

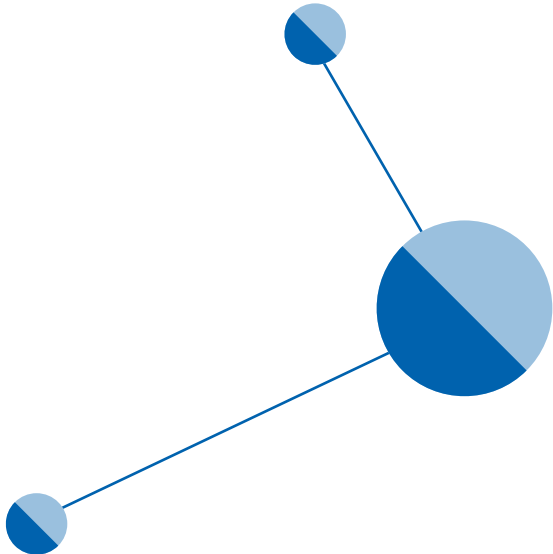
# Managing uncertainty: predictive analytics for GE's Jenbacher gas engines

The Distributed Power offering from GE's Asset Performance Management software solutions makes the whole system smarter



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# Attributes of GE's Asset Performance Management software solutions powered by Predix for Distributed Power products—by the numbers

>39,000	delivered aeroderivative gas turbines and reciprocating engines
>4,500	units are connected and provide advisory services
>617,000	managed sensors
3.5 terabytes	generated and captured per year
~50%	cases solved remotely
~98%	reliability and uptime boost of Jenbacher gas engines

GE Power & Water's Distributed Power business is a leading provider of power equipment, engines and services focused on power generation at or near the point of use. Distributed Power's product portfolio includes highly efficient industrial reciprocating engines and aeroderivative gas turbines that generate 100 kW to 116 MW of power for numerous industries globally. Headquartered in Cincinnati, Ohio, the Distributed Power business employs about 5,000 people around the world.

GE's Distributed Power business provides life cycle support for more than 39,000 aeroderivative gas turbines and reciprocating engines worldwide to help you meet your business' challenges and success metrics—anywhere and anytime. Supported by our authorized service providers in more than 170 countries, GE's global service network connects with you locally for rapid response to your service needs.

You operate your equipment around the clock and around the world, and GE provides assistance when and where you need it. With innovative technological and data solutions we can take you from simple maintenance services to sophisticated technology upgrades, and from end-to-end outage services to predictions of your next service event. There's GE's Asset Performance Management software solutions powered by Predix\*, for instance, which connects people, machines and industrial big data so that you can predictively and proactively manage your assets and operations. This combination of machine big data, predictive analytic software and GE expertise can help lower your unplanned downtime, making your workforce more effective, creating fuel efficiencies, reducing your operating costs and uncovering new revenue opportunities. It all adds up to increased value for your installed base.

"Our investments in hardware, software and data-driven technology can make your assets and operations more efficient, flexible, dependable, and cleaner. Our innovative technological and data solutions can take you from simple maintenance services to sophisticated technology upgrades, and from end-to-end outage services to predictions of your next service event. It all adds up to increased value for your installed base."

\* Trademark of General Electric Company

# Introduction

## The Industrial Internet

The concept of machine-to-machine (M2M) communications has a rich history in the industrial world, and many technologies and standards exist that provide the foundations for a high degree of functionality across a broad range of industries. However, advances in computing, software development, networking, analytics, and security have made it possible to extend the concepts inherent in more than five decades of M2M interaction to a new level of functionality and efficiency. These advances are already beginning to ignite a new industrial revolution. This is the revolution of machines—machines that are self-aware; that can connect and interact with other machines and their human operators; that can be provisioned, managed, upgraded and decommissioned remotely; that can function safely and securely; and that can improve industrial operations at all levels of the global economy.

## Condition Monitoring & Analytics

The Industrial Internet is changing the way we manage and enhance global economic output. Combining brilliant machines with big data analytics creates valuable asset and operational insights in ways never before possible. Just as the consumer Internet has transformed people's ability to provide and access information anytime or anywhere, the Industrial Internet holds the potential to bring about profound transformation to industrial productivity and growth. The results: better performing and longer-lived physical machines, substantial savings in fuel and energy, and improved energy operations outcomes at a lower cost.

The ability to capture this potential largely depends upon the foundation that can support the solution ecosystem. A software platform that can connect machines, data, and workers by supporting

a variety of industrial data, new analytic capabilities, and innovative ways to collaborate will be key to transforming this vision into a reality. Predix, GE's software platform for the Industrial Internet, is a comprehensive and integrated platform to make this vision a reality.

The Predix platform fosters industrial-scale analytics to enhance assets and operations by providing a standard way to connect machines, data, and people. Deployed on machines, on the premises, or in the cloud, Predix combines an industry-leading stack of technologies for distributed computing and big data analytics, Asset Performance Management, M2M communication, and mobility. GE's Asset Performance Management software solutions powered by Predix for the Industrial Internet using predictive analytics to help enable powerful customer outcomes. These solutions deliver multiple benefits:



### Machine-Centric

- Easily connect machines to the Industrial Internet
- Embed analytics into machines, making them intelligent and self-aware
- Retrofit and upgrade machine software without mechanical modifications



### Industrial Big Data

- Gain actionable insights from massive amounts of high-velocity machine data
- Manage all your assets, from steel bolts to smart factories
- Orchestrate real-time analytics processing across distributed machines and data, over deterministic networks



### Modern Architecture

- Deliver consumer-grade mobile experiences for industry-grade control and insights
- Receive big data computing fabric, including Apache\* Hadoop\*, historians, and graphs
- A platform that runs on machines in your data centers, in the public cloud or in the private cloud



### Resilient and Secure

- Ensure high-availability for mission-critical operations
- Protect sensitive data across machines, networks, and clouds
- Comply with industry and government regulations and for security-sensitive industries

### Predix

GE's software platform for the Industrial Internet, is a comprehensive and integrated platform to make this vision a reality.

## Managing Uncertainty with Asset Performance Management

Asset Performance Management is an emerging market category of software and services offerings aimed at helping industrial companies enhance the performance of their assets to increase availability, decrease costs, and reduce operational risks. Asset Performance Management integrates the technologies of connectivity, data capture, integration, visualization and analytics for the explicit purpose of automating Asset Lifecycle Management, Remote Monitoring, Condition-based and Predictive Maintenance, and Real-time Operator Intelligence; that is, getting the right information and guidance to the right people at the right time. Asset Performance Management practices and the technologies that support them are designed to improve decisions on how to operate, when to maintain and what type of activities to perform on equipment. This can include assessments of relative performance; maintenance costs and spare-parts inventory levels; failure history; failure impacts; usage patterns; and correlations with external factors, such as production data and weather.

### No Unplanned Downtime

New digital technologies and analytic tools are facilitating predictive Asset Performance Management that can reduce the bottom-line damage caused by unplanned downtime. Impacts from unplanned downtime include:

- Missed revenue opportunities when oil drills are taken offline suddenly
- Commercial building activities affected with unexpected repairs
- Customer and public perception issues with abrupt power outages
- Lost production on the factory line during peak operating hours

What if industrial companies could predict when machines are about to fail? How would that change the game?

The ability to proactively manage big machine repairs is a powerful revenue enhancing and risk management tool for operations and business teams worldwide. New sensor technologies can capture petabytes of data, even under extreme conditions.

This data, fed to predictive analytic solutions, can identify emerging problems in the following ways so operating teams can intervene to take more immediate corrective actions:

- Proactive notification: Alerting operating staff when an issue begins to emerge, granting the longest lead time to plan for maintenance
- Operating visibility: Enhanced understanding of which parts are at risk for failure so that the right replacements can be ordered proactively
- Identification of root cause: Eliminating guesswork and facilitating rapid repairs by discovering the real source of the issue from the myriad of possible machine components, thereby facilitating rapid repairs.

New digital technologies and analytic tools are facilitating predictive Asset Performance Management that can reduce the bottom-line damage caused by unplanned downtime.

# Solutions

## Enhanced profitability

Machine sensors and sophisticated monitoring systems are capturing a wealth of data from a broad spectrum of industrial equipment. Industrial companies are using this data for real productivity and profitability gains. Beginning with GE's Asset Performance Management software solutions advanced analytics enable powerful insights around potential equipment weaknesses, root cause analysis, and alerts for critically impaired components. With analytic insights, GE customers enhance asset performance, which contributes directly to the bottom line. Based on the insights gained from Asset Performance Management, forward-thinking industrial companies are driving the next level of profitability — operations optimization — by transforming their operating procedures through GE's Asset Performance Management software solutions. The benefits of reduced downtime and improved maintenance will be enormous for GE and its customers. But that's just beginning. The connectivity and data collected through Asset Performance Management deployments provide a foundation for higher-level optimization of operations and business processes. Jet engine data collected for predictive

maintenance can be used to optimize flight schedules and reduce fuel burn. Asset Performance Management data on the performance of an aeroderivative gas turbine can be linked to grid demand to optimize power generation trading. Data on the location and status of hospital assets can be used to optimize patient workflows. Few technology areas will have greater potential to improve the financial performance and position of global enterprises than predictive analytics. And the connectivity and resulting data from Asset Performance Management will enable a virtuous cycle of optimization and innovation that will make GE's services increasingly strategic to our customers.

**Advanced technologies to drive business results**

Industrial companies are realizing opportunities from the use of new software and big data technologies that are paving the way to better business decisions and, ultimately, greater profitability. Petabytes of big data, garnered from intelligent machine sensors, feed advanced analytics that produce valuable business insights. New mobility strategies, data visualization, and cloud configurations are changing the operating landscape of today's industrial companies.

From Asset Performance Management via machine sensors and analytics through transformed operations that leverage new insights, industrial companies are using new digital technologies and delivery models across their operating environments:

- Embedded machine sensors collect big data and drive condition-based maintenance, creating significant savings for our customers.
- Predictive analytics lead to insights that help customers make better business decisions that drive operational improvements.
- New ways to make use of mobile collaboration technologies create efficiencies for in-field operations that drive process improvements.
- Innovations in data visualization help technicians and operational decision-makers understand the operating landscape and reveal trouble spots on the horizon.
- New cloud operating models allow industrial operators to reduce capital investment by taking advantage of secure big data environments.

Few technology areas will have greater potential to improve the financial performance and position of global enterprises than predictive analytics.

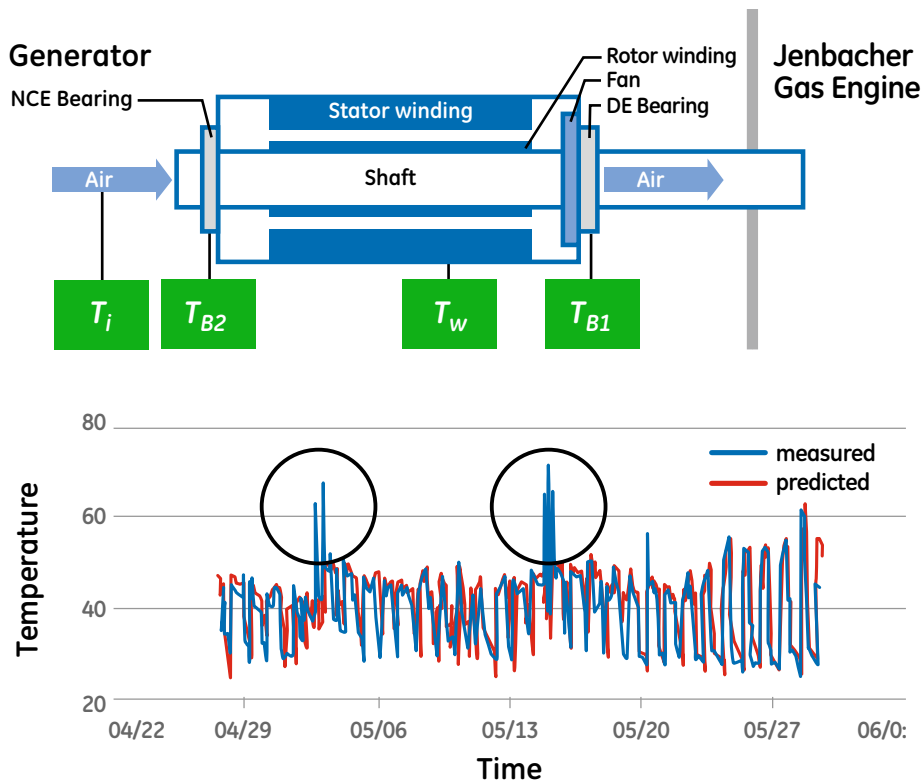
## On Site Power Visibility for Jenbacher gas engines

### Advanced analytics

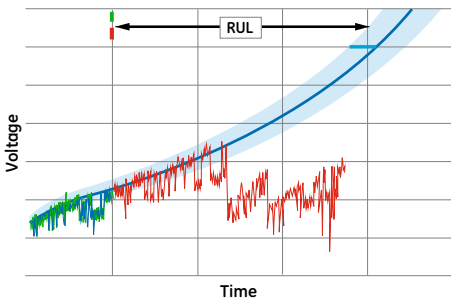
The simplest way to implement analytics is to build a Remote Monitoring & Diagnostics center and do manual monitoring based on absolute thresholds. The Distributed Power offering from GE's Asset Performance Management software solutions powered by Predix is a new customized set of data-based solutions that allows operators of Jenbacher gas engines to gain real-time intelligence needed for making better decisions to achieve your desired outcomes and increase the uptime of the asset. This approach distinguishes between real time and batch algorithmic analytics.

On real-time analytics, the On Site Power Visibility\* for Jenbacher gas engines uses the incoming data stream to predict signals or conditions and compare that prediction with the measured condition. On batch analytics, On Site Power Visibility considers a defined period of historical data to calculate the condition or to extrapolate the wear, clogging or fouling of a component.

An example of real-time analytics is predicting generator bearing health where the target is to detect overheating because of bearing failures inside the generator. The approach for allowing predictive analytics uses an adaptive model that makes expected bearing temperature a function of generator winding temperature, engine load, and ambient temperature so that discrepancies between expected and measured bearing temperatures can be escalated. The algorithm escalates this issue and sends out a warning notification. Ultimately, this leads to a manual investigation on the bearing and to a preventive exchange before engine trips and unexpected downtime occur.



Another example of batch analytics predicts the remaining useful lifetime of the spark plugs to enhance the design limit usage and the maintenance of the Jenbacher fleet. The algorithm target provides an adaptive model for predicting the remaining lifetime for all spark plug types. This is based on an adaptive physics-based model for different erosion modes for all sparkplug types. It computes model parameters by fitting measured data to the model so that the wear can be extrapolated with the highest accuracy into the future.



Example of how the algorithm interprets the data so that the remaining useful lifetime can be predicted.

In the deployed scenario, up to 90 days of historical data is loaded after a detected exchange of the spark plug on a Jenbacher gas engine. Then, the time is calculated between the trigger of the algorithm and the expected culmination of the design limit of the spark plug. It is important to note that neither a simple consideration of patterns in the data nor a separated physics approach will lead to the required accuracy for analytics. Combining an empirical and a physics-based approach will achieve the best results. The accuracy of analytics is essential for the service business and can be directly translated into monetary benefits.

On Site Power Visibility from GE's Asset Performance Management software solutions powered by Predix allow operators of Jenbacher gas engines to gain real-time intelligence needed for making better decisions to achieve desired outcomes and increase the uptime of the asset.





# Benefits

## Authorized service providers and key account customers

GE's monitoring solutions combined with OEM-developed analytics provide the foundation for using data-enabled decisions to operate businesses.

The preventive identification of upcoming maintenance events based on unit lifetime or potential breakdowns will support the ability to improve and target inventory and resource planning. Monitoring bigger fleets will enhance this process. By freeing up financial resources in this way, the company will increase its financial stability and potential depth reduction.

More than 50 percent of incoming issues on Jenbacher gas engines can be solved remotely with the help of the operator's staff. This helps the service provider as well as the customer avoid paying to send field technicians to solve minor issues.

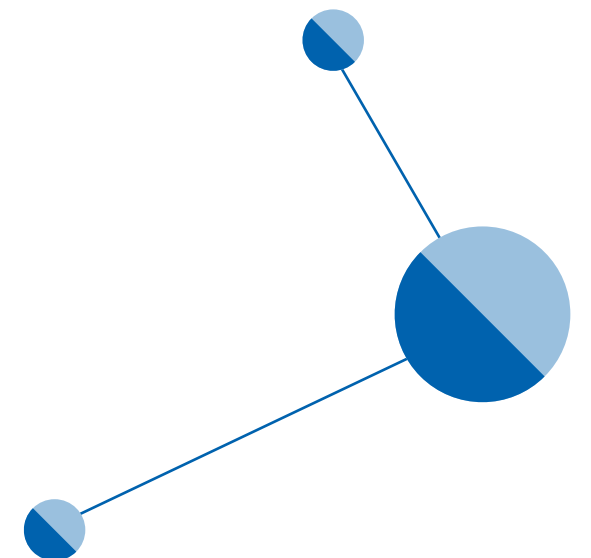
With this support from GE, end customers and operators will gain enhanced insights and greater ability to operate their gas engines. This intensified relationship will increase customer satisfaction and competitiveness against third-party service providers.

## Fleet owners and single plant operators

A good example of this support is the monitoring of the generator bearing temperature on a Jenbacher gas engine, which mainly indicates a dry-out of lubricants. Failure to monitor this unexpected condition could cause major damage to the generator and an unfavorable situation for fleet/plant operators. High reinvestment costs and lagging caused by the resulting unplanned outages will reduce operator profits. How this can happen can be seen in an installation of a 3.3 MW

Jenbacher J620 gas engine. Depending on the local condition of the generator and how it has been serviced, unforeseen downtime can occur and result in replacing the equipment. Typically, shutdown times of six-to-eight weeks can arise, and income shortfall of about \$160,000 (depending on feed-in tariffs and downtime) can be expected. By using On Site Power Visibility to provide the remote monitoring and analytics for this specific component, a projection can be made one-to-two weeks in advance of expected failure and prevent such an outage.

With On Site Power Visibility from GE's Asset Performance Management software solutions powered by Predix more than 50 percent of incoming issues on Jenbacher gas engines can be solved remotely with the help of the operator's staff.



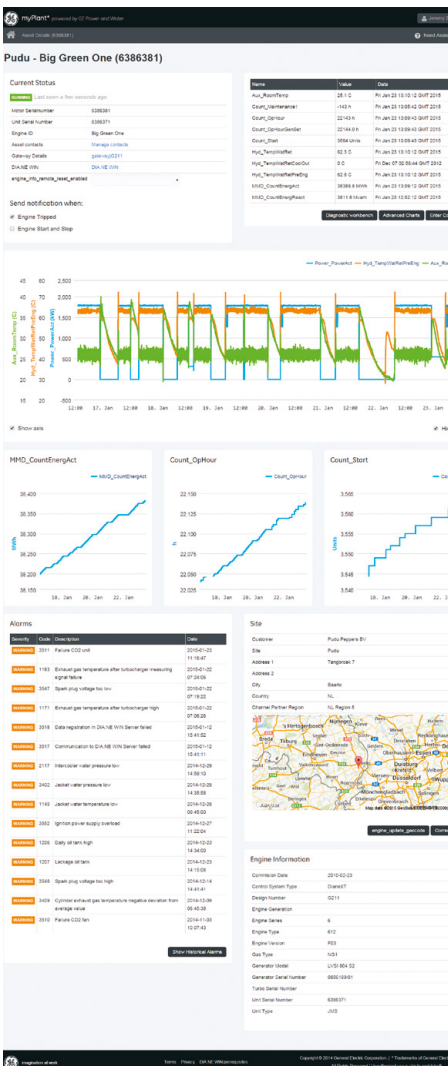
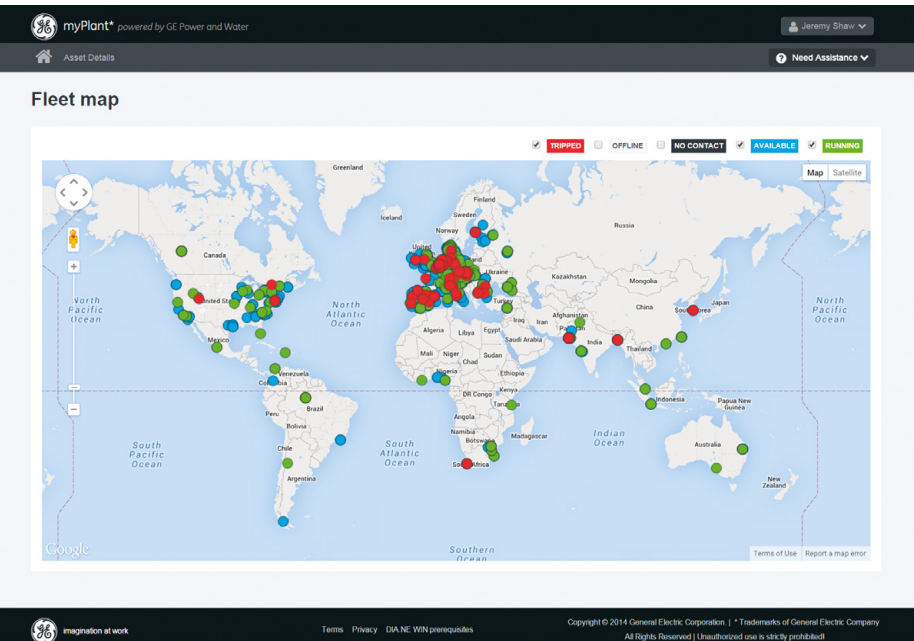


# Sign on to Asset Performance Management

myPlant\* 2.0 remote monitoring and diagnostics platform for Jenbacher gas engines is providing you access to GE's Asset Performance Management software solutions powered by Predix.

On Site Power Visibility from GE's Asset Performance Management software solutions is a customized set of data-based solutions aimed at helping you enhance the performance of your Jenbacher assets to increase availability, lower costs, reduce operational risks and drive large profits. On Site Power Visibility is part of the intelligent support services bundled with Multi-Year Agreements (MYA) for the asset or the new unit warranty period.

The packages are offered as part of a Multi-Year Agreement (MYA), for customers without an existing contractual service agreement.



## On site power visibility

On Site Power Visibility provides solutions for Asset Performance Management:

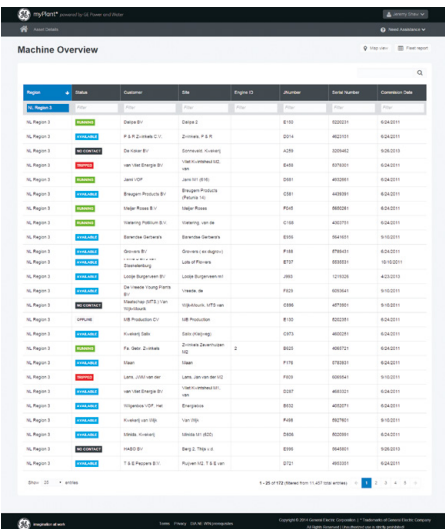
- 24/7 remote login, including remote reset\*\* of non-critical alarms to quickly restore operation and maintain productivity
- Immediate notification of engine messages, starts and stops through email or cell phone SMS

You will get:

- Remote troubleshooting service from our Quick Response Centers (QRC)
- Real-time data trends, engine messages, trip notifications and remote connectivity for a single asset

On Site Power Visibility adds solutions for Asset Performance Management as well as advanced diagnostics and predictive analytic solutions to enhance asset and fleet output and availability in the following ways:

- Centralized visibility to the fleet operation, including location and the running state of the assets on each site
- Centralized visibility to the fleet operation and site as well as asset level availability, power, and operating hours
- Engine fleet overview, including real-time fleet trends, events, availability, and operational and performance reports



Advanced trending of all historic data and engine messages to diagnose and increase engine efficiency:

- Analytics to predict the remaining useful life of key components, thereby increasing their life so that the total cost of ownership is reduced and asset availability is enhanced
- Full resolution diagnostic trend charts on any data set for any time frame
- Access to predictive analytics to detect and forecast future component condition so that fast and efficient repair takes place before a problem occurs

On Site Power Visibility from GE's Asset Performance Management software solutions powered by Predix is helping you enhance the performance of your Jenbacher assets to increase availability, lower costs, reduce operational risks and drive large profits.

\* Trademark of General Electric Company  
\*\* Remote reset functionality requires control system support, which is sold and activated separately



[www.ge-distributedpower.com](http://www.ge-distributedpower.com)

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We provide lifecycle support for more than 39,000 aeroderivative gas turbines and reciprocating engines worldwide to help you meet your business challenges and success metrics – anywhere and anytime. GE's global service network connects with you locally for rapid response to your service needs.

Headquartered in Cincinnati, Ohio, Distributed Power employs about 5,000 people around the world.

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**Imagination at work**

