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ELEMENTS AND ENABLERS OF THE DIGITAL POWER PLANT:

DIGITALLY-ENHANCED PRODUCTIVITY AND PERFORMANCE IMPROVEMENTS

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Abstract:

It has been a multi-year journey to today's digital power plant, each step along the way enabled by advancements in digital technologies and driven by needs of power plant owners and operators. This paper advocates heavy involvement of owners and operators to most effectively harness the potential of power plant digitization.

It starts with the data, most of which has always been there but often underutilized. For years, companies have been offering "Big Data" analytics and diagnostics to provide added value based on software and data science expertise and experience. These have been used in Remote Monitoring and Diagnostics Centers at MHPS for nearly 20 years, and have improved reliability statistics of turbomachinery. Targeted integration of data-based capabilities with deep power plant system knowledge and fleet-wide experience has led to new proactive operating and maintenance strategies tailored to individual plants. For example, today's advanced pattern recognition technologies (APR), coupled with real-time communications and expert knowledge create fleet-wide knowledge bases of normal and abnormal system behavior under a wide range of conditions, providing advancements in knowledge and predictive analytics capabilities. Combining those with the "Voice of the Customer" (VOC) through significant involvement of all levels of the power plant's O&M personnel assures cost-effective implementation of elements of the digital power plant for each specific plant.

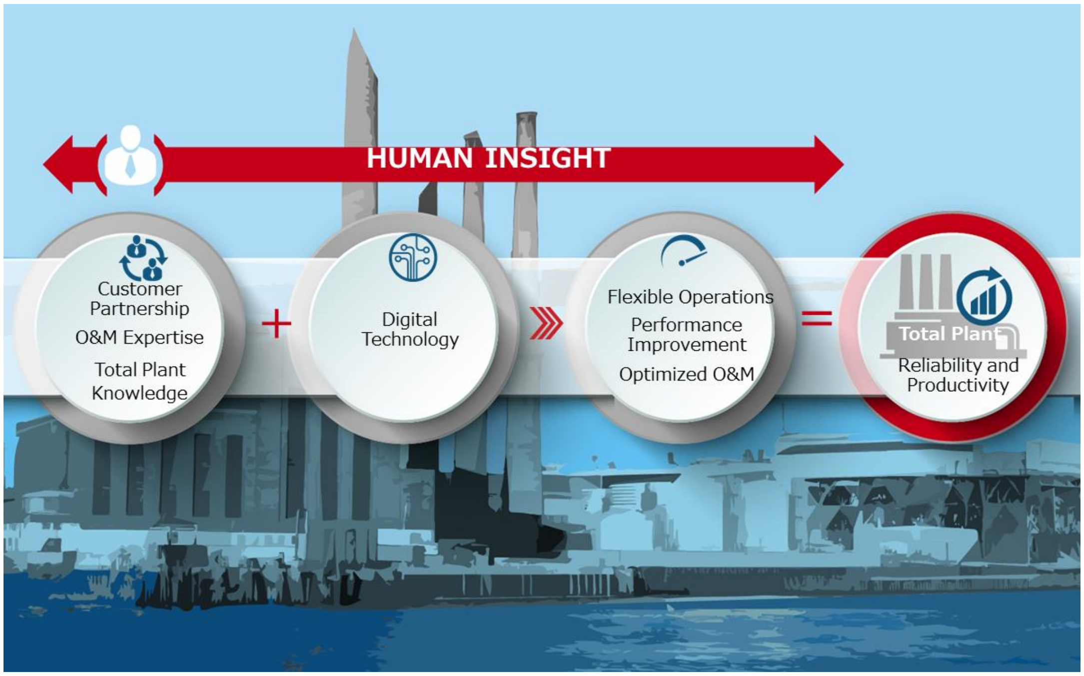
This paper will describe the journey of Mitsubishi Hitachi Power Systems (MHPS) to define and implement cost-effective digitally-enhanced improvements. One plant improved reliability by more than 2%. Some improved dispatch and participation in ancillary services markets adding

millions of dollars of value. Others enhanced proactive outage planning based on analysis of real-time operating conditions and fleet performance. All were driven by specific needs from "Voice of the Customer", and achieved by targeted application of fleet-wide product knowledge and the latest digital technologies.

MHPS ICT (Information and Communication Technology) Concept

The digital power plant is an all-encompassing "big picture" concept that became commonly discussed about 10 years ago. Strategic thinkers across the power industry have increasingly been talking about the digital power plant -- promoting its promise, current status and prospects for its full implementation. It has been a multi-year journey to today's digital power plant, and each step along the way has been enabled by what at the time were the latest advancements in digital and communications technologies, and always driven by evolving needs of power plant owners and operators.

At MHPS the result of leveraging those steadily advancing digital and communications technologies is called ICT, an acronym signifying Information and Communication Technology combined with heavy involvement of power plant owners and operators in a collaborative manner to most effectively unleash the potential of power plant digitization. It combines digital technology with extensive customer collaboration and comprehensive total plant design, operation and maintenance experience. One of the most important aspects of this approach is the leveraged human insight – the combined power of the equipment and total plant knowledge of MHPS and owner/operator’s engineering, operations and maintenance experts. Machine analytics and software help with speed and productivity, but they are not enough.



MHPS ICT Concept

The MHPS ICT concept provides new opportunities for flexible operation, performance improvement, and optimized power plant O&M, with the ultimate objective of maximizing total plant reliability and productivity.

Early Elements of the Digital Power Plant

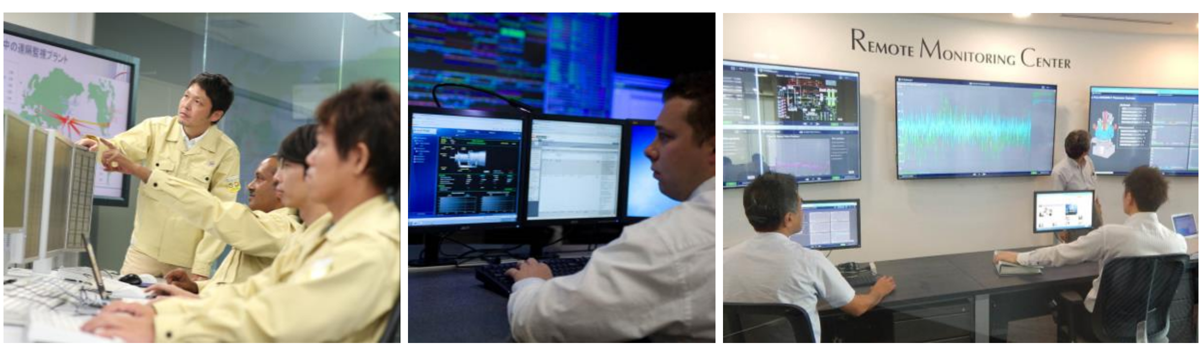
It is difficult to pinpoint the initial origin of the first elements of the digital power plant, but it dates back at least to the 1970’s when control systems began to transform from analog to digital, first on local controls using PLCs and then total system controls. Since then and accelerating in the past two decades, the rapid advance of microprocessors, advanced sensors and sophisticated analytics that use massive computing power has steadily made available new elements that can be incorporated into the digital power plant. A power plant is a critical infrastructure that must have controllable reliability. Introduction of those newly available elements has proceeded at a measured pace with careful evaluation and qualification at each step along the way. In many cases, these elements were built upon earlier introductions of similar technologies in consumer and commercial applications, to assure that initial introduction in power plants contributed positively to plant reliability.

The initial elements or “building blocks” of the MHPS’ approach to the digital power plant emerged in the 1980’s. These included advanced boiler combustion management systems in the early 1980’s and MHI’s first total plant digital control system in 1983, followed by application of early AI/Expert System in advanced boiler operation optimization support systems in 1987 and in a machinery health monitoring system for automatic diagnosis of abnormal vibration of turbine generator shaft systems in the early 1990’s.

An early system-level implementation of massive power plant data acquisition and digitization commenced in 1997 when MHPS commissioned the T-Point power plant at the Takasago Machinery Works in Japan, which is an in-house fully operational and heavily instrumented gas turbine combined cycle power plant dispatching into the Kansai Electric grid. T-Point’s objective was to go beyond typical industry approach of validating individual pieces of equipment separately for short periods in factory test rigs. Its purpose was to provide long term validation of newly-developed major equipment systems and their integration into a real operating environment. MHPS gains important experience and validation from T-Point before deploying and operating that type of equipment in a customer’s commercial power plant. For example, at the T-Point over 2000 sensors are used to verify reliability and long-term performance of the plant. T-Point is an MHPS designed total power plant, and consists of an MHPS gas turbine, MHPS steam turbine, Mitsubishi Electric Company generators, MHPS HRSG, MHPS plant DCS and other Mitsubishi designed major equipment. Today, T-Point continues to provide data and knowledge acquisition and long-term validation of MHPS’ latest designs.

MHPS T-Point Validation Power Plant

T-Point was followed in 1999 with the full-scale implementation of MHPS's first power plant remote monitoring and diagnostics center, referred to as the Remote Monitoring Center (RMC). This RMC is located in the MHPS Takasago Machinery Works and first began monitoring and providing gas turbine combined cycle plants with real-time early warning, fleet benchmark, and engineering knowledge to improve reliability, reduce unplanned downtime, and implement better outage planning based on predictive analytics. A second RMC was established in 2001, in Orlando, Florida, USA to increase service coverage in the Americas. In 2016, the third MHPS RMC was opened in Alabang, the Philippines to increase coverage in Southeast Asia and Oceania. Today these centers monitor and provide support to power plants all over the World. An early strategic decision, till today, is to carefully introduce advanced analytics and software to improve response speed and productivity, while keep in mind the value of human expert insight and the importance of teamwork with operations and maintenance personnel at the monitored power plants.



MHPS Remote Monitoring Centers in Japan, United States and Philippines

Another important example of an element in the journey towards the digital power plant is the A-CPFM (Advanced Combustion Pressure Fluctuation Monitor), which is an advanced adaptive expert system, located in the power plant controls network. As DLN (Dry Low NOx) combustion systems became more common in recent decades, driven by stricter emissions and water use regulations, advanced monitoring and control of combustion pressure fluctuations became necessary. The first MHPS DLN combustion system entered commercial service in 1984 with an early version of pressure fluctuation monitoring. Subsequent improvements made possible by more advanced sensors, increased data acquisition and analysis speed, and expert system application to create real-time models for individual combustor-specific firing stability estimation, now make possible anticipatory response and automatic combustion tuning. The current generation of A-CPFM goes far beyond just monitoring and protection. It is a powerful tool for improving power plant reliability and autonomous response to ambient, grid-driven and fuel composition variations when applied locally at the plant. It is even more powerful when combined with the additional modelling, fleet comparisons and human insight available when connected to one of the remote monitoring centers.

Further examples of important steps in the journey towards the digital power plant are upgrades of existing power plants that have become more common in recent years as advances in operating plant data acquisition, thermal performance analysis, and fleet performance comparisons quantify the benefits of retrofitting more recently designed and validated components into existing power plants. At one plant in Asia, these advanced digital technologies and human insight resulted in a pre-outage to post-outage output increase of nearly 9% and a heat rate decrease of more than 4%. At another plant in the United States a similar approach resulted in approximately 7% pre-outage to post-outage output increase and heat rate decrease of about 2%. In both cases, comprehensive plant data acquisition and analysis by local owner/operator engineers and remote monitoring by MHPS accurately suggested the improvement approaches and then validated the results – which are providing tens of millions dollars of added value per year.

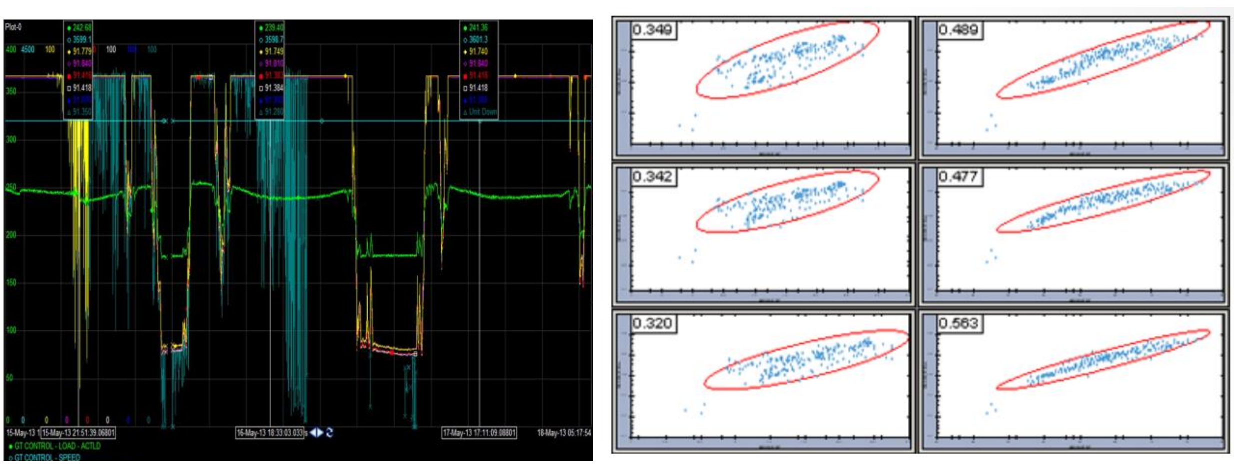
Enablers of the Digital Power Plant

One of the first enablers of the digital power plant was integrated circuits and their role in dramatically reducing the cost of digitization and data analysis. Another important enabler was the large-scale digital storage technologies that could store and allow manipulation of massive amounts of data from thousands of sensors per power plant. The final link to make a digital power plant possible was high bandwidth data communications, so engineering analysis and fleet-wide comparisons could take place in real time without a large team of experts located at each power plant.

Once these three initial enablers were available, it was possible to bring advanced sensors, advanced analytics, and human experts together in real-time to solve problems and achieve higher levels of total plant reliability and productivity.

In parallel, sensor technology is evolving significantly, enabling acquisition of higher resolution data for key operating parameters. Gas turbine sensor examples include the substitution of solid state flame sensors for phototube type flame eyes, availability of low noise CPFM acoustic vibration sensors and blade path temperature thermocouples with faster thermal response. Electric generator examples include advanced on-line monitoring for partial discharge and sensors for stator coil end winding vibration monitoring. Boiler examples include optical fiber temperature measurement and acoustic emissions sensors to give early warning of boiler tube leakage.

Advanced pattern recognition and expert systems have changed data analysis process to be more efficient and scalable over the years. Software properly configured can provide accurate insight when problems are developing that are not so obvious to the human eyes. Monitoring of a large fleet with advanced pattern recognition software becomes less manpower intensive since the software is constantly performing analysis and alerting personnel when anomalies emerge. As a result, MHPS has been able to scale its monitoring services for its growing fleet and still provide a high level of human interaction. Combining software with OEM engineering expertise has enabled MHPS to provide its customers with a superior, proactive monitoring and diagnostics service.



Potential trip avoidance using Advanced Pattern Recognition

Cyber security advancements have enabled MHPS to continuously meet the ever-changing cyber security concerns and requirements of customers and government. To keep safe operation of power plants and to protect customer's data is our objective.

From a model known as “default deny” with standard firewall equipment to our latest advanced one way data gateway device, we have been applying evolving cyber security technologies for power plants and remote monitoring systems. The advanced one way data gateway, Netmation Secure Gateway, is providing flexible remote access capability with high cyber security. White list based malware countermeasure and other basic host based security tools are also effectively implemented.

Essentially, through the advancement of technology, we are ever-empowered to detect and prevent breaches, identify anomalies and intrusion, and maintain reliable operations.

More advances in all of these enabling technologies will take place, so the journey of the digital power plant will continue. One of the latest advances is the introduction of the MHPS Netmation 4S (Force) DCS and control system, which takes digitization to new levels with advanced reliability, security and safety enhancements.

The Voice of the Customer (VOC)

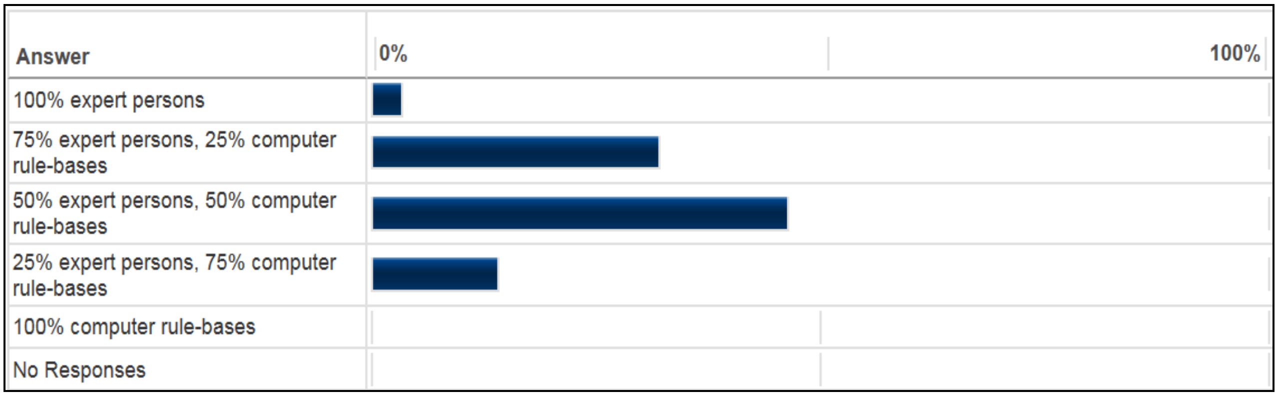
MHPS has a customer-first approach that relies on collaboration to identify potential issues, engage on potential opportunities and jointly work to improve power plant performance. Power plant owners and operators today face complicated challenges in an energy market that will continue to evolve at a rapid rate. At MHPS the "Voice of the Customer" or VOC is a very important driving force.

The Users' Groups that represent the Users that own and operate MHPS designed equipment and systems are an important source of VOC. Over the past several years input was solicited from those Users' Groups to make sure that the elements of the digital power plant being conceived and delivered by MHPS were on target to the needs of the User communities.

Since remote monitoring and diagnostics was one of the early and most fully developed elements of the digital power plant, input on that was sought first:

- Almost 75% of responding power plants in the US are remotely monitored, with approximately 2/3 of those having at least one major system remotely monitored by the original OEM of that equipment, usually a gas turbine. Outside the US, slightly over half of the responding plants are remotely monitored.
- Of those responding companies that have remote monitoring on multiple plants, approximately 20% used only their own remote monitoring, approximately 15% used only OEM remote monitoring and approximately 60% used a combination of their own and OEM remote monitoring.
- As expected, a large percentage of gas turbines – approximately 70% - are remotely monitored. However, the responding companies reported that over 50% of their steam turbines, electric generators and boilers/HRSGs were also remotely monitored.
- The three highest values assigned to OEM direct involvement in monitoring and diagnosis of equipment operating data were:
    1. Ability to correlate data analysis across fleet of similar equipment
    2. Ability to notify owners/operators of similar equipment when an incident occurs on one unit
    3. Access to the design engineers and design basis of the equipment
- Over 50% of the responding companies saw value in having the turbine generator OEM expand their monitoring and diagnostics scope offerings beyond the turbine generator scope towards at least the full thermal cycle

Another area investigated was Users' opinions about the optimum mix of recommendations from direct involvement of people with expert knowledge, versus rule-based computer analysis using algorithms, trends and historical data patterns. Below is the distribution of responses. It indicates that an approximately 50/50 mix is probably optimum, with some bias towards expert humans.



A third area investigated was to determine which existing software and data protocols were most important to consider. A key finding was that one data protocol and data historian was dominant in the responding plants, with approximately 70% of US plants and 55% of non-US plants using the same platform.

These were important inputs that have been used to refine the MHPS approach to the design and packaging of existing and new elements of the digital power plant – now being called **ICT Solutions**.

Another way to assure appropriate response to the “Voice of the Customer” is by jointly defining and demonstrating new ICT Solutions using pilot projects with champion customers.

Several current examples of this pilot project approach are:

- Collaboration with one of the largest investor-owned utilities in the United States to implement eight targeted ICT Solutions that address jointly-identified opportunities to maximize reliability and flexibility, as well as improve information visibility, analysis, and response at two large gas turbine combined cycle plants in operation and a third that is under construction.
- Collaboration with a power generation joint venture in Asia to retrofit ICT Solutions to a large, operating coal-fired power plant to achieve long-term reliability and life extension.
- Collaboration with several power plant owners and operators in Europe, whose plants’ duty-cycles had changed substantially since installation due to the evolving European energy market, to apply ICT Solutions to increase the flexibility and economic dispatch of those plants. To date 18 targeted ICT Solutions have been installed and are operating on 9 European combined cycle plants (total power block including GT, ST, HRSG).

<u>The Voice of the Plant (VOP)</u>

As important as the “Voice of the Customer” is, the “Voice of the Plant” or VOP is of equal importance and needs to be carefully listened to. The “Voice of the Plant” comes from the thousands of sensors in the power plant. It is about utilizing plant sensor and control system data, coupled with advanced analytics and human insight, to avoid unplanned downtime and enable predictive maintenance.

Nearly 20 years of experience with centralized remote monitoring and diagnostics has yielded important lessons-learned on how to best leverage VOP.

- As the monitored fleet grew, the importance of data analysis using Advanced Pattern Recognition (APR) became increasingly evident. APR is automated analysis of the mass of data coming off the sensors to detect small, but significant changes in the pattern of the data. It is very effective in bringing attention to potential issues long before they affect plant availability, so planned corrective action can take place.
- APR detects issues but in most cases it also takes expert knowledge to determine the root cause and most appropriate corrective action. One example is an APR alarm that revealed a single BPT deviation that was changing very slowly. Based on sensor and operational information such as the magnitude of deviation, number of BPT sensors that showed the deviation, and the number of times the deviation occurred, the engineering and remote monitoring team then determined that it might be damage to a spring clip. After inspecting the corresponding combustor basket, the predicted spring clip damage was confirmed. Since repair parts were prepared in advance based on the root cause analysis, this damage was quickly rectified and the gas turbine was successfully restarted after a short weekend outage.
- The relationship between the plant operators and the remote monitoring operators and engineers is very important. Outcomes are better when they work together as a team to proactively monitor, alert and implement corrective actions that can avoid unplanned downtime and improve plant performance and reliability.

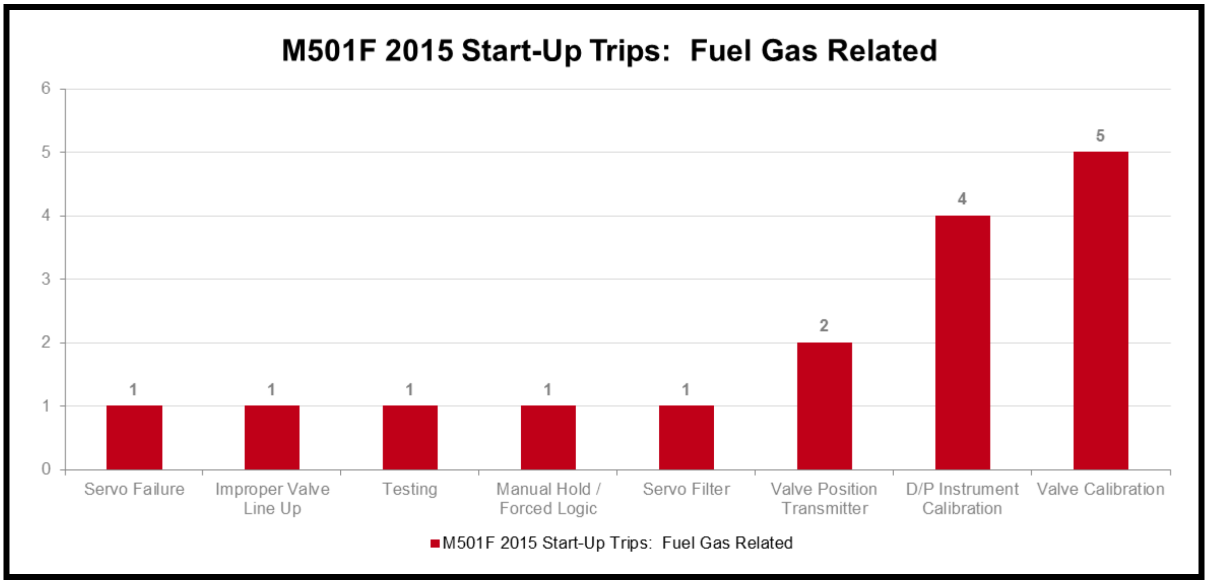
MHPS has built its data monitoring platform by incorporating in-house developed software with the best software in the market to create a robust but flexible system. Its robustness comes from the ability to bring in large amounts of data and store redundantly at high resolution – by collecting, storing, and viewing data in real-time. System flexibility allows connection to many different control systems that exist at power plants. The initial data monitoring platforms did not provide the same level of robustness or flexibility, so an early business decision was made to change platforms to align with future business needs.

Making the "Voice of the Plant" available for off-site analysis, correlation with fleet-wide data and long-term storage requires highly secured devices, firewalls, dedicated networks, etc. For example, the process of getting data from the power plant back to the remote monitoring center in Orlando has evolved over time. From the network equipment used to collect the data, to the method used to communicate it, times have changed and MHPS has continued to embrace technology to improve its processes. Earlier data systems could require four or more servers on site to collect, view, and communicate the plant data back to the RMC. Today, technological advances have allowed virtualization of all the original servers into a single host machine, along with application of the latest advances in data security. Further evolution will take advantage of

Cloud technology, when and where it makes sense, to make databases even more redundant, scalable, and cost-effective.

To protect valuable power plant data, we are utilizing an industrial Cloud data center with world-class cyber security standards. This Cloud service comes along with various cyber security protection/monitoring services which enable us to achieve our commitment effectively.
All plant data is stored in the cloud platform safely and our engineers handle, analyze the data within the Cloud platform using remote application to prevent flowing data outside.

Another important aspect of VOP is detailed analysis and corrective actions related to all sources of unplanned trips, runbacks and failed starts on the fleet of similar equipment. This information is commonly known as RAM (Reliability, Availability and Maintainability) statistics. This information is compiled on a fleet-wide basis by engineers in the Remote Monitoring Centers and cognizant Service Engineering departments and thoroughly analyzed. An example is shown below for M501F fleet start-up trips.



As part of the corrective action procedure to respond to this VOP input, and reduce the chances of future reoccurrence of similar events throughout the fleet, each event category is evaluated for possible modification of O&M instructions, equipment design upgrades or control logic modifications. In this example case of starting reliability, several specific digital power plant elements or ICT Solutions have resulted, and are further improving fleet RAM statistics.

The positive effects of this type of response to the "big data" coming from the plant are evident in both internal MHPS RAM statistics and the third-party ORAP database of RAM statistics maintained by Strategic Power Systems (SPS) based on data that the owners/operators report to ORAP and SPS validates. Examples include a 40% reduction in trip events per unit on large 50 Hz. gas turbines since 2007 and very favorable comparisons for MHPS designed 60 Hz. gas turbines over the past 5 years in the SPS ORAP data:

Period	Apr 2011 – Mar 2016		
Category	**Advanced Technology**	**M501G**	**"F" Class**
Number of Units	26	21	633
Reliability*	98.72%	99.19%	97.73%
Availability*	91.71%	92.07%	91.06%
Forced Outage Factor**	0.87%	0.46%	0.89%
Unscheduled Maintenance Outage Factor**	0.28%	0.33%	0.58%
MTBF** (hours)	3,978	4,711	2,166
MTTR** (hours)	20.19	21.56	18.60
Frame	7H/9H W501G M501G/M701G		GT24/26, 6F/FA, 7F/FA, 9F/FA, 7FB/9FB W501F, V84.3, V64.3A, V84.3A, V94.3A M501F/M701F

* - Values based on "Simple Cycle Plant" = GT + Gen. + Controls + Direct Ancillaries + Station Equip.
** - Values based on "Gas Turbine only"

Source: ORAP®;

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Analysis and response to "Voice of the Plant" data is easier and more effective when there is a direct data feed from the plant to an RMC or other centralized place where data correlation and analysis by expert systems and human experts can take place on a fleet-wide basis. For that reason MHPS promotes the benefits of connection to the plant, whether through full RMC implementation when that makes economic sense or less intensive connection to the power plant. MHPS also promotes participation in the SPS ORAP RAM statistics process.

On a self-reporting sample of large 50 Hz. gas turbines conducted by the M701F Users' Group, those plants connected to an RMC had 2.4% higher reliability than those plants that were not connected. Because of the demonstrated benefits of remote monitoring, MHPS now operates three Remote Monitoring Centers and is continually upgrading their capabilities as new technology and best-in-class software becomes available. These Remote Monitoring Centers have proven their value on plants utilizing MHPS OEM equipment and plants utilizing equipment from other OEMs. Current initiatives in these remote monitoring centers include several to strengthen the "Voice of the Plant" based on the "Voice of the Customer":

- Standardization of global data infrastructure using the software platform used by the majority of power plants.
- Retain "human" expert diagnostics but increasingly supplement with expert software systems to more productively leverage deep engineering knowledge with software applications.
- Achieve 50/50 split of human expert and automated rule-based software to provide

optimum guidance and support.

- Expand plant control system features to allow more information and diagnostics to be accessed locally at the power plant to provide increased awareness and real-time guidance to plant personnel.
- Make available optional levels of monitoring and diagnostics (M&D) for those plants who do not need full 24/7 support, who need broader coverage of power block systems or who desire lower cost, reduced intensity support.

Combined Cycle Plant M&D				
Scope / Coverage	GTG	STG	HRSG	Total Plant
High	✓	✓	✓	✓
Medium	✓	✓	✓	✓
Low	✓	✓	✓	✓

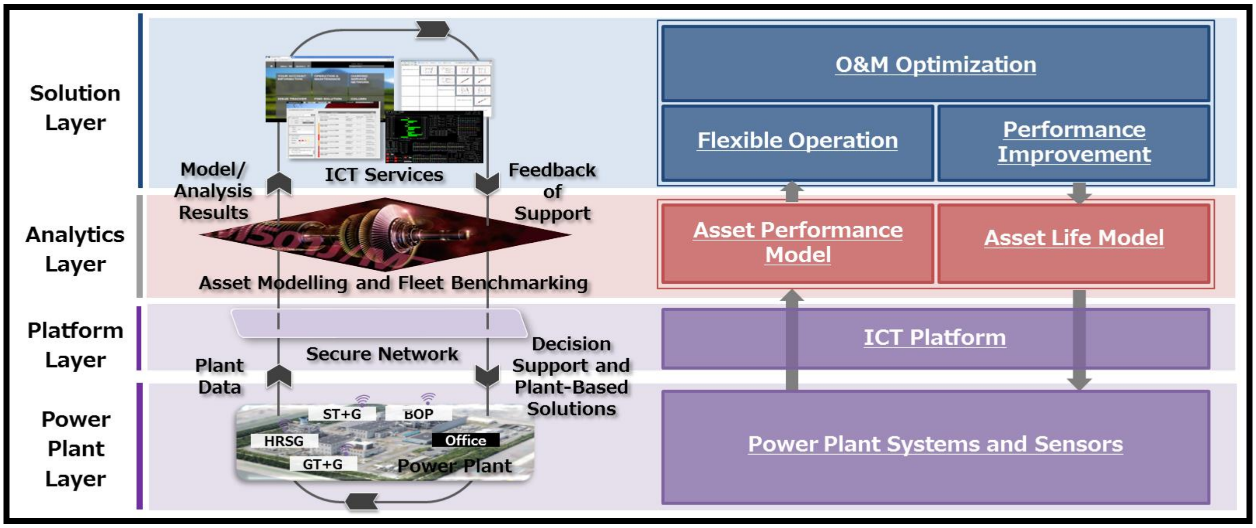
Conventional Plant M&D				
Scope / Coverage	Boiler	Fuel Feed	STG	Total Plant
High	✓	✓	✓	✓
Medium	✓	✓	✓	✓
Low	✓	✓	✓	✓

<u>ICT is a powerful tool</u>

ICT integrates inputs from the power plants (VOP) and close collaboration with customers (VOC) to define the most cost-effective way to digitize new and existing power plants. ICT uses advanced pattern recognition, expert systems and artificial intelligence to create better customer outcomes, however, it starts with human insight from a close partnership and shared goals with power plant owners and operators.

It builds on the extensive total plant design experience and extensive shared O&M experience of MHPS and its customers. ICT adds the most effective amount of advanced digital technology to this combined knowledge base. It is about gathering significant amounts of digital performance metrics that provide a comprehensive picture of what is taking place at a power plant or across a fleet, filtering that mass of information to get focused insights, and then leveraging expert human knowledge to help customers achieve improved plant optimization and help plant operators quickly make informed decisions that result in measurable business performance improvements. It's about intensive customer support during outages and between outages to maximize plant reliability and availability. It's about utilization of plant sensor and control system data – "the Voice of the Plant" – to avoid unplanned downtime and enable predictive maintenance.

It's not about software. There are a multitude of excellent power plant software providers who have been in business for years, and most power plants already have a lot of software. What they need is expert knowledge and human insight. A key difference is that MHPS ICT uses best-in-class software as a tool to provide the knowledge and actionable insights that power plants need today.

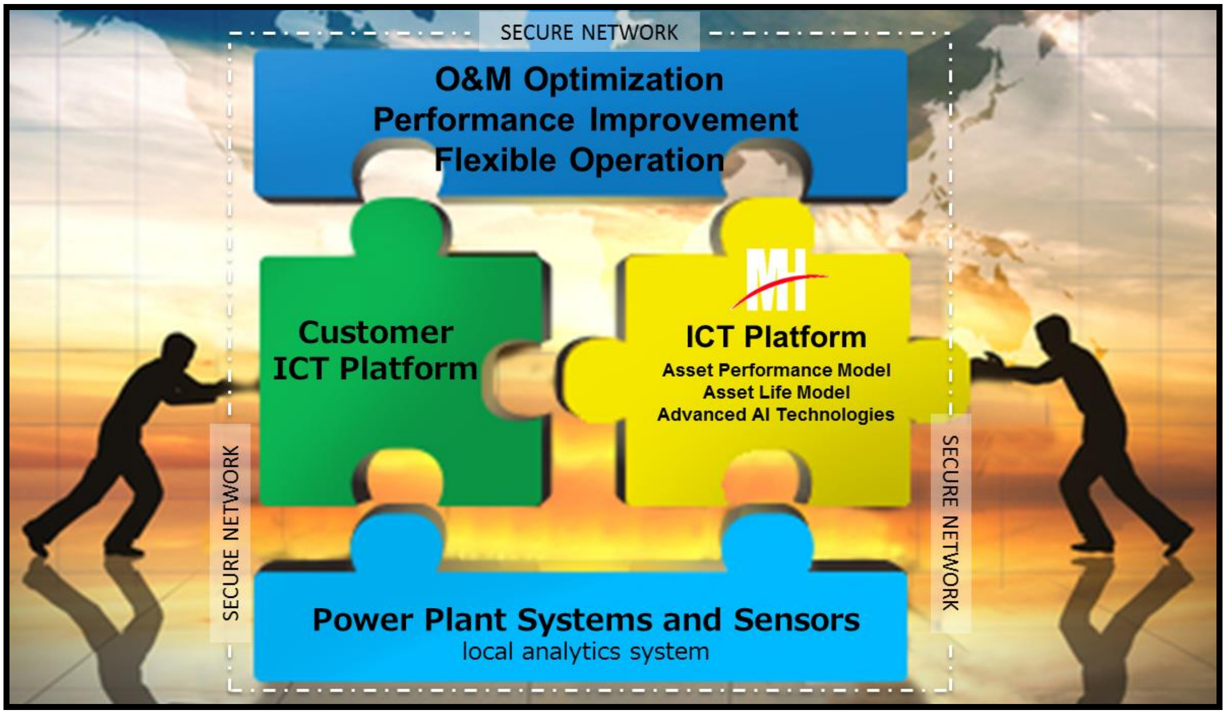


Information and Communication Technology (ICT) Architecture

MHPS ICT is a closed loop flow of data and the knowledge that is derived from that data. It starts with data collection, but it is much more than just collecting a bunch of data points. Its goal is to utilize the collected data to create actionable insights and data-driven ICT Solutions – the elements of the digital power plant. Those ICT Solutions can be applied remotely at a fleet-wide level or locally at each power plant using knowledge derived from fleet-wide analytics.

Tailored Service by Collaboration with Customers

Collaboration is another key difference for MHPS ICT, which provides tailored service by continuous interaction with power plant owners/operators. Power plant system providers and power plant owners/operators are all together in a complex business that is changing more every day. Together they need to put the puzzle together by assembling the elements of the digital power plant to make new and existing power plants as productive as they can be. There is a lot of data and human knowledge at every power plant – but much more data than can be effectively managed by the plant personnel alone.



Digital Power Plant Puzzle

As a result, power plant owners and operators have their experts and their own "ICT" systems in their headquarters and engineering departments (in the green box on the left). The MHPS ICT Platform (in the yellow box on the right) connects seamlessly with owner and operator existing systems to combine equipment/system designer human insight and owner/operator human insight, and to leverage both using the most advanced digital technologies. Together MHPS and power plant owners and operators can use ICT to achieve O&M optimization, performance improvement and flexible operation that will save every power plant many millions of US dollars over the life of the plant.

Collaborative relationships which leverage the power of the digital power plant are taking place all over the World. Some of the pilot projects for ICT Solutions in the US, Europe and Asia were mentioned earlier. Beyond that, there are major joint ICT programs taking place with large power generators in Asia and elsewhere. The objective of these programs is to integrate the vast knowledge of MHPS and those large power generators to create unique and high value services that can be jointly applied to maximize the benefits of data utilization on both combined cycle and conventional power plants.

Building on the knowledge gained from collaborative relationships and data from each of the MHPS Remote Monitoring Centers and field data acquisition, MHPS has over the years implemented a large number of targeted, data-driven ICT Solutions that leveraged steadily advancing technologies to improve power plant reliability, performance and flexibility ---- specifically targeted at individual customer needs.

These ICT Solutions are in three key areas:

1. Centralized fleet monitoring and diagnostics
2. Data-Driven ICT Solutions at the power plant
3. Data-Driven ICT Solutions that connect to the power plant

Centralized fleet monitoring and diagnostics were among the earliest elements of the digital power plant, first implemented many years ago and currently available in a range of customizable scopes for both combined cycle and conventional plants. More recently, the knowledge gained from advanced digital design tools, the T-Point validation power plant and intensive monitoring of many customer power plants has resulted in an integrated family of ICT Solutions -- additional elements of the digital power plant

Examples of Data-Driven ICT Solutions that utilize local sensor data and run in the control systems at the power plant include applications to provide:

- On-Line Flexibility and Response
- Startup Reliability Improvement
- Faster Startup
- Grid Support and Frequency Response

Examples of Data-Driven ICT Solutions that connect to the power plant and use a combination of local and centralized analytics include applications to provide:

- Interactive Thermal Performance Improvement
- Steam Turbine Fast Start (FSS)
- Guidance PC and KPI Monitoring
- Planned Outage Reduction Simulation

The family of ICT Solutions is a growing resource that MHPS uses interactively with plant owners and operators to maximize the value of their assets. New ICT Solutions are continually implemented in pilot applications with customers and will subsequently be available across the fleet.

The Future of ICT and Digital Power Plant

The scope and implementation of the digital power plant has been growing for several decades and this growth will certainly continue. Many companies are developing new sensors, software and digital technologies that will need to be evaluated and carefully introduced into the critically important power plant environment when their reliability and economic benefits are proven. ICT will continue to present opportunities to power plant system providers and the owner/operators of power plants.

MHPS sees opportunities for increased precision in data acquisition technologies as an important step in improving power plant reliability and flexibility. There are also substantial benefits to be obtained from increased use of data external to the power plant to inform predictive and adaptive controls, such as weather forecasts and grid events.

MHPS sees opportunities for further improvement in power plant reliability, availability and maintainability from increased incorporation of advanced machine learning systems, whether they are called artificial intelligence, expert systems, deep learning or something else, and MHPS is working with industry leaders in these technologies to most effectively adapt them to power plant applications. Opportunities include increased power plant automation and autonomy as well as the knowledge to inform new, more effective approaches to such strategies as reliability-based maintenance.

In all areas, though the overall MHPS strategy of increased collaboration with owners and operators of power plants will continue and intensify. The digital power plant is not a “one size fits all” solution. The benefits to be obtained from leveraging the combined knowledge of designers, manufacturers, operators and maintainers are too large to ignore, and increased digitization of communications and knowledge sharing through ICT will be a big part of the future of the digital power plant.

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