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Managing Microgrids Using Grid Services

(extended abstract)

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Abstract – *In order for electric power generating capacity to be supplanted to a meaningful extent by sources smaller than 200 kw, an automated means of managing systems of small sources must be found or their sheer number will overwhelm the power production community. Microgrids—power systems comprising multiple small interconnected generators—are a promising response to this need, but an automated microgrid management system has not been demonstrated. This paper describes the energy management task and its execution in a standardized grid services environment.*

Keywords: cooperative systems, energy management system, EMS, intelligent control, microgrid, web services.

1 Introduction

A microgrid is a small interconnected power system whose sources are no larger than approximately 200Kw. A microgrid differs from a group of independent but physically proximate small generators in that microgrid generators can be used communally, i.e., any generator can supply any load, although economic and technical constraints can result in preferred configurations and schedules. Intra-system cross-supply and communal management are what make a small power system a microgrid. The microgrid concept is discussed here because an automated management approach is required if they are to be broadly used: Replacing one percent of U.S. generating capacity would require on the order of 50,000 200 kW generators, quadrupling the number of generating units.

In this paper we lay out the management process for a microgrid and describe an approach to accomplishing the necessary activities utilizing grid service mechanisms. Necessary extensions to the standards are described. Interestingly, the electric power grid is often cited as the inspiration for the word "grid" in *grid services*: computation should be as available and easy to tap as electricity. In this paper we come full circle to use a grid-services approach for managing an electric power system.

2 The essential "service" approach

The essential thesis of service orientation is that a large task can be broken down into smaller tasks that are accomplished in parallel by independent providers and the results marshalled into the required product. Simple: Break a big task into subtasks; allocate the subtasks to providers; marshall the results into the finished output.

For computational tasks, this is difficult[1] because computational tasks are idiosyncratic. According to [1], a successful open service architecture "must enable interoperability between … diverse, heterogeneous, and distributed resources and services as well as reduce the complexity of administering heterogeneous systems." [2] points out that "scattering and gathering steps can incur significant delay … computing on far-flung resources is complicated and can add seconds to each transaction … [computation] must wait for computing resources to become idle, which means that performance can be nondeterministic … Grid performance issues include resource availability and reliability, utilization and load, response time, delay, and delay variation (jitter)." The benefits of grid computing are neither universal nor automatic.

The grid approach defines standards for specifying and managing computational services. In the electric power domain, the existence of standards is precisely why such a thing as utility electricity exists: The U.S. standard 60-cycle, 120/220 volt "house current", (and many other generation, transmission, and distribution standards) had to be specified and an entire industry brought into conformance.

In large part, standardizing computational services means abstracting in a useful way tasks that are commonplace enough to be usefully exported. Not every task can be broken into subtasks, or "parallelized", but many can. A grid model is of interest only if it's possible to specify relevant tasks so a generalized computer can accept them for execution. We take this as given.

Standardized grid services present a situation where the "breaking apart" of a task into its constituent elements is all we need to do; once the a computational task has been broken into subtasks of the appropriate sort (often very difficult to do), the rest of the job—the orchestration, scheduling, etc.—is "standard" and can be performed by any number of providers.

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[1] At one time it was not straightforward for electricity, either.

Significant, broadly applicable efforts have appeared, not least of which is the work of the Open Grid Forum (OGF), including [3] on utilizing grid services to integrate distributed systems. [4] describes grid-based agent technology used for resource and service discovery. [5] describes a grid-based resource broker implementation and [6] discusses an operational grid-based message-passing interface.

The OGF also maintains a significant use-case library [7], which includes, among others, cases on protein pattern scanning, ground water pollution, digital terrain modeling, and disaster recovery.

3 The Power Generating Task

The elemental power system tasks are much simpler to specify than computational tasks. The essential power system task is to produce power at a given rate for a given period of time. For example, "produce 1000 watts for one hour".[2] Normally the actual power usage will not be so precise, but in practice, the buyer will alter the power production of his or her own power sources to accomodate variations between the requested amount and actual usage; the seller need only maintain production as specified. Users with no generating capability buy power per unit, in which case the supplier varies power production as needed to meet demand. Power must also be transmitted and distributed, but this is also easy to specify: "Transport power produced at point A to points B, C, and D."

So once we have defined the "units of production"—in other words, whatever the system has been built to supply, be it computation or power—most if not all other requirements are standard from system to system. These include, but are not limited to, again according to [1]: a unified interface, monitoring, analysis, optimization, and management of service level agreements, information, resources, and execution. These can be supplanted by various infrastructure utilities such as naming, notification, security, and transaction processing. These are standard tasks whether we're talking about computation or producing power.

Performing these activities in the computer realm requires additional infrastructure because not only all the ancillary processes but also the tasks themselves, along with their feedstocks and products, are informational.

4 Power System Management

The overarching task of managing a power system is to operate the generators so that the loads that "belong" to the microgrid are satisfied (loads are not normally associated with sources, but they are in this formulation so that a responsible entity can be named). However, this can become very complicated for even a simple power system, as described fully in [8]. It's particularly important to balance power production and power use at any given moment in a small power system because relatively small differences between production and load can cause the sources to self-protectively halt production.

Exploration of power system management using grid services is occurring, although it does not appear in [7] as an exemplar use case. Useful work includes discussion of resources that are *not* merely computational, including [9] on spectroscopy instruments, [10] on seismic imaging, and [11] on seismic analysis.

There are several relevant efforts to utilize grid services to accomplish power system operations. [12] discusses monitoring and control and is particularly relevant because it takes a distributed approach. [13] approaches the computing requirements of large-scale power systems. [14] describes the operations and advantages of using grid services in power system control centers. [15] describes optimization of reactive power utilizing agent-based grid computing. [16] discusses islanding, which is directly relevant to microgrid operation, and explains how grid services can be used to allow operation in islanded mode. [17] describes power system restoration accomplished in a collaborative grid using grid services.

Energy management task categories to be accomplished utilizing standardized grid services:

- Interact with humans
- Maintain Cybersecurity
- Collect and record external conditions and system state, configuration, and behavior.
- Predict future state (actual and hypothetical)
- Determine desired system state achievable from current actual system state
- Determine appropriate system configuration for given conditions (actual, forecast, expected, hypothetical)
- Configure system to support given system state
- Interact with non-system elements to support given system state
- Detect unexpected or state; determine and execute appropriate response

Since these jobs have been distanced from power system operation by abstraction—it's not necessary to know exactly *how* to "configure system to support given system state"— they can be matched with grid services. For example, the "collect and record" item is supported by the "monitoring" and "analysis" grid services. In the full paper a complete match between grid services and power system management requirements is detailed.

[2] Although this would result in 1 kW-hour, we cannot merely specify that we need 1 kW-hour, since this could be satisfied an infinite number of ways: 2000 watts for half an hour, 1 watt for 1000 hours, etc.

5 Power System Simulation

Simulation of a power system under management is used to predict the behavior of the system in order to determine the relative value of different configurations and to estimate the outcome of planned courses of action. Independent system operators and regional power coordinators customarily use state estimation software to predict the behavior of the power grid given known and planned conditions. Simulation software is directly useable as a grid service given the ontological extensions needed to specify the desired simulation.

6 Conclusion

Open grid standards are a useful and viable approach to managing power systems. Power system operations are increasingly computerized and much required power system tasking is directly represented in standard grid service terms. Power production is inherently parallelizable, since any viable power source (i.e., those found in service in an operational power system) can produce power, so the grid service model is immediately applicalble. Future work includes an examination of using grid services to integrate different power types (batteries, flywheels, photovoltaic systems, windmills, microturbines, fuel cells, conventional rotating mass generators, etc.) into a reliable, efficient, easy-to-use power system.

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