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Applying Predictive Analytics to Power Backup

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According to a 2013 study by the Ponemon Institute,[1] the leading cause of datacenter outages is battery UPS failures following a power outage. UPS failures account for 24% of all datacenter crashes. Another 7% of outages are caused by generator failures, in which the generator doesn't start or fails during the power outage. These causes account for almost a third of all datacenter outages.

Given the amount of detailed data that UPS and generator-monitoring facilities can provide, a field of mathematics known as *predictive analytics* can be put to good use to detect pending failures and to correct faults before they cause a datacenter incident.

What Is Predictive Analytics?

Predictive analytics is an area of data mining that exploits patterns found in historical data to predict risks or opportunities. It provides a predictive probability that some event will happen. Often, the unknown event of interest is in the future. Examples of the use of predictive analytics are credit-scoring (the probability that a person will pay his bills) and credit-card fraud (the probability that a transaction is fraudulent).

Predictive models associate the specific performance of a unit in a sample with multiple, measurable attributes of that unit. The objective of the model is to assess the likelihood that a similar unit in a different sample will exhibit the same performance given a similar set of attributes.

The available units with known attributes and known performance are the "training sample." The units with known attributes but unknown performance are the "out-of-training sample." Based on the relationships of attributes and performance in a training sample, predictive analytics attempts to assign a probability to different outcomes of an out-of-sample unit based on its known attributes.

Many analytical techniques are encompassed by predictive analytics. One of interest in computing systems is *survival analysis*. Survival analysis estimates the time to failure of a component based on the current value of certain attributes of that component. This is the form of predictive analytics that is of interest in this article.

Historically, using predictive analytics tools required advanced skills. However, as increasingly more organizations added predictive analytics to their decision-making processes, vendors responded by creating software tools that removed the mathematical complexity and that provided user-friendly interfaces.

[1] 2013 Cost of Data Center Outages, *Ponemon Institute*; December 2013.
http://www.emersonnetworkpower.com/documentation/en-us/brands/liebert/documents/white%20papers/2013_emerson_data_center_cost_downtime_sl-24680.pdf

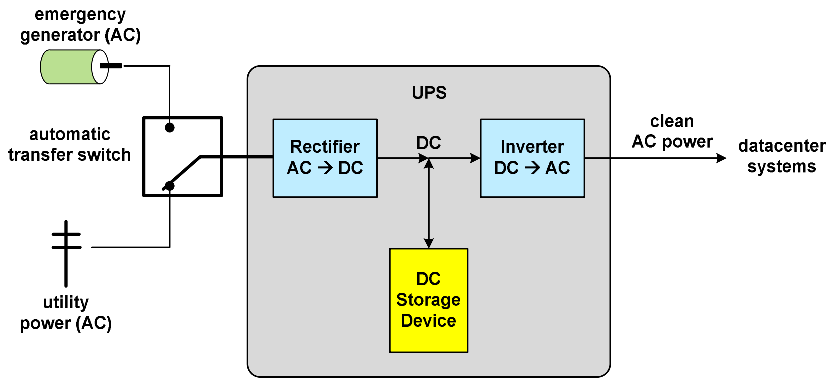
According to the Rexer Analytics 2013 Data Miner Survey, the most popular commercial packages are IBM SPSS Modeler, SAS Enterprise Miner, and Dell Statistica.

Applying Predictive Analytics to Battery UPS Systems

What Is a UPS System

Power reliability is addressed in modern-day data centers with backup generators. However, it takes several seconds for a generator to start up and come online. During this time, a power loss occurs unless there is another source of power that can come online instantly for a time long enough for the generators to begin supplying power.

This other source of power is an Uninterruptible Power Supply (UPS) system. As shown in Figure 1, a UPS contains a rechargeable energy source that is thrown into service when the primary utility power is lost. It provides power to the data center until the backup generators come into service. Should there be a generator failure, the UPS system provides power for a long enough period of time to support an orderly shutdown of the systems in the data center.



A UPS System
Figure 1

A typical UPS system is shown in Figure 1. Its first job is to clean utility power to the standards required by the data center. “Clean power” is a constant voltage at a constant frequency (60 hertz in the United States). As power is transmitted from the generating plants to the consumers, it can become “dirty.” Voltages can fluctuate depending upon the power being consumed by other end users. High-frequency noise can be induced into the power feed by appliances. This dirty power can cause problems in a data center.

To clean the dirty utility power, the potentially dirty utility power is fed to a rectifier in the UPS system. The rectifier converts the AC (alternating current) utility power to DC (direct current). This relatively clean power is then converted back to AC by an inverter in the UPS system to provide clean power to the data center.

In the event of a utility power failure, an automatic transfer switch detects the power loss and rapidly connects the UPS rectifier to the emergency generator system. The UPS generates the controls to start the generator, and power is restored to the data center.

One problem with this approach is that there will be a several second outage to the data center, and it likely will be disastrous. This is where the ‘uninterruptible’ in “UPS” comes in. Connected to the DC bus from the rectifier to the inverter in the UPS is a device that stores energy in DC form. When the output of the rectifier fails, the energy from the DC storage device feeds the inverter and keeps power flowing to the data center until the emergency generators can come online. This is typically a time measured in seconds.

In addition to this delay, the automatic transfer switch is often designed not to switch to the backup generator for a few seconds so that brief utility power outages do not deplete the DC energy source for starting the generators. Eighty percent of power outages last less than two seconds, and 98% last less than ten seconds.

The predominant form of DC storage devices in use today are strings of batteries. However, batteries have several challenges that can make the battery strings unreliable.

Disadvantages of Battery Systems

Battery storage systems have not proven to be reliable. The Ponemon study referenced above found that 55% of respondents blamed battery failure as the root cause of a datacenter outage due to a primary power failure. Human error came in second.

A typical data center operating on one megawatt of power will have about five strings of 40 batteries each. This is a total of 200 batteries. The failure of any one battery will take its string out of service. With one string out, there may not be enough backup energy to provide datacenter power for the time it takes to get the generators online. This will cause a datacenter outage. Statistics show that 70% of UPS service calls are the result of bad batteries. 40% of cases where power was lost to a critical load were the result of battery failures.

As a battery ages, its internal resistance goes up. This prevents the battery from delivering its rated power. In many cases, the pending failure of a battery cannot be detected until the battery is called upon to deliver power.

Predicting Battery String Failures

Battery-monitoring systems can produce a massive amount of data points. However, rarely do these monitoring systems have the intelligence to manipulate the data to provide actionable insights. This is where predictive analytics comes in. It can offer clear, actionable alerts for intervention, maintenance, and preemptive repairs.

The first step, of course, is to install an effective monitoring system. Ensure that the contractor installing the monitoring system takes into consideration servicing access to the batteries.

It would be much simpler if every battery had one simple set of parameters. However, these parameters vary with battery manufacturer and battery model. Parameters can include, among others, string voltage, unit voltage, battery impedance, ambient temperature, unit temperature, ripple, and unit discharge. These alarms have different priorities, so which ones are important? If you are using predictive analytics to predict failures, all are important.

Increasing availability is what predictive analytics can do for a facility. For instance, it can help predict when a battery in a string is nearing end-of-life so that the battery can be replaced before it causes a string failure and a potential UPS failure.

Applying Predictive Analytics to Electrical Generators

Predictive analytics also can be applied to the generators. Data centers may be considered the “brain” of a company, but it is the generators that are key to keeping that brain running and reliable in the face of a power outage. A generator is arguably the most critical piece of equipment in a mission-critical facility. Nevertheless, generator failures play a major role in unplanned datacenter outages.

In order to have visibility into potential failures, sophisticated monitoring systems collect data via sensors in the data center’s power generating systems. Typically, the data gets reviewed; but most of it is not used for immediate actions. Further analysis would enable facility managers to extract meaningful, actionable insights. By examining this sensor data post-collection with predictive analytics, information can be provided that will help data centers ensure uptime by predicting equipment failures before they happen, especially with regard to generators.

Currently, facility managers monitor their sensor information in real time to check the current status of their generating systems. Are they getting too hot? Are they still running? However, the true value of this mass of data points comes from storing the data and analyzing it from a historic viewpoint. Analyzing the performance over time enables a facility manager to determine patterns that can be used to predict outages before they happen. This is the role that predictive analytics plays.

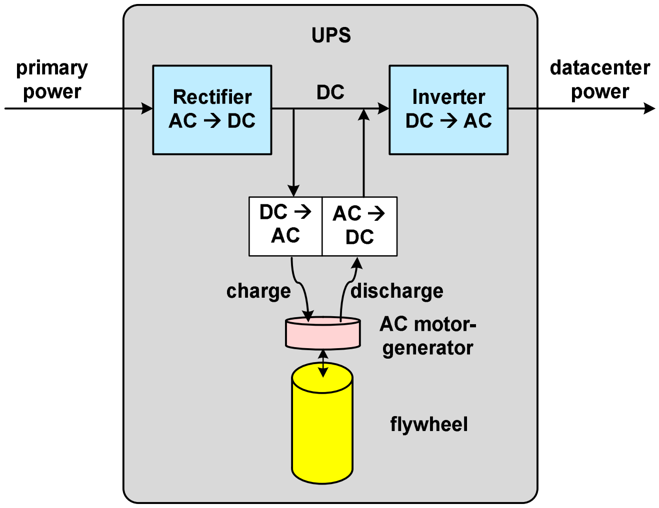
An Alternative for Battery UPS Systems

So far as battery systems are concerned, there is now available a useful alternative – flywheels.

A flywheel solves many of the problems associated with batteries. A flywheel can store energy just like a battery. The primary difference is that a flywheel stores kinetic energy whereas a battery stores electrical energy.

A flywheel is a disk that is spun up to a very high speed, typically in a vacuum to reduce drag. Once it reaches its operating speed, it takes very little additional energy to maintain the speed. Current flywheel technology results in flywheel UPSs that are up to 98% efficient. That is, it takes only about 2% of the delivered power of the UPS to maintain the speed of a flywheel (in battery terminology, to keep it fully charged).

The flywheel is connected to the DC bus via a generator. Should the main power fail, the generator driven by the flywheel continues to deliver DC energy to the inverter and maintain the datacenter power until the backup generators can come online. In battery terminology, this is the discharge of energy from the flywheel.



A Flywheel UPS
Figure 2

In principle, a DC motor-generator is employed. However, DC motor-generators require brushes and commutators that are subject to wear and require maintenance. To address this challenge, an AC motor-generator, which does not have these problems, is often utilized, as shown in Figure 2. To interface the AC motor-generator to the DC bus of the UPS, an inverter converts the UPS DC bus voltage to AC, which drives the AC motor-generator working as a motor to charge the flywheel. If the primary power fails, the energy in the flywheel drives the AC motor-generator as a generator. Its AC output is converted to DC via a rectifier and powers the datacenter until the generators can be brought online.

The amount of energy stored in a flywheel is proportional to the mass of the flywheel and to the square of its speed. Doubling the mass of the flywheel doubles its stored energy. Doubling the speed of the flywheel quadruples its stored energy. Therefore, it makes engineering sense to trade mass for speed. Early flywheel UPSs used steel disks and rotated at speeds in the order of 7,000 rpm. Newer flywheels use relatively light-weight carbon filaments that have a great deal more tensile strength than steel. These flywheels are spun at tens of thousands of rpms.

Equally important, the light mass of fiber filament flywheels means that they can be suspended by magnetic bearings, as opposed to the mechanical bearings of older flywheels. The older mechanical bearings required periodic maintenance and replacement. Magnetic bearings are maintenance-free.

Most flywheel systems come with a remote monitoring capability. As opposed to batteries, it is easy to measure the charge stored in a flywheel system. It is basically just the speed of rotation.

A single flywheel system can deliver several hundred kilowatts of power. In fact, some existing commercial systems provide over a megawatt of power. Think about it – 200 batteries can be replaced with one flywheel system!

This power can be delivered for times ranging from seconds to minutes depending upon how much power must be delivered by the flywheel compared to its capacity.

Summary

In today's data centers, protection from primary power outages is typically provided by backup generators and UPS systems that supply power until the generator can be started and brought online. The failure of a generator or a UPS system is one of the major causes of datacenter outages.

Generators and UPS systems typically are monitored by extensive monitoring systems. However, most of the data generated by these monitoring systems is unused for any actionable purpose. By analyzing the data in real time using predictive analytics, actionable insights can be generated for intervention and maintenance before a failure occurs. This can improve the availability of a data center significantly.

Acknowledgements

Information for this article was taken from the following sources:

2013 Cost of Data Center Outages, *Ponemon Institute*; December 2013.
Predictive Analytics, *Wikipedia*.
Rexer Analytics 2013 Data Miner Survey, *Rexer Analytics*; 2013.
New Methods of Maximizing Your Oldest Data Center Technology, *Datacenter Knowledge*.
Stay Out of the Dark: Applying Predictive Analytics to Generators, *EC Magazine*; November 20, 2015.
Flywheel UPS Systems, *Availability Digest*; January 2014.