is actively participating in 3 consortia that are carrying out pilot projects on energy control.

All over the world, energy consumption is constantly increasing. There are several reasons for this – such as global economic growth, advancing electrification, and a growing world population. It has long been clear that to guarantee a stable power supply, we need a fundamental revolution in the overall energy control cycle for energy generation, storage and distribution. One approach is to use self-contained solutions in which electricity and heat are produced and consumed locally, where the consumer is. This solution is intended to ensure stable electric power distribution generated from renewable energy sources in the case where the system power is disabled due to a blackout or other reasons, and also to reduce CO_2 emissions which are unavoidable in conventional power generation such as coal power plants.

What's Smart?

Electricity and heat generation in the consumer's own home is part of the local energy supply, because it takes place where the energy is required, instead of in a large central power plant which distributes it via power cables. The word "smart" is frequently used to describe local energy concepts – "smart house" and "smart grid" are two examples. What these mean is that energy generation, energy consumption control and energy storage are all integrated, with individual components connected to a central control unit via a communication network (figure 1). This monitors every change in the overall energy system and reacts by adjusting the energy supply and consumption. The goal is to ensure an adequate energy supply at all times and also minimize the number of storage units needed, because rechargeable batteries are still a high cost factor. A typical smart house has regenerative energy installations such as photovoltaics, solar thermal devices and wind power. For energy storage, classic components such as stationary rechargeable batteries and hot water boilers are used. Electric vehicles are connected to the system

Figure 1: Schematic of an idealized smart house.



Projects Supported by dSPACE

Fukuoka Smart House Consortium

The Fukuoka Smart House Consortium is a joint project by various companies and research institutions. Since June 2010, they have been researching possibilities for a sustainable power structure that will meet the interests of public authorities and power companies alike. The Chairman is Yoshimichi Nakamura from the Smart Energy Laboratory, and the Vice-Chairman is Hitoshi Arima, President of dSPACE Japan K.K. dSPACE supports project implementation with know-how and with dSPACE hardware and software. The smart-house concept was designed jointly with a technical partner, the Smart Energy Laboratory founded by Yoshimichi Nakamura.

Yokohama Smart Community

The Yokohama Smart Community is another project where dSPACE Japan K.K. is actively involved. Hitoshi Arima is its Chairman. Following project launch in 2011, the design of the smart house began in early 2012. Here too, the goal is to research ways to generate energy while avoiding CO_2 and saving resources. As with the Fukuoka Smart House Consortium, dSPACE supports the project with technical know-how, software and hardware. dSPACE also offers the participating groups a presentation platform, such as the dSPACE User Conference in Tokyo, where the mini smart house and other results were presented.

Long-Term Goals of the Experiments

- Promote a renewable energy society
- Consortium (activity forum) and platform (development environments)
- Compact Smart Community that harnesses the power of community
- Create total visions for food, energy and care
- Develop ways for individuals and companies to prosper in each region.
- Disseminate futuristic new concepts of the electric system
- Provide a social infrastructure for a decentralized energy system

Many participating members in pilot projects are proactively involved in the development of energy-related technologies and independent research. In July 2012, the Nagasaki Smart Society was established to provide more opportunities for community-based demonstration experiments. We will dedicate ourselves to building a sustainable social system through cutting-edge science technologies.

Figure 2: Brick house in Island City in Fukuoka where demonstration experiments are carried out.

primarily for recharging, but can also be used as temporary additional energy sources if required. This is a way to even out fluctuations in supply and demand (figure 2).
Despite its independence, a smart house is not cut off from the public power grid. It can draw power from the grid when it experiences an acute energy bottleneck, and supply power to the grid during massive overproduction. Developing control algorithms for the central control unit is a challenge because optimum energy management has to detect numerous factors and mutual effects and handle them all.

Current Technical Situation

The technical developments that have taken place over the last few years are what make smart houses and smart cities possible. Batteries now have a much greater capacity and better charging properties than they used to, and at an affordable price. The number of electric vehicles is also increasing. They need a practical and feasible charging facility – which a smart house provides – and can also themselves be used as storage. Networked communication between different household appliances has also advanced, allowing them all to be controlled by one central unit. When all these innovations are brought together, building a smart house is both possible and economically viable.

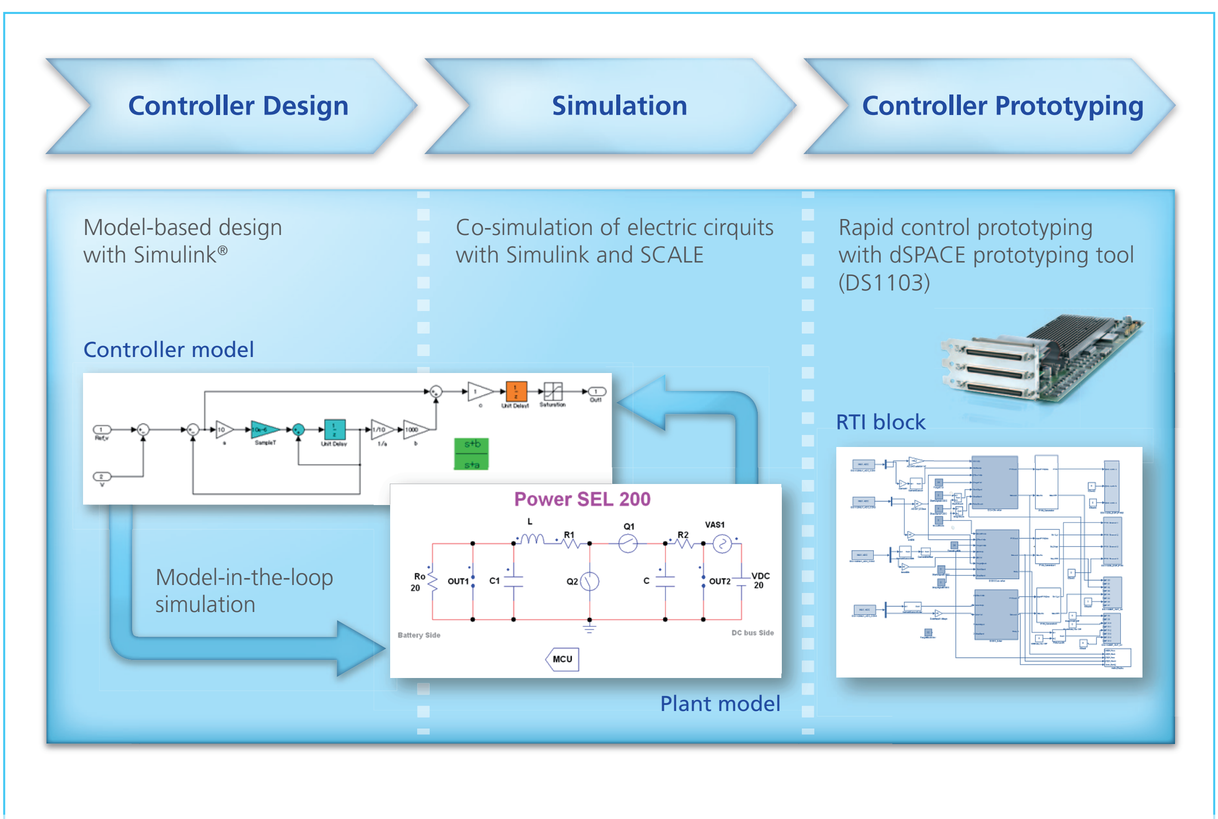
Control Algorithm Evolution

Efficient energy management in a smart house comprises a number of tasks:

- Monitoring electricity generation
- Managing electricity storage
- Reconciling consumption with supply
- Controlling energy consumption according to availability

The pilot project at the Fukuoka Smart House Consortium started with the development of the energy management control algorithms in Simulink. The model-based approach dramatically reduced development times in comparison to conventional approaches. Realistic testing requires not only the actual control algorithms, but also an environment model that represents outside effects. The environment model that was used for testing together with the control algorithms has been developed by Professor Nakahara of the Electronics Research Lab at Sojo University using SCALE. The controller model was optimized iteratively by model-in-

Figure 3: The model-based development process for the Fukuoka Smart House pilot project.



The objective of energy management experiments is to use the generated energy on-site as much as possible.

the-loop simulation (figure 3). After optimization, the finished control algorithms were downloaded to the dSPACE rapid control prototyping hardware DS1103. This serves as the central control unit for a mini smart house.

Mini Smart House

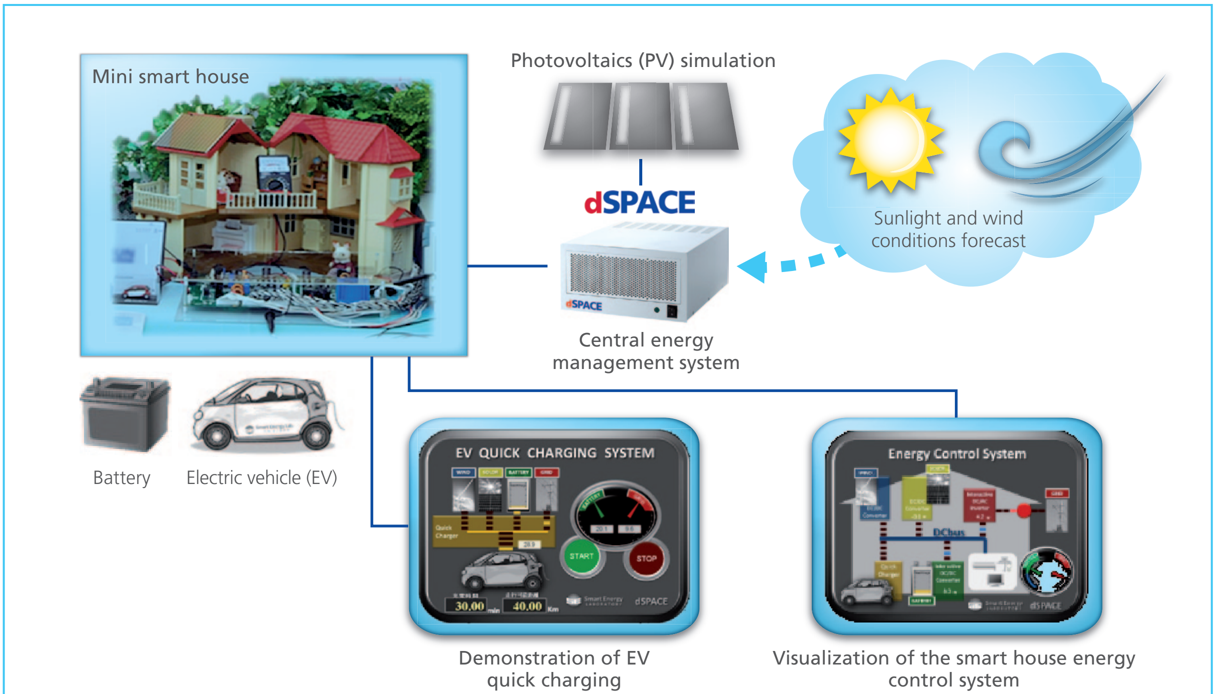
The mini smart house is a downsized physical model (figure 4) of a real smart house and is used as a test object to further test the control algorithms. To develop intelligent energy management, it was first necessary to obtain data on the behavior of energy cycles in order to understand the effects of different control strategies on energy efficiency. Despite having only a fifth of the energy requirement of a real house, the model house has a complete central control unit. Weather forecasts are used to calculate and simulate electricity generation by photovoltaic and wind power installations. A real battery and a simulated electric vehicle are used as storage units. The assumed energy consumption is based on the standard consumption curves of an average family. The objective of energy management experiments is to use the generated energy on-site as much as possible to avoid pressure on the public power grid caused by feeding electricity into it. Self-consumption and storage prevent the extreme fluctuations that would occur if numerous households supplied power simultaneously during high winds. Nevertheless, it still has to be possible to supply power to the grid to balance energy shortages at other locations.

The energy flows and control options are visualized with dSPACE ControlDesk. This made it possible to thoroughly test the effects of different behaviors and their impact on energy efficiency, and to simulate their effects on the overall mini smart house system. Whenever necessary, the control algorithms were adapted quickly and easily to incorporate new research findings.

Life-Size Smart House

The research results gathered from controlling the mini smart house were then transferred to a real house. This smart house was built in Fukuoka (figure 2), and a permanent exhibition of the latest smart house and energy control technologies opened there in April 2012. At the Fukuoka Brick House exhibition, you can view

Figure 4: Schematic of the mini smart house.



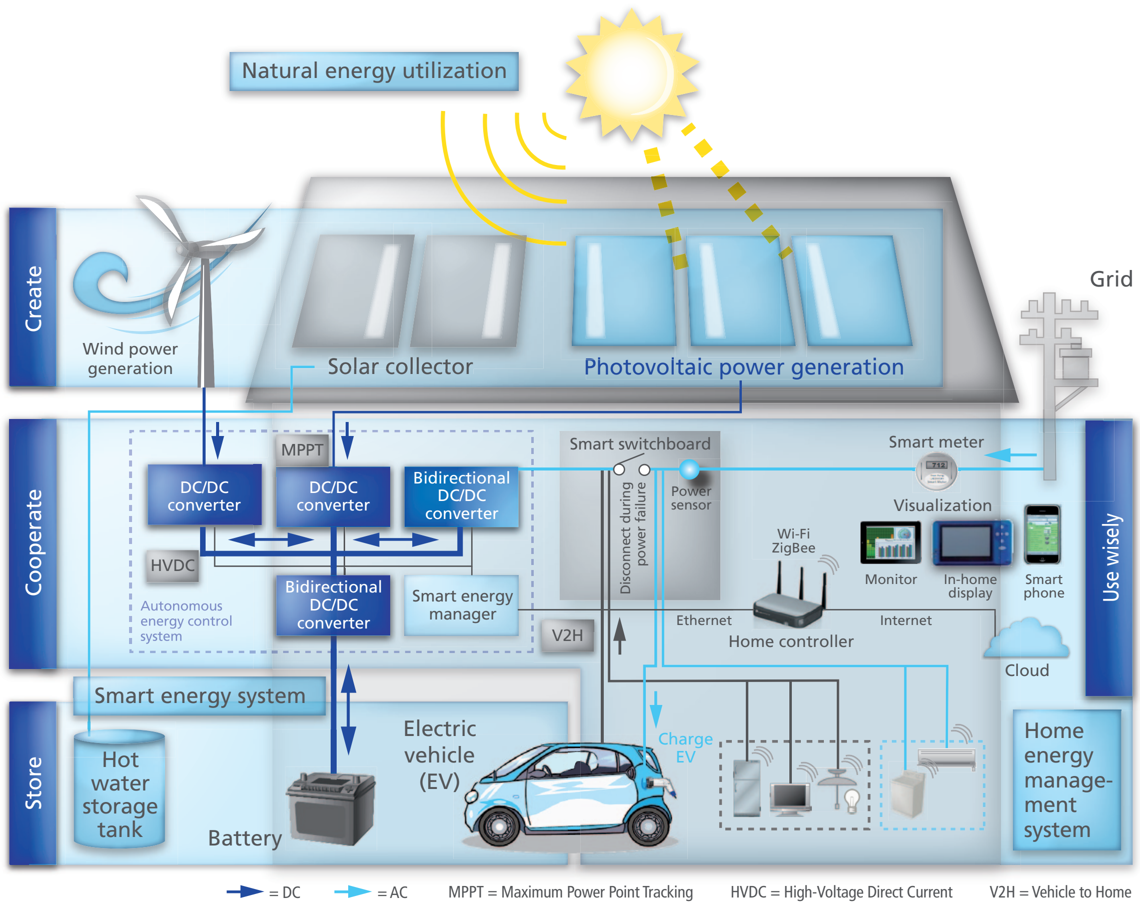


Figure 5: Transferring the mini smart house concept to a real building.

experimental products and element technologies which are either the result of individual research or were codeveloped by participating companies, educational institutions and other organizations.

Concept of Smart House Technologies

The energy is generated by photovoltaic and wind power installations, and stored in a stationary lithium-ion battery that is charged during energy-rich phases. The same applies to the hot water boiler and the electric vehicle's battery. There is also a connection to the power grid (figure 5). Here too, the central control unit is the heart of the system where all the data comes together for evaluation. Large batteries are very expensive, so efficient energy management and consumption control are essential. Weather forecasts provide only a rough estimate of the energy yield expected from regenerative energy generation, so the system has to be highly flexible. Restricted availability must also be taken into account, because solar energy is present only during the day, while wind energy is plentiful during the fall and winter months. Sensible energy management shifts actions that are not time-critical, such as charging the electric vehicle or running the washing machine, are restricted to high-yield times.

Access via WLAN

The smart house's central control unit can be accessed by smart phone or tablet via WLAN, so that the house's occupants can view the current status and consumption values, make changes, or obtain information on a power cut.

Conclusion

So far, the experiments and experience with smart house energy management have been very promising. Model-based development has proven very useful for the development of efficient smart energy concepts.
dSPACE will continue to proactively research energy control technologies through various pilot projects. ■