Fusion of Data and Power for a Controllable Delivery Power Grid

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Abstract

Currently, electrical power distribution systems rely on permanently energized grids, giving place to discretionary energy access and thereby straining the grid's stability.

We propose a proactive digital management approach to the supply of power as a **digital energy grid**, which is cognizant of the demand before energy is delivered. Energy is assigned the addresses of specific loads. Loads issue requests for energy in advance and specific amounts.

We report the design and construction of an **energy packet switch** as a cornerstone to supply energy in the form of energy packets to loads. Energy is supplied under request, in discrete units, and in a balance between energy availability and policy compliance. This approach enables more efficient, robust, and resilient delivery of energy.

Controllable Delivery Power Grid

To overcome exposing the power grid and the transmitted energy to discretionary demands any time, power is assigned to (load) addresses who are the only ones with allowed access to the transmitted energy. The destination addresses may be embedded into the electrical signal or sent through a parallel data network. Here, we adopt a parallel data network for communication between loads and the energy supplier, as Figure 1 shows.

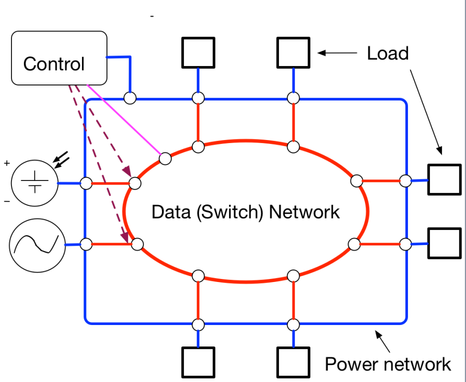

Fig. 1 Concept of digital energy grid.

Activities

We investigated methods for attaining higher controllability on the delivery of electrical power on smart buildings, microgrids, and the overall power grid.

We built a testbed for performing proof-of-concept experiments. Figure 2 shows a test bed with light bulbs as active loads and an electric motor and refrigerator as reactive loads. Figure 3 shows photographs of some elements of the test bed, including the data-power devices that enable it, such as Power Access Points (PAPs) and a Gigabit network for communications between loads and the provider.

Test bed with Appliances

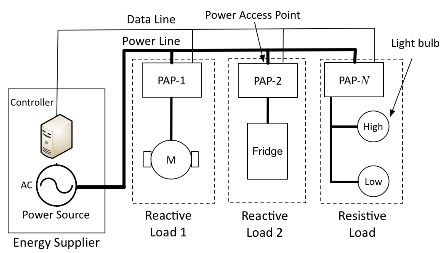

Fig. 2 CDG test bed with resistive and reactive loads.

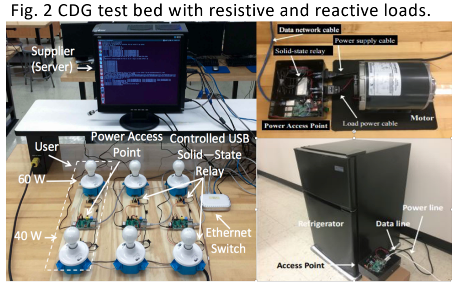

Fig. 3 Some Elements of CDG test bed.

Energy Packet Switch

We designed and implemented an energy packet switch (EPS). The EPS is a network- and data-controlled device that has multiple inputs and outputs. The switch aggregates, partitions, supplies, and request energy to other components. Ituses multiple supercapacitors are used as energy containers. Figures 4-6 show a test bed with an EPS as a central component.

Educational Activities

Six undergraduate, two M.S. students, and two Ph.D. students participated directly in this project. They were closely involved in experimenting with the principles of energy, power, computing, and networking. They also experimented with the construction of the test beds, simulation, hardware and software design, and analysis of algorithms. The project was presented to an undergraduate class as an example of design and experimentation.

Power plane of a testbed with EPS and loads

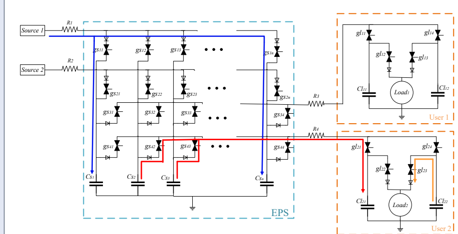

Fig. 4 Schematic of the EPS test bed with two energy sources and two users.

Energy Packet Switch and Test Bed

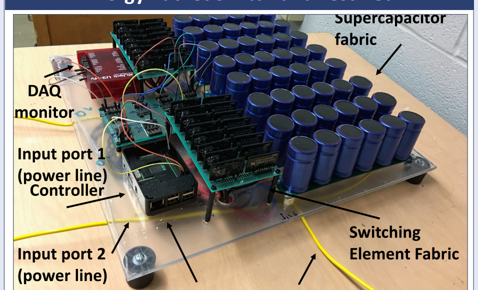

Fig. 5. 2 × 2 energy packet switch with supercapacitors as energy containers .

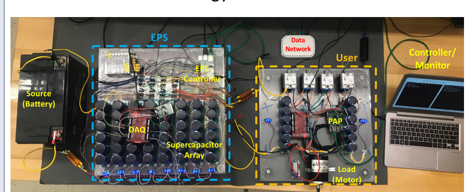

Fig. 6 Implementation of the EPS test bed.

Experiments with EPS test bed

We carried experiments on the EPS test bed to first demonstrate that the EPS can provide discrete amounts of energy, the maximum amount of energy requested by users, and to observe the behavior of the EPS when the energy demand is high.

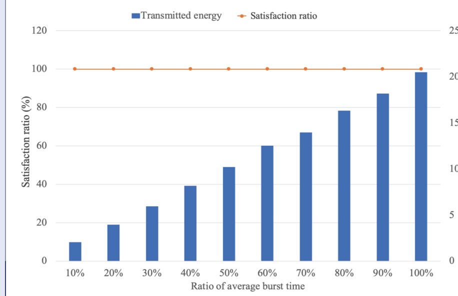

Fig. 7 Satisfaction ratio and total transmitted energy.

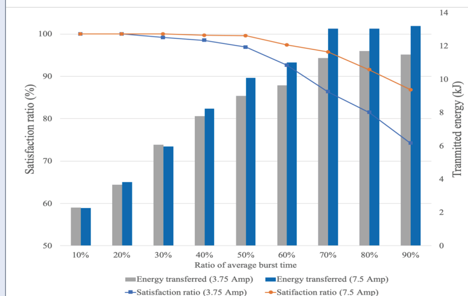

Fig. 8 Satisfaction ratio and transmitted energy with reduced EPS capacity.

Conclusions

We showed that the fusion of power and data controls the delivery of energy proactively. We have tested power delivery with active and reactive loads. We also show that we can supply energy in discrete amounts so that power can be consumed continuously. To achieve this, we designed and implemented an energy packet switch, and experimentally demonstrated the ability of the EPS to transmit a discrete amount of energy on demand.

Acknowledgement

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