GRid-Connected Advanced Power Electronic Systems (GRAPES)

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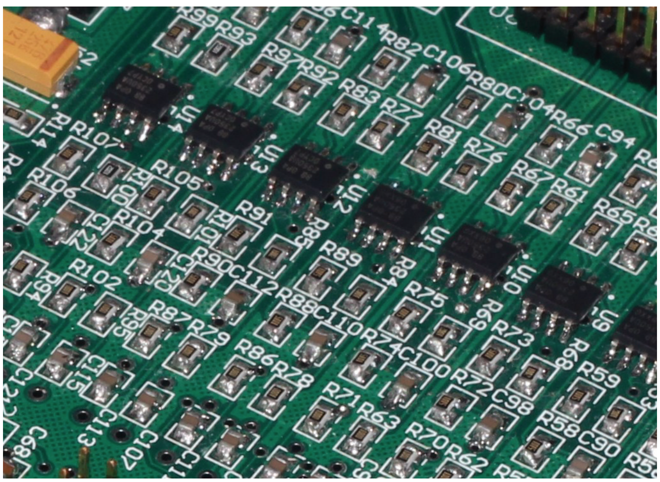
Smart Green Power Node



The many control channels of the Smart Green Power Node control module evoke notions of the larger power control channels that route electric power between sources, loads, energy storage systems and the grid. Such optimal power routing minimizes energy costs for the consumer.

GRAPES researchers have developed a "smart green power node," a combination of electronic power converters, power routers, and control algorithms that put the "smart" into residential power systems. "Dumb" power systems have been the standard for the past 100 years, with power cables running to everything that needs power and everything using power whenever we or it wants to. But emerging electronic and information capabilities, new energy resources and new environmental priorities have created a need for better ways to integrate renewable energy systems, energy storage, and time-of-use power management into simple-to-use systems that will consume energy more wisely while minimizing the cost and environmental impacts of our energy consumption.

The Smart Green Power Node does this by directing the flow of electric power from resources such as solar photovoltaic or wind to storage batteries or to the house wiring, and it coordinates the operation of various smart appliances on the home's power network. The thermostats of heating or air conditioning systems and of water heaters and of the on/off status of deferrable appliances such as clothes washers or dish washers are managed by the Smart Green Power Node so as to optimize system efficiency, minimize energy cost, and maximize comfort and convenience of the homeowner. Maximizing essential consumption (by running appliances or storing energy in the battery) when power is cheap or readily available (e.g., the sun is shining), and minimizing grid consumption (by turning appliances off or by powering essential appliances from the battery) when power is expensive (e.g., during load peaks) or not available (e.g., nighttime or no wind), minimizes the total cost of power for a homeowner.

The Smart Green Power Node contains electronic devices that convert dc power from batteries or photovoltaic panels to the 120 V or 240 V ac power that is used in homes. And it contains computing hardware and software that collect information from the internet - things such as weather forecasts and current or future (e.g., next hour, next day) prices for electric power - and information from a home's occupants - things like patterns of electric power use and comfort settings - which inform the node's decisions on when and where to send power. The demonstration unit is rated at 2 kW. Although this is less power than a typical home often uses, this size maximizes the "bang for the buck" in terms of return on investment. But the system is modular so a homeowner who wants greater power capability can simply plug in more power modules. Likewise, the storage battery can be sized to maximize the return on investment when considering the local prices of electric power, the lifestyle and energy use habits of the homeowner, and the availability of renewable energy sources. At less than $1/W now, and perhaps far less when produced at commercial scale, the Smart Green Power Node is a low-cost mechanism for maximizing energy utility.

The Smart Green Power Node has been an exemplary study in cooperative work between the two sites of the GRAPES center. More than 15 students in total have played a role in its development, with various aspects of the research and development done at each site. From business case analyses, to power circuit design, from network connectivity to decision-making algorithms, from simulation-based analyses to cost-conscious design of power converters, the many parts of this puzzle could only be completed by relying on the broad intellectual and human resources of the two institutions. Furthermore, this project has had the most consistent support from a broad base of center members - from electric utilities to equipment manufacturers to semiconductor manufacturers - everyone understands and appreciates the tremendous promise of this system.

The SGPN will change the way that residential power customers use electricity. It will simplify the integration of renewable resources such as solar and wind, and it will make smart energy use more feasible for the average power consumer. It will also enable more effective use of the existing power grid by incorporating battery energy storage through one simple off-the-shelf solution.

Economic Impact: The potential economic impact of the Smart Green Power Node is enormous. In the US alone, residential electric power consumption totals roughly 1000 kW hours per month per home which costs the 125 million residential energy consumers $160 billion per year. If the Smart Green Power Node reduces power bills by only 10%, that would amount to $16 billion of energy savings per year. Not just savings in dollars would result, but also there would be savings in the offset costs of building new power generating facilities and in reduced CO_2 emissions overall. While in the U.S, the average residential price for electricity ranges from $0.10/kW hour to $0.36/kW hour, global prices tend to be much higher and therefore payback will be even more rapid in these other regions of the world. And then there is the land beyond the edge of the grid; in undeveloped regions the Smart Green Power Node can serve as a stand-alone micro-grid, being the one and only source of reliable power. The actual cost savings that homeowners will be able to realize from this system varies widely and depends on the pricing structure for electric power, the lifestyle and habits of the homeowner and the local climate. Case studies indicate that payback periods will range from several years to a decade or more. Outcomes will be strongly affected by decisions of governmental regulatory commissions. While there is great uncertainty in many of the essential circumstances, two trends are virtually certain: future prices of electric power will be higher than today's prices and prices will become more volatile, changing on seasonal, daily and hourly schedules. Both of these trends will make this system become more and more valuable.

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