This article is part of the IEEE Reliability Society 2009 Annual Technology Report.

Representativeness Models of Systems: Smart Grid Example

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Introduction

Given the great emphasis on energy efficiency in contemporary society, in which the Smart Grid plays a prominent role, this is an opportune time to explore methodologies for appropriately representing system attributes. I suggest this exploration is important for effective system development because the primary factor in correctly mapping between requirements and implementation is how representative the system design is of requirements. Because representativeness is an abstract term, it is imperative that we identify ways to quantify it. I use several metrics. Among these is the priority of system elements (e.g., electric generator) based on importance to system success. Also, fault tree analysis can identify elements that operate in an unsafe state, and the probabilities of reaching these unsafe states. Finally, state transition analysis provides traces of which elements are on the routes to unsafe states. These analyses provide the information needed to reduce element faults and failures on a priority basis.

History

The term "Smart Grid" was coined by Andres E. Carvallo on April 24, 2007 at an IDC energy conference in Chicago, were he stated that the Smart Grid was the combination of energy, communications, software, and hardware. He went on to explain that such combination would only come to live with the creation of a new systems architecture, integration, and modeling framework, which he presented. In short, he predicted a new direction for the industry in which he called for the creation of the "smart grid" for each utility to deliver the 21st century promise of new forms of energy, and levels of efficiency and conservation for customers across the globe. The 21st century Smart Grid would reach every electric element, would be self-healing, would be interactive, and would be distributed [1].

Technologies

The smart grid replaces analog mechanical meters with digital meters that record usage in real- time. Smart meters provide a communication path extending from generation plants to electrical outlets, and other smart grid-enabled devices. By customer option, such devices can shut down customer discretionary loads during times of peak demand.

Smart grid technologies have emerged from earlier attempts at using electronic control, metering, and monitoring. In the 1980s, automatic meter reading was used for monitoring loads from large customers, and evolved into the Advanced Metering Infrastructure of the 1990s in which meters could store how electricity was used at different times of the day. Smart meters add continuous communications so that monitoring can be done in real time, and can be used with smart devices in the home. Early forms of such demand-side technologies were dynamic demand-aware devices that passively sensed the load on the grid by monitoring changes in the power supply frequency. Devices, such as industrial and domestic air conditioners, refrigerators, and heaters, adjusted their duty cycle to avoid activation during times when the grid was suffering a peak condition. Using real-time information from embedded sensors, and automated controls to anticipate, detect, and respond to system problems, a smart grid can automatically avoid or mitigate power outages, power quality problems, and service disruptions (see current sensor and software-driven reconfiguration control in Fig. 1) [1].

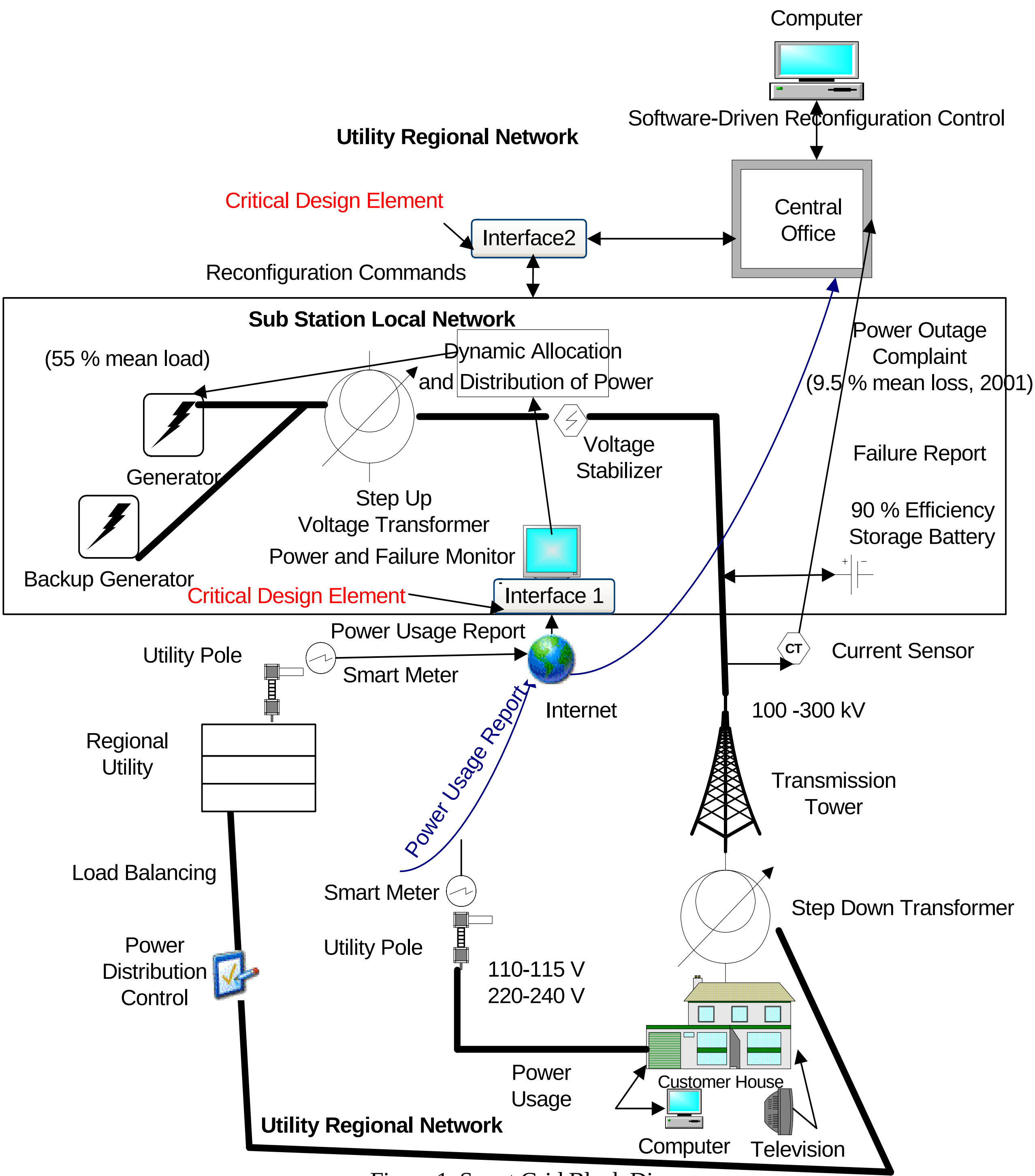

Figure 1. Smart Grid Block Diagram

Vision

The smart grid of the future would not be one integrated physical computer system directly controlling every battery and switch in the United States. Rather, each individual house might have its own intelligent control system, with values controlled and tuned by the user, such as the amount of power delivered, and for what purpose [2]. The smart grid will likely have a control system that analyzes its performance using distributed, autonomous controllers that have learned successful strategies to govern the behavior of the grid in the face of an ever-changing environment, such as equipment failures. Such a system could be used to control electronic switches that are tied to multiple substations with varying costs of generation, and reliability [1], [3]. A software-driven control system would have the flexibility of being programmed to respond to varying power demands.

References

[1] http://en.wikipedia.org/wiki/Smart_grid
[2] Paul J. Werbos, "Putting more brain-like intelligence into the electric power grid: What we need and how to do it,", 2009 International Joint Conference on Neural Networks, 2009, pp.3356-3359.
[3] http://en.wikipedia.org/wiki/Smart_grid - cite_note-Anderson-25