Wide-Area Real-Time Distributed Energy Resource Management
Dan Collins P.E., Founder Engage Networks,
Applicable Wisconsin Industries of the Future Cluster(s)

- Wisconsin Food Industry
- Wisconsin Metal Casting Industry
- Wisconsin Plastic Industry
- Wisconsin Printing Industry
- Wisconsin Pulp and Paper Industry
- Wisconsin Water and Wastewater
- US Glass Industry
A number of benefits accompany wide-area real-time access to distributed generation resources. These benefits include the ability to collect, analyze, and compare large sets of data collected on a regular basis from the distributed resources and their loads. The primary benefit to the collection of data is the ability for energy resource managers to control loads to mitigate peak electric costs. This is supplemented by the ability to receive alarms when anomalous events occur. Acquiring data from remotely located GenSets over wide-area networks can provide data from hundreds, even thousands, of generators on regular intervals, ranging from a few minutes to a few hours depending on the needs of the users of the data. The ability to communicate in real-time with generators enables wide-area control capabilities and the information collected and stored in a database can be utilized for financial analysis and maintenance.
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Data Transportation And Analysis

It is important to have the capability to issue control commands to one or more generators quickly, and also receive feedback in real-time in order know the status of the GenSets. This closed loop supervisory control insures that the power requested from the generators is actually delivered. Furthermore, by setting up alarms to alert the appropriate individuals, a user can continuously monitor the generators for unexpected events.

From a financial perspective, it is necessary to realize that distributed generation resources are viable sources of revenue. As distributed generation technology improves, it is becoming more commonplace for property owners and managers to install generators on-site for prime-power applications, providing base-load or by peak shaving. This differs from historical paradigms, where generators where used only for back-up power. Understanding the process of financial evaluation is important for anyone desiring to become involved with distributed generation. End users, generator manufacturers and sales representatives, distributed resource management organizations, and utility representatives should all understand how using generators would impact the bottom line. Purchase price, installation costs, run-time strategies, utility rate structures, market pricing, generator efficiency, fuel costs, and curtailment incentives are just a few of the factors that need to be understood.

Communications Architecture

The amount of time and effort needed to actively manage generation assets has created a market for the outsourcing of generator maintenance and management. To make this business model effective, an organization needs to possess the capability to remotely manage a large number of GenSets. To do this in a cost effective manner, it is necessary to take advantage of existing infrastructures to maintain continuous communications with distributed resources. While telephone lines have been used in the past to enable wide-area communications, the real-time demands of the new distributed generation market are quickly making telephone communications cost prohibitive.

With the rapid and continuous expansion of high-speed Internet accessibility, the Internet has become a means for communicating with geographically dispersed resources in a cost effective manner. Any communications solution must be flexible and robust. With careful design and management, the Internet is a cost effective way to manage distributed resources.

It is important to note that the Internet can have multiple meanings. In the simplest terms, the Internet is defined as any wide-area TCP/IP based network. This definition includes wide-area virtual private networks, public Internet, frame relay networks, corporate WANs, telephone, wireless and a variety of other network infrastructures. A general architecture is illustrated in Figure 1. This figure illustrates a
server cluster responsible for remote monitoring and control of geographically disperse distributed
generation resources (GenSets.) The software on the server cluster communicates with the GenSets
over a wide-area network. The GenSets themselves can be connected to the network a number of
ways. The generator itself may have communications circuitry supporting TCP/IP protocols, in which
case the generator can be tied directly into the wide-area network. Additionally, the generator may only
have local, serial communications capabilities. In these situations, additional communications hardware
can be integrated to serve as a gateway connecting the generator to the network. Where multiple
generators reside at a single site, it is also possible to provide connectivity to all of the generators on
site utilizing a single gateway device.

Internet connectivity is not limited to the use of gateway devices and embedded communications
technology. A number of other physical mediums can be utilized to connect the GenSets to the
network. These mediums include:

- Use of a local area network
- DSL line
- Modem over phone line
- Cellular modem
- Cable modem
- Wireless Ethernet

The key to successfully using TCP/IP protocols to transmit information is that the protocol functions
over a wide variety of physical architectures, thus allowing for greater flexibility during the deployment
of a GenSet. Furthermore, the popularity and rapid expansion of the Internet is resulting in an
increasing number of creative methods for achieving connectivity to TCP/IP based networks.
Data Quality

The quality of the data recorded by the system is also of utmost importance. Quality data cannot be guaranteed solely through the use of software. While it is true that validation and editing routines can be used to compensate for corrupt or missing data these techniques should only be relied upon as a last resort. It is critical that highly reliable communications hardware be installed at the generator to insure consistent communications and reliable data. This is true for load metering equipment as well. A reliable communications platform may be characterized as follows:

- Dedicated purpose hardware – the hardware utilized to operate the communications platform should be designed and manufactured to specifically serve this purpose. The use of PCs or industrial PCs are developed for generic applications and as such tend to have a lot of overhead and un-used components that increase the chances of failure.
- Real-time operating systems – The use of a real-time operating system in the platform is critical as wide area communications tends to be asynchronous in nature.
- Industrial temperature ratings – The communications platform must be able to withstand the wide range of temperatures experienced in many distributed generation environments.
- Low susceptibility to noise and vibration – Due to the harsh physical and electrical conditions present in many distributed generation deployments the communications platform should be able to withstand significant physical and electrical abuse by the generation equipment.

In addition to high-quality communications and metering equipment, the load data should have a secondary quality assurance mechanism in the form of validation estimation and editing routines.
These routines serve as watchdogs and failsafe mechanisms for load data. The load data is often used to analyze the financial impact and prove to outside parties that the generation equipment is being used to affect the load. The use of these watchdog routines can insure quality consumption data when un-anticipatable problems occur with metering equipment.

Data Sources
A complete distributed resource management system must monitor and control generators, but it must also monitor other variables such as a sites load, environmental variables, thermal-loads, and fuel consumption. A quality solution must be flexible enough to meet the needs of a wide variety of sites, each with their own requirements. To satisfy these needs, a distributed generation solution requires the flexibility to communicate with a wide range of communications hardware. Communications hardware includes:

- Metering equipment (electrical, gas, thermal loads, etc.)
- Communications bridge/gateway – proves real-time access to generator
- Discrete I/O
- Analog I/O

While each site may not require all of these options, the system as a while will more often than not encompass some combination of these features.

Supervisory Control
Of critical importance for the management of distributed resources is the capability for supervisory control. A clear distinction here is made between control and supervisory control. Control functions are performed on-site by the generator controller. These functions are high-speed in nature and require sub-cycle response that cannot and should not be attempted wide-area. Supervisory control involves the issuing of general commands such as start, stop, and set power level. While these commands should involve a closed loop to ensure proper response, the response time can be much slower, measured in seconds, or even in minutes depending upon the step response of the generator to commands.
Generator Dispatch

The dispatch of a generator fundamentally involves the ability to set the power level; the power factor offset (where appropriate) and start or stop the generator. As GenSets are typically installed over a wide timeframe it is unlikely that all installations in a wide-area distributed generation application will be utilizing the same makes and models of generators. However, by limiting the basic dispatch screens to a few fundamental items consistency may be maintained throughout the dispatch screens, regardless of the type of generator being commanded.

A generator dispatch screen should also be available at the group level. At the group level, multiple generators are dispatch from a single interface as if they functioned as a single unit. The maximum available power for the group will be the maximum power available for all of the generators combined. The order in which the generators are deployed will have an effect on maintenance costs, operating costs, and performance. The determination of start order will be based upon a significant number of variables that vary from one make and model to another. Thus, there will be a need to determine the order in which to dispatch a plurality of generators that takes into account multiple variables in the decision making process. The Fuzzy Generator Dispatch system has several core design objectives:

- Account for an unlimited number of parameters
- Work for any combination of generator makes and models
- Does not require knowledge of the systems mathematics to configure.
Generator Run-time Scheduling

To aid in the “hands free” management of distributed generation resources, a generator scheduler is available that allows the user to create schedules for generation equipment. Any number of schedules can be added. A schedule will be repeated on a weekly basis and will be defined by the day of the week, the start time, the stop time and the power level. Once configured, the generator will run according the schedule. Should an unexpected event occur, a specified list of users would be emailed immediately. An unexpected event is defined as:

- Generator fails to start
• Generator fails to stop
• Generator fails to achieve power output
• Generator stops unexpectedly

The following figure illustrates the configuration screen for a generator schedule.

**Event Based Dispatch**

The event-based dispatch feature allows users to configure generators to perform some action (start/stop/change power level) when a series of alarms occur. For each of the three action times, users may define a series of alarm conditions such that when the conditions are met, the action will be initiated. The following figures illustrate an overview screen defining what conditions are associated with each action and the editor tool for these actions.
Maintenance

Any wide-area generation management solution should involve maintenance features. Just as significant savings may be realized by centralizing the management of generation resources, so too may savings be realized by centralizing many of the maintenance procedures.

Scheduled Generator Tests

The scheduled generator tests are intended to start a generator on a regular bases to ensure that when the generator is needed, it will be available. The generator start-up tests may be scheduled to run on a weekly or monthly basis. The test will involve initiating communications, starting the generator, verifying that the generator started, and then stopping the generator. The test results will be logged to the database and may be viewed at any time. In the event that a test fails, appropriate individuals will be notified via email. The following figure illustrates the configuration screen for the scheduled generator tests.
Operational Statistics
As part of the distributed maintenance offering a report specifically designed for displaying the operational statistics of a generator will be created. These statistics are updated every time the system communicates with the generator. The operational statistics page will consist of one page displays information such as the following:

- Runtime hours
- Number of warm starts
- Number of cold starts
- Number of shutdowns (protective and emergency)

Because each generator will be different, the operational statistics page will vary from generator to generator. A group operational statistics page will be provided that provides the operational statistics of every generator within the group. This list will be sort able by column. The following figures illustrate an operational statistics report for a single generator and a report for a group of two generators.

<table>
<thead>
<tr>
<th>Operational Statistics for Device: &quot;Parallon 75 Simulator&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runtime Hours: Unknown</td>
</tr>
<tr>
<td>Emergency Stops: 52057</td>
</tr>
<tr>
<td>Protective Shutdowns: 5218</td>
</tr>
<tr>
<td>Cold Starts: 7120</td>
</tr>
<tr>
<td>Warm Starts: 1001</td>
</tr>
</tbody>
</table>

Fault Analysis
The distributed maintenance offering allows the user to configure a fault warning system at the device level. This fault warning system will allow users to determine if a fault is imminent in a piece of equipment. The fault warning system will page or email a user when a warning occurs. The fault status will be indicated on
screen in a similar fashion as the following figure. The users will have the option of confirming or dismissing these warnings. The confirmation of a warning will serve as an affirmation that the system made the correct assumption thus improving the prediction ability of the software. A dismissal of a warning will indicate that the system has made an incorrect assumption. The artificial intelligence engine within the system will learn from this mistake and will therefore improve its predictive abilities.

**FAULT LIST**

<table>
<thead>
<tr>
<th>FAULT</th>
<th>RISK LEVEL</th>
<th>ENABLED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearings Breakdown</td>
<td><strong>HIGH</strong></td>
<td>(CLICK TO DISABLE)</td>
</tr>
<tr>
<td>Engine Failure</td>
<td><strong>LOW</strong></td>
<td>(CLICK TO DISABLE)</td>
</tr>
</tbody>
</table>

**NOTIFICATION LIST**

**FAULT SETUP**

**FAULT INFORMATION**
- Fault Name: Engine Failure
- Generator Type: Honeywell Parallon 75
- Notify When Risk Exceeds (%): 50

**FAULT CRITERIA**
- Actual Engine Speed Status is High
- Engine Speed Reference is Medium-High

**CANCEL** **SUBMIT**

**Load Analysis**

Distributed generation resources are financial tools intended to save money. Historically, generators were used for the purpose of backup generation. If the power went out, the generators went on, the business stayed open, and money was saved, or more accurately, money was not lost. Simply stated, generators used as backup power may keep business from losing money during an outage, but actually saving money is a more complicated task. To save money by using generators, one must be able to fully analyze the load to which the generators are going to be applied.

**Generator Schedule Design and Analysis**

A generator schedule design and analysis tool will allow users to apply distributed generation resources to a load and perform what-if scenarios on generator run-time schedules. The feature should be graphical in nature (Illustrated in following figure) and will allow the user to drag a line, indicating the generator output, up and down over the load shape. This the tool will automatically recalculate the energy costs over the given period of time and display the savings (or losses) incurred by running the generator.
The users may opt to employ a generation strategy and have the system automatically configure the run-time schedule tool to evaluate that strategy. These strategies are illustrated in the following figure. The schedule design and analysis tool does require access to metered load (kW) data.

**Operational Strategy:**
- None
- Constant Generation at [ ] kW
- Peak Shave at [ ] kW

**Generator Variables:**
- Generation Capacity: 150 kW
- Generator Efficiency Rating: 25%

**Environmental Variables:**
- Electrical BTU Conversion: 3412 Btu/Watt-Hr
- Natural Gas BTU Conversion: 10000 Btu/Therm

**Billing**
The ability to create billing reports is important in a distributed generation application to understanding how funds are being spent on both the purchase of electricity and fuel as well as in other applications such as co-generation. Billing reports utilize rate structures to generate financial reports. The rate structures need to be flexible enough to model rates for a number of different commodities. These billing reports may be run against a device, a group, or a domain.

**Differential Billing**
Differential billing applies two rates to a single group, domain, or device; a single rate over two time periods for a single group, domain, or device; or two rates across two time periods to a single group,
domain, or device. The report itself will apply each rate structure and/or time period and report the difference in financial amounts as well as the details of each bill. Differential billing within the context of a generation application are utilized to analyze savings, month-to-month performance, and as a tool to investigate other billing options and negotiations.

Profiling
One of the most straightforward methods for understanding generation needs is to view profiles of a load. By understanding a profile, one can determine how a generator may best be utilized to efficiently supply energy to a site.

Standard Profile
The standard profile graph displays a typical shape of a load for a set of days over a time range. For example, a profile may indicate to a user what a typical weekday load shape looks like. Furthermore, the profile graph should indicate the maximums and minimums for each time of day. The following figure illustrates a profile graph where the solid blue represents typical (average) usage, the purple line indicates maximums and the pink line indicates minimums. The profile report should also display, textually, the peak, minimum, and average value for each line.
Calendar Profile
The calendar graph will display usage for an entire month. The data will be plotted within a calendar. Clicking on a day of week will allow you to view the data on a larger graph, clicking on multiple days will overlay the trends. A sample calendar profile is illustrated in the following figure.

![Calendar Profile](image)

3-D Profile
The three-dimensional profile plots time of day on the x-axis, day of week on the y-axis and usage on the z-axis. This allows users to view a typical week all at once. The graph is rotatable. The graph should utilize a gradient color scheme with a legend to the right of the graph as indicated in the following figure.

![3-D Profile](image)

Figure 4: Sample 3-D Profile

Advanced Data Analysis
Variable Correlation
The system should allow users to generate correlation reports that allow them to analyze the relationship between two variables, either from the same device or different devices. This is valuable for maintenance personnel analyzing parameter relationships as well as energy managers attempting to understand relationships among demand, generator output, thermo-loads, and fuel usage. The system will produce a report that plots one variable against another and displays the correlation.
coefficient (measure of the relationship). The graph will also have the ability to highlight variables that significantly deviate from the illustrated relationship. The user will define what variables are to be displayed on the x- and y-axes. When the user selects a device, all of the available variables for that device will be displayed as options. When the user selects a data point, only that variable will be displayed in the list of available values. When the user selects a group or domain, the aggregatable values will be displayed in the list of available variables. The user will then define the date range over which they would like to analyze. This first step is illustrated in the first of the following two figures. The report itself will graphical in nature with an “X” for every data point in the system as shown in the second of the figures. The correlation coefficient will be displayed as well as a line of best fit.

![CORRELATION](image)

Figure 5: Setting up a Correlation Report
In the final analysis, the system for real-time wide area distributed energy resource management must be easily usable. For certain audiences, simplified reporting produces wider acceptance and use of the product. This results in more savings for the principal parties. This can also lead to a keen awareness by the user, and an interest in the extended detailed information and benefits that can be gained from using a wide area, real-time distributed energy resource management system.

Figure 6: Correlation Report
Figure 7: Simplified report sample screen