Analysis of Extremely Reliable Power Delivery Systems:

A Proposal for Development and Application of Security, Quality, Reliability, and Availability (SQRA) Modeling for Optimizing Power System Configurations for the Digital Economy

Consortium for Electric Infrastructure to Support a Digital Society

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REPORT SUMMARY

This report provides a methodology for understanding, assessing, and optimizing the reliability of new digital systems, processes, and enterprises. Special emphasis is given to the need for Security, Quality, Reliability, and Availability (SQRA) of the interface between electricity supply and digital systems, a process that must comprise all elements of the power delivery and end-use process—from the power plant, to the interconnecting systems, to the response of the digital systems, processes, and enterprises themselves.

Background

The digital revolution of the past few decades has focused considerable attention on the interface between new, digital systems and the supporting infrastructure they require. This is profoundly reflected in increased demand by the users of digital systems, processes, and enterprises for electric power with higher reliability and quality than is typically delivered via today's conventional centralized power system. These requirements will only increase as modern economies move into the 21st century, and as manufacturing processes and service industries become ever more dependent on digital systems. Even residential customers are becoming increasingly digital-based as more homes use microprocessor-controlled appliances and digital entertainment systems. Furthermore, the increasing use of the home-office is blurring the distinction between commercial and residential power users. Overall, in the future, all power users, whether commercial, industrial, or residential, are expected to demand more reliability from the electric power delivery system than ever before.

Objectives

To develop a framework for understanding, assessing, and optimizing the reliability of powering new digital systems, processes, and enterprises. These energy needs will be met with a combination of electricity supply implementation techniques, new technologies, and new approaches, a process that must comprise all elements of the power delivery and end-use process—from the power plant, to the interconnecting systems, to the response of the digital systems, processes, and enterprises themselves.

Approach

Issues considered in this report include more intelligent definition of power quality levels beyond mere minutes or seconds of unavailability, adding consideration of mean-time between failure (MTBF) and mean-time to repair (MTTR), and assessment of SQRA-enhancing options that maximizes digital system uptime at optimal cost.

Results

Power Quality Levels

When quantifying the availability and quality of the electric power interface with digital systems, processes, and enterprises, it is important to define what constitutes a failure. Different digital systems respond differently to various voltage disturbances. It is appropriate to define different levels of quality because digital systems will respond differently. The definition must go beyond traditional utility definitions of reliability (interruptions greater than five minutes) and include shorter-duration events that cause disturbances to digital systems, processes, and enterprises.

Different levels of electric power interface are appropriate for different needs, so several levels of "quality" are defined. In order of the most sensitive definition of a failure to the least, the levels chosen are:

Level 1: Any voltage sags below those established by the Information Technology Industry Council (ITIC) in the guideline knows as the "ITIC curve." A failure is any voltage:

- Below 70% of nominal for greater than 0.02 seconds, or
- Below 80% of nominal for greater than 0.5 seconds.

The steady-state values on the ITIC curve (voltage below 90% of nominal for more than 10 seconds) are excluded. The overvoltage portion of the ITIC curve is also excluded.

Level 2: A failure occurs if the voltage drops below 70% of nominal voltage for more than 0.2 seconds.

Level 3: A failure is an interruption of at least 1 second.

Level 4: A failure is an interruption of at least 5 minutes.

Digital systems, processes, and enterprises that are more sensitive would need better levels of quality. An electric power interface could be designed to deliver an MTBF of 5 years for level-4 loads and an MTBF of 1 year for level-1 applications. A whole facility might be given a certain a MTBF of 1 year for interruptions longer than 5 minutes (level 4), but the server room might be designed to have a level-1 MTBF of 10 years.

Comparison of Alternate Quality/Reliability Arrangements: A Case Study Approach

To illustrate application of the PQ levels strategy and other important analysis techniques, this report applies SQRA analysis to several case studies with widely different types of digital systems, processes, and enterprises with varying electric power interface configurations. These include an internet data center, a textile manufacturer, a hospital, and a residential development.

A complete SQRA analysis to minimize costs includes several steps:

1. Find the mean time between failure of each configuration.

2. Estimate the annual equivalent configuration cost of each.

3. For each configuration, find the annual outage cost based on the MTBF.

4. Rank each scenario based on the total annual cost, which is the sum of the configuration costs and the outage costs.

Figure I shows the cost versus performance of several different arrangements on the 2-MVA data center. Performance is given as mean time between failures in years and nines of load availability assuming an average of 1 hour of downtime per failure. The options vary widely in both cost and performance.

Figure II plots two different outage costs along with the cost/performance scenarios. Now, we need to add the outage costs to the configuration costs and find the minimum. Figure III shows the total costs of each scenario along with the performance of each.

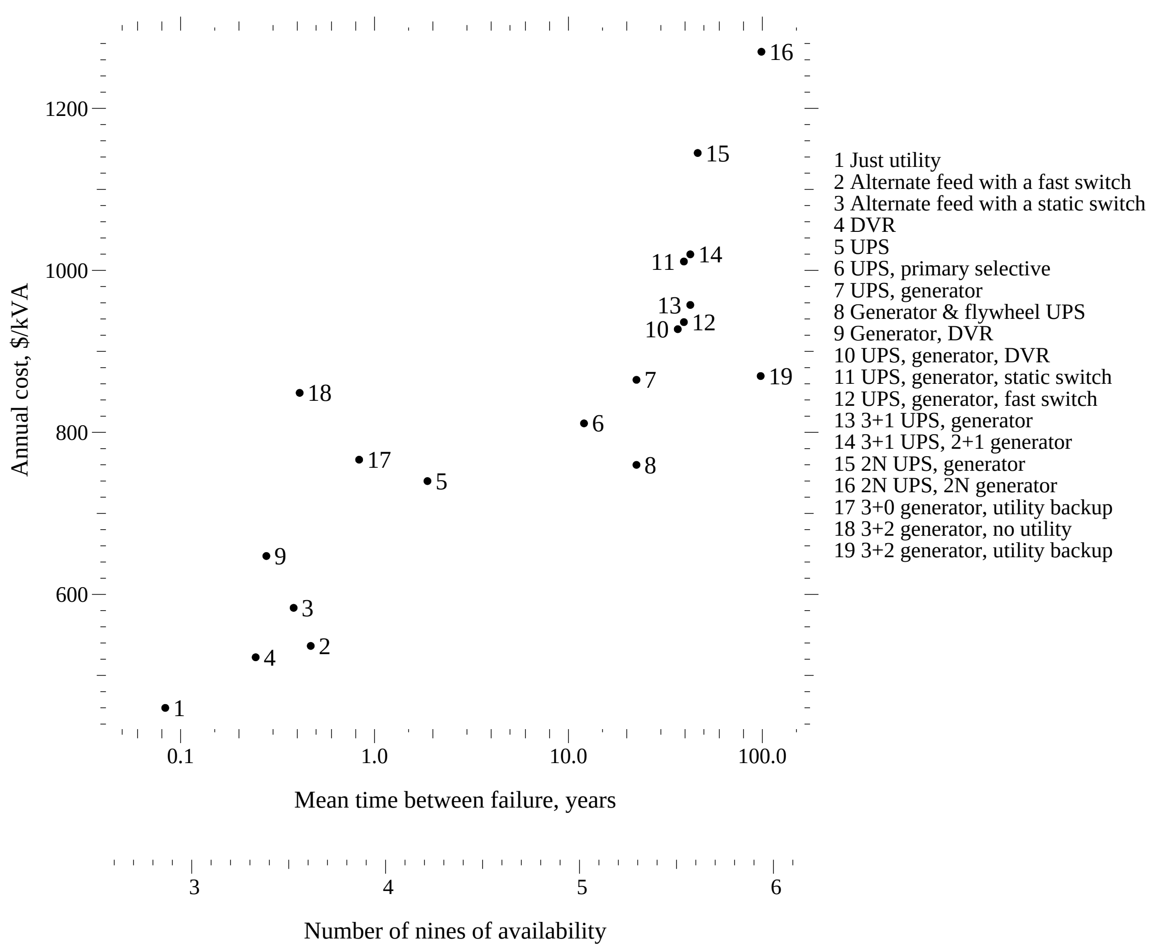

Figure I
Cost vs. Performance of Several Utility-Side and Facility-Side Configurations

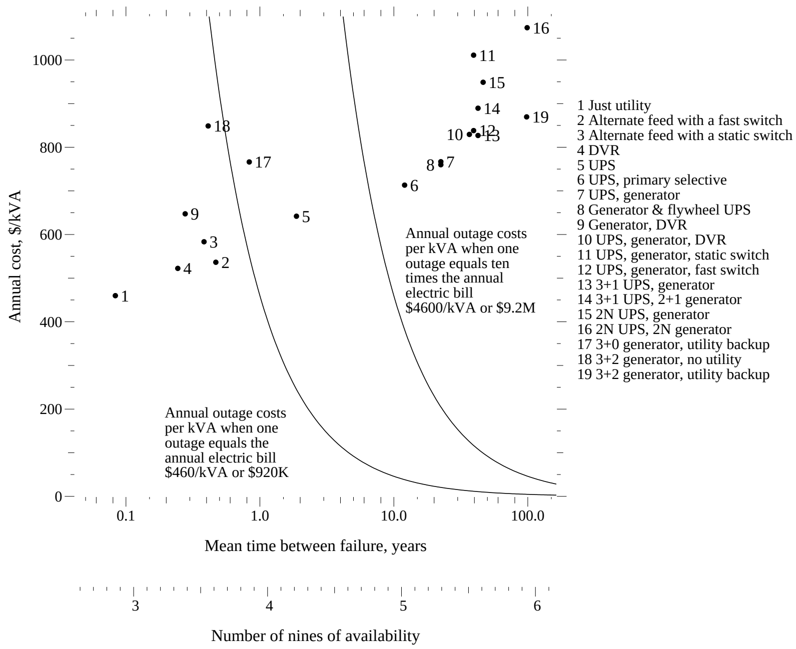

Figure II
Outage Costs Cost Along With Performance of Configurations

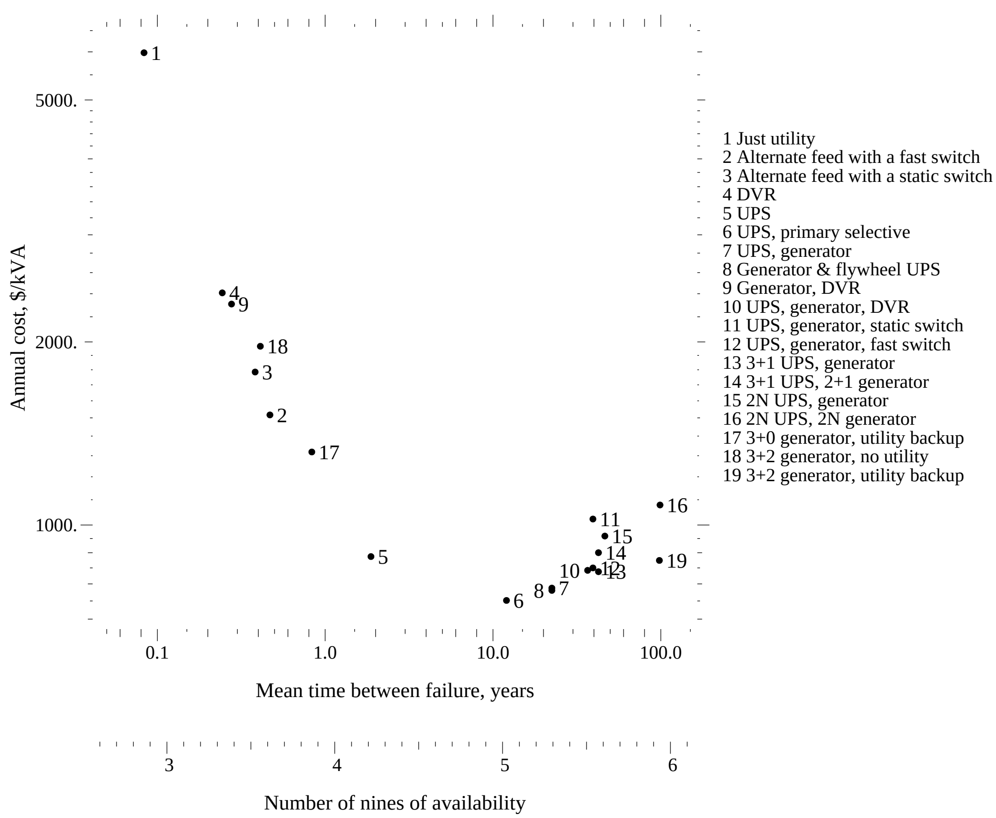

Figure III
Total Costs of Each Configuration (Outage Costs Plus Configuration Costs) for the Case Where One Outage Has a Cost Equal to the Annual Electric Bill ($920K per outage)

EPRI Perspective

The electricity power delivery system has emerged at the century's beginning as the most critical infrastructure, in the sense that it enables all other infrastructures. In the coming decades, electricity's share of total energy is expected to continue to grow, as more efficient and intelligent processes are introduced into industry, business, homes, and transportation. Electricity-based innovation—ranging from plasmas to microprocessors—is essential for enabling sustained economic growth in the 21^{st} century.

Keywords

Security
Power Quality
Reliability
Availability
Digital technologies
Digital Society