SMART GRID

TAKING OUR CUE FROM NATURE

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Smart Grid – Taking Our Cue from Nature

> *"Today's electricity system is 99.97 percent reliable, yet still allows for power outages and interruptions that cost Americans at least $150 billion each year"* – *The Smart Grid: An Introduction, US*

The Electricity grid is in dire need of modernization. In 2003, the United States Department of Energy articulated a vision for the modernization of the North American Electricity Grid in its paper entitled "*Grid 2030: A National Vision for Electricity's Second 100 Years*". This paper identified some of the key challenges to be overcome and goals to be achieved in order to realize this grand vision. One of these goals in the Demand Side Management arena is to prove the feasibility of smart appliances. It is this particular goal that is the focus of this paper.

A number of different initiatives have commenced to address the problem of intelligent appliances. One such initiative is the development of a grid-friendly appliance controller by Pacific Northwest National Laboratory (PNNL). This controller monitors line frequency and power quality. When necessary, the connected load would be turned off for a few minutes in response to a grid overload condition. This actively balances grid supply and demand. Although the PNNL controller is very practical in its intended use, it is possible to develop technology to further extend and optimize the capabilities of energy consuming loads/appliances.

Another such project, the Olympia Peninsula Project sponsored by PNNL and Department of Energy, installed a variety of smart devices such as thermostats, water heaters and clothes dryers. These devices were tied to the real-time grid price for electricity. Consumers could set these smart devices to provide a balance between comfort, utility and economy. Consumers were allowed to choose the style of electricity contract they desired, from fixed price to five-minute real time pricing. The smart devices were able to interpret real-time prices and respond by reducing their electricity consumption for high-price periods (within customer preferences) which resulted in an overall 10% reduction in energy costs for the consumer and a 15% peak reduction for the grid. However, one small cautionary note – care must be taken not to trade one grid constraint problem (the electricity grid) for another (the internet).

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"[Ants] think locally and act locally, but their collective action produces global behavior." – *Emergence by Steven Johnson*

There are other approaches to solving these problems. In order to realize the vision of a cost-effective, optimal and simple implementation of smart appliances (electricity consuming loads), we can take our cue from nature. After millions of years of evolution, nature has developed mechanisms that allow a group of like entities (a swarm or colony of simple insects such as ants or bees) to exhibit very complex behavior patterns. Ants and bees themselves have very simple brains that are programmed with a very simple set of instructions. These instructions allow the colony to build nests, gather food and defend all without any semblance of a centralized leadership structure. Each simple ant will change its function, from food gathering to nest maintenance to nest defense solely based on what it can deduce about its surroundings from pheromone trails left by other ants or bees. Thus the hive or colony as a whole exhibits a measurably complex behavior of survival and adaptability to its surroundings which is greater than the sum of the intelligence capabilities of each individual member. Such behavior is known as emergence or swarm logic.

One of the chief obstacles to overcome for electricity consuming loads is that they do not directly communicate with each other, and therefore cannot orchestrate their use of energy in a simple form advantageous to the entire network. To overcome this, an analogue of emergence or swarm behavior can be implemented for electricity consuming loads. By attaching a very simple brain to each load, along with a method by which the load can convey critical information to all other loads in the "colony" or network, very interesting results arise. Consider a specific implementation whereby a group of such loads are orchestrated to reduce and optimize their peak demand on a 7 by 24 hour basis. If such loads fall into the category of discretionary loads, that is, loads which can tolerate some small delay when they are called to turn on (such as air conditioners, space heaters, hot water tanks, fridges and freezers), swarm behavior can be used to make sure that only the minimum number of loads will be allowed to run at any point in time.

The natural duty cycle of a load is defined as the percentage of time over a given time interval that a load must run in order to satisfy its control target criteria.

When a swarm controller is attached to each load in a network, the controller can deduce various operating characteristics of the attached load such as its natural duty cycle, the power draw of the load, the length of time it has been allowed to run, and the length of time it has yet to run to satisfy its duty cycle. When this information is communicated to all other loads in the network, each individual load can independently decide if it should allow it's appliance to run or not. Now such a controller is, as mentioned, a very simple device, so it does not have the control strategy needed to actually control, but rather it operates in one of two modes where it reverts control of the load back to its native control mechanism, or disables the load from running. Coupled with a transceiver for communication, loads are prevented from running simultaneously when it is not necessary, thereby smoothing out peak demand over time.

With the availability of consumption and peak data from each load, it is possible to profile the load over time. This data can be used to ascertain load failures, or even load maintenance requirements. Consider an HVAC load that normally consumes at a peak rate of 10kW. If over time, this peak consumption rate begins to increase, the load may require servicing due to a possibly failing compressor, or clogged air filters each of which would account for this increase. This opens up an entirely new business line for HVAC service firms to proactively manage their customer's HVAC assets and to take preventative actions before failures occur.

Characteristics of a Swarm Based Controller

- **Robustness**: No single point of failure
- **Plug and Play**: The addition or removal of a controller will cause the network to rebalance in a very short time period with no human intervention
- **Fire and Forget**: Once installed, no user intervention is ever required
- **Reduction in Energy Costs**: A facility subject to peak demand charges will see a reduction in peak demand with a commensurate reduction in the overall energy bill
- **Monitoring**: The consumption and peak of each load can be tracked and the resultant data analyzed for failure, or for signs that maintenance is needed

By using the "duty cycle" to schedule the loads in a network, other interesting control strategies can be realized. For example, if the duty cycle on some or all of the loads is artificially reduced by a small amount, the overall peak demand and consumption are reduced. Although in this scenario, the loads will not be able to meet the control targets as defined by their natural control mechanism, they nevertheless continue to run and provide service. This is a simple implementation of Demand Response with a number of advantages over traditional Demand Response (DR) mechanisms. Typically, to achieve DR for HVAC, temperature set-points are increased by several degrees. This has a number of undesirable consequences. An increased temperature setpoint causes all of the HVAC units to turn off simultaneously, resulting in a very quick rise in humidity (the key characteristic determining occupant comfort). As well, once the facility heats up sufficiently, all of the HVAC units typically turn on simultaneously resulting in a new peak demand. With the simple swarm controllers described, a reduction of the duty cycle does NOT turn the HVAC units off, but simply runs them in a slightly reduced capacity. Therefore, DR does not become an all on or all off proposition, but rather allows for a very fine-grained control over how much cooling is actually delivered.

With this level of fine-grained control, it would be possible to implement a true smart grid that can respond in a much more palatable fashion to the generation and transmission requirements of the grid. For example, if generation facilities were unavailable or if transmission capacity was not present, the group of controllers can be set to run in degraded mode automatically thereby reducing the strain on the grid.

Because such a controller is an inherently simple device, it is inexpensive, and will run without a command and control mechanism. It will require a communications gateway to the outside world if it is to receive information about grid events and take appropriate DR action, and convey valuable sensor data. This can be facilitated by a simple cellular modem (for relatively low volume data transmission) or by an internet infrastructure building backbone as contemplated by Cisco in their vision of the future smart building as part of their Connected Real Estate platform (for high volume data transmission). The low cost-point means that these controllers can be implemented in residential as well as small and mid-sized commercial facilities, a currently underserved segment of the market for smart technologies.

In Phase 1 of the U.S. Department of Energy's Grid 2030 Plan, smart appliance feasibility is to be proven by 2010 with Phase 2 (wide-scale implementation) by 2020. REGEN Energy™ has developed just such a controller (the EnviroGrid™ controller) and has proven its feasibility in a number of pilot studies. For example, on packaged rooftop air conditioning units, the install time for one of these controllers is only 15-20 minutes. The use of split-core current sensors simplifies installation, as it is not necessary to touch any of the high voltage wiring. With a simple communication gateway either grid-initiated DR, or automated DR (DR tied directly to generation) is possible. With peak demand rates in congested areas skyrocketing, the installation of these inexpensive EnviroGrid controllers provides an immediate payback to consumers that experience peak demand charges on their bill. Smart appliances are no longer in the feasibility stage, but are now available for deployment.

REGEN's EnviroGrid Controller

About the Author

Roman Kulyk is the Chief Technology Officer at REGEN Energy Inc. pioneers in the application of swarm technologies to building and grid energy management. The company is presently focused on distributing their technology through channel partners in the United States and Canada. You can contact Mr. Kulyk at roman.kulyk@regenenergy.com.

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