Evaluation of Remote Monitoring for Heat Rate Improvement

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EPRI Project Manager

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REPORT SUMMARY

The information contained in this technical update report represents first-of-a-kind evaluation of the heat rate effect of operating remote monitoring centers. The study delves into the details of remote monitoring with respect to plant performance improvement. Industry experience is used to quantify both the heat rate gains and startup and operating costs of employing a remote monitoring center. This cost-benefit analysis can be used to evaluate the effectiveness of remote monitoring with respect to plant performance. Through the use of this information, Electric Power Research Institute (EPRI) members should be better able to quantify those effects.

Background

Remote monitoring of power plant operation has been a successful tool used to identify reliability-related problems in advance, permitting timely maintenance actions and preventing in-service failures. In parallel, as plant staffs have shrunk in size, remote monitoring systems are also being used to monitor thermal performance to varying degrees. In addition to tracking and improving equipment reliability, some remote monitoring centers have thermal performance software installed for monitoring heat rate. The value of finding and fixing reliability issues can often be quantified, but placing a value on heat rate monitoring is not as easy.

This report evaluates the use of remote monitoring systems and personnel as it relates specifically to heat rate improvement.

Objective

This project is intended to determine the effectiveness of improving plant performance through the practice of remote monitoring by visiting operating remote monitoring centers at different power generating companies.

Approach

The process for evaluating the effectiveness of using a remote monitoring center for heat rate improvement began with a series of questions, sent out in survey form to each of the three power generating companies participating in this project. The questions were used to gain an understanding of the relative size of the companies, the mix of generation technologies being monitored, and the priorities of the remote monitoring center.

In addition to the written questions and responses, a site visit to the remote monitoring center for each company was conducted to obtain a firsthand understanding of how each center operates and what benefits each provide to the company. The site visits were approximately 1-1/2 days in length, and consisted of interviews with the monitoring center staff and observations of the monitoring center in action.

When the site visits were complete, the information gathered was written up and provided to each respective generating company for review and response. The information presented in this report has been approved for use by each of the companies.

Results

The main priority of the remote monitoring centers at these three companies was to improve reliability, but they also monitored for heat rate improvement to varying degrees. All of the companies visited were able to verify heat rate improvements based on the activities of the monitoring center in addition to the improvements in equipment reliability. In many cases, the

heat rate improvements were significant and well surpassed the incremental costs for monitoring heat rate in addition to reliability.

Applications, Value, and Use

This evaluation—designed and conducted by EPRI and its subcontractor—provides guidance to power generating companies on the costs, limits, applicability, and benefits of establishing and operating a remote monitoring center with respect to plant heat rate. It also provides information on methods used for remote monitoring and the attributes of successful programs. This information, along with the cost-benefit evaluation, might assist power generating companies in the justification of a remote monitoring center.

Keywords

Fleetwide monitoring
Heat rate improvement
Performance monitoring
Remote monitoring center

ABSTRACT

Remote monitoring centers (RMCs) have been used for many years to track and improve equipment reliability, and in many cases these same RMCs have thermal performance software installed for monitoring heat rate. The value of finding and fixing reliability issues can often be quantified, but placing a value on heat rate monitoring is not as easy. This report evaluates the use of remote monitoring systems and personnel as it relates specifically to heat rate improvement. The remote monitoring centers at three different companies were visited. The main priority of the three companies was to improve reliability, but they also monitored for heat rate improvement to varying degrees. All of the companies visited were able to verify heat rate improvements based on the activities of the monitoring center in addition to the improvements in equipment reliability. In many cases, the heat rate improvements were significant and well surpassed the incremental costs for monitoring heat rate in addition to reliability.

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Remote Monitoring for Heat Rate Improvement

Remote monitoring of power plant operation has been a successful tool used to identify reliability related problems in advance, permitting timely maintenance actions and preventing in-service failures. In parallel, as plant staffs have shrunk in size, the remote monitoring systems are also being used to monitor thermal performance to varying degrees. This report will attempt to evaluate the effectiveness of remote monitoring with respect to improving plant heat rate by analyzing the remote monitoring activities of three separate power generating companies.

Evaluation Process

The process for evaluating the effectiveness of using a remote monitoring center (RMC[1]) for heat rate improvement began with a series of questions, sent out in survey form to each of the three power generating companies participating in this project. The questions were used to gain an understanding of the relative size of the companies, the mix of generation technologies being monitored and the priorities of the remote monitoring center. A copy of the survey is included in Appendix D of this report.

In addition to the written questions and responses, a site visit to the RMC for each company was conducted to obtain a first-hand understanding of how each RMC operates, and what benefits each provide to the company. The site visits were approximately 1½ days in length, and consisted of interviews with the monitoring center staff and observations of the monitoring center in action.

Once the site visits were complete, the information gathered was written up and provided to each respective generating company for review and response. The information provided in this report has been approved for use by each of the companies, and where necessary, data has been scrubbed to avoid sharing of any proprietary or confidential information. Information specific to each generating company is included in the appendices of this report.

Evaluation Results

Each company was asked to rank the priorities of their RMC. The list below shows the priorities in order of overall importance with the average of the individual company rankings shown in the brackets to the right:

- Reliability / Availability [1.3]
- Other (Environmental Impact) [1.5]
- Maintenance Optimization (cost and/or schedule) [2.7]
- Capacity [4.3]

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[1] Remote Monitoring Center (RMC) is the generic term used in this report for any fleet-wide monitoring center. Each company had their own term for their monitoring center. The generic term is used here in all cases to maintain each company's anonymity.

- Fuel Efficiency / Heat Rate [4.7]
- Ancillary Services (ramping, spinning reserve, etc.) [5.0]

Two of the three companies included Environmental Impact as an additional priority, with a rank of either 1 or 2. The main basis for the high ranking was that if a power plant cannot operate within its environmental permit limits, it will not be allowed to operate at all.

Based on the relative rankings shown above, heat rate improvement was not a top priority at any of the companies included in this evaluation. That does not mean that heat rate was not considered an important item nor does it mean that heat rate was not monitored at the facilities. This just indicates that heat rate issues were considered only as time allowed when all other concerns with a higher priority level had been dealt with (either resolved or deferred to a later date). At the largest monitoring center visited there was a significant staff of engineers dedicated to tracking heat rate issues, in addition to the personnel working on other priorities.

The RMC's were found to provide significant value based on improvements in both reliability and heat rate. Reliability improvements were used in the majority of cases to justify the cost of the RMC, but in all cases the additional value due to improved heat rate and lower rates of equipment degradation were recognized. When calculating the full value of minimizing equipment degradation, savings due to reduced fuel consumption as well as increased revenues from higher capacities and improved equipment flexibility were all included.

To determine the value of the RMC itself, most of the companies included an additional factor in their calculations to reduce the value of any "finds" (items found which, when remedied, led to improved performance) by the probability that site personnel would have adjusted operation or maintenance activities on their own without the additional information provided by the RMC. Even considering this conservative approach to the value provided by the RMC, all the companies found remote monitoring to be an extremely valuable addition to their operation.

All the companies recognized that when small adjustments could be made (either operationally or mechanically) to keep equipment operating well within control tolerances, downtime for major maintenance activities were also reduced. In this way, monitoring for changes in heat rate was found to also lead to improvements in reliability and availability. In the same way, monitoring (and maintaining equipment) to maximize reliability has also been found to lead to improved heat rates.

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CASE EXAMPLES

Information on specific case examples of “finds” (items found which, when remedied, led to improved performance) can be found in the appendices for each generating company for both reliability and heat rate based issues.

One of the most famous “finds” by a company using Advanced Pattern Recognition (APR) software is known as “Entergy’s Big Catch”. This find was profiled in the October 2008 edition of Power Magazine. The “Big Catch” identified a cracked generator rotor prior to a catastrophic failure, which was later upon inspection deemed to be imminent. The unit was taken offline safely without incident within 5 hours of the initial alarm in the APR system. The savings resulting from catching the cracked rotor before it failed catastrophically were estimated to be over $20 million, not including the significant potential for injuries to personnel.

The examples listed below are items pertaining primarily to heat rate which were found to be common among the companies visited.

Condenser Performance

Losses in condenser performance were often found using the thermal performance monitoring software, based on the calculated condenser cleanliness value. The APR software may also have flagged an alert if back pressure was higher than expected for the given operating conditions. When condenser performance degraded to a point where it was significantly impacting capacity and heat rate, a condenser cleaning could be scheduled to improve performance. The thermal performance software could then be used to verify the improvement made by the cleaning procedures. In some cases maintenance action was also required to return the condenser to full performance.

Thermal performance modeling, including offline “what-if” analysis was also used in some cases to determine the effect to heat rate of plugging tubes versus re-tubing a condenser. Where re-tubing was warranted, the performance impact of tube material options could also be investigated by RMC personnel to determine the optimal replacement material.

Maintaining optimal condenser performance can have a significant effect on plant capacity and heat rate. For a large steam turbine, a 1.7 kPa (0.5 inch HgA) increase in back pressure can result in a loss in output of more than 0.5% (depending on the current operating load) with a corresponding increase in overall plant heat rate.

Steam Cycle Alignment

A common point of heat rate losses are due to issues with steam cycle isolation and value lineup, collectively termed steam cycle alignment.

Units which are operated on a frequent start/stop cycle will find bypass lines are more prone to leak-by. High pressure steam lines which drain directly to the condenser can result in performance losses to both capacity and heat rate. This is due to the loss of steam mass flow through the turbine, and a corresponding increase in back pressure from the higher heat load on the condenser.

Baseloaded units may find that after an infrequent startup cycle, some startup valves remain open. These are items which the local facility staff may find on their own, given time and their normal operator rounds, but with the addition of the RMC, leaks and valve issues are identified much faster, resulting in significant savings from avoided lost capacity and improved heat rate.

It is recommended that the RMC have a procedure for monitoring steam cycle alignment, especially following startup and shutdown cycles. A dedicated display screen may provide the most benefit. Where bypass lines do not have sufficient instrumentation to be able to remotely identify leaks, instrumentation should be added. One RMC utilized wireless pipe wall thermocouples to install additional temperature monitoring points to the steam cycle piping. While the instrumentation may not be as accurate as fully wired thermowell based temperature elements, the indications from the instrumentation have been paramount to early detection of significant leaks in the system.

Even with the additional instrumentation there are several estimates which must be used in order to determine the value to heat rate of the reduction and/or elimination of specific leaks. One analysis on a specific steam turbine showed that if the main steam drain valve was left 100% open, the loss in mass flow rate alone would be worth more than 2% in lost steam turbine output – with a corresponding increase in unit heat rate. When the valve is only leaking-by the loss will be much less, but considering this is just one of more than 30 valves on the system, many of which are on the high energy steam lines, there is a high probability that leaks are occurring somewhere with a measurable and adverse impact to heat rate.

With the number of valves on the steam bypass, and steam seal systems, priorities on which valves and lines to monitor must be made based on the potential effect to capacity and heat rate as well as the valve's historical performance. For a given unit, even when only the top valves are monitored, the likelihood of one or more valves developing a leak is high. Being able to catch leaks when they are small minimizes the cost of maintenance on the valves, decreases the number of valve replacements, reduces potential safety hazards, and maintains better unit heat rates.

Feedwater Heater Performance

Losses in feedwater heater performance can be due to many different causes, from problems with extraction valves, drain valves, vent lines, and pass partition plates. While the APR system may indicate "something is different" in the feedwater heater operation, a more in-depth review of the heater performance utilizing the thermal performance monitoring software is often needed to find the root cause of the problem and provide a more informed resolution to the local facility staff.

The personnel at the RMC's included in this evaluation were all experienced in investigating feedwater heater problems, diagnosing the root causes and providing resolutions for each problem to the local facility. In addition, the facility staff then acted on those recommendations in a timely fashion. The early indications of potential problems found by each RMC allowed the local facility staff to make more informed decisions. Adjustments in operating setpoints were also recommended at times by the RMC to minimize equipment damage until the problem could be completely resolved. This allowed more time to prepare for any required maintenance – both for scheduling the outage and purchasing and delivery of parts (if necessary).

Instrumentation Issues

While instrumentation issues may not be considered in many cases to be directly linked to heat rate performance, instrumentation which is reading in error can cause problems with equipment which may affect heat rate. The RMC's were all known to find problems with instrumentation well in advance of failures. One example would be a sensor which is no longer updating, but still providing a constant reasonable value to the Distributed Control System (DCS). The APR system would alert RMC personnel to this problem as operational conditions changed but the specific sensor did not. Depending on the sensor (bearing vibration, temperature, pressure, etc.), this could be a significant problem not just for heat rate monitoring, but also for safe equipment operation. All of the RMC's visited recognized the requirement of good data for equipment monitoring, and the ability of the RMC to find and resolve bad data.

Examples of instrumentation errors leading to poor heat rate are as follows:

1. Final main steam temperature: If this indication is reading higher than actual, increased attemperation spray flow will result. Excessive attemperating spray flow results in large heat rate penalties and may also lead to damage in the high energy piping.
2. Excess oxygen reading: Errors in this indication may cause the combustion control system to push the unit into super sub-stoichiometric operation, resulting in high unburned carbon and increased tube wastage.
3. Gas turbine compressor discharge pressure: If the compressor discharge pressure is indicating lower than actual there is the potential to over-fire the unit, reducing the life of hot gas path parts, causing seal damages, and increasing heat rate. If compressor discharge pressure is higher than actual, the control system will limit the output of the gas turbine, reducing available capacity and increasing heat rate.

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REMOTE MONITORING CENTER OVERVIEW

The RMC's of the three companies visited provided a means to review the commonalities between different sizes of RMC's. This section will outline those commonalities and provide an overview for the equipment and personnel needed.

Location

All the companies participating in this project located their RMC within their corporate offices. It should be noted that the industry has implemented different forms of RMC's not covered in this report. A central, corporate location allows for additional information sharing between the RMC and other engineering groups as well as management, dispatch, and marketing groups. An area of sufficient size should be found to allow for multiple monitors both at each workstation and up on a wall. Due to the nature of the RMC, there are often alarm signals and loud communications between multiple personnel. Where the noise of the RMC would be a distraction to other workers, a separate room may be required.

Equipment

The more monitors available, the more information can be put at the fingertips of the monitoring center staff. The number of monitors ranged from 3 to 7 per workstation, with 3 to 10 oversized screens available on the wall. A minimum of one common wall-mounted monitor was available for every 5 facilities being monitored. Being able to keep some information about each facility's generation load on an overhead monitor supports the ability of the RMC to react quickly to changes in operation.

The number of monitors utilized, in part dictate how many computers are required for each workstation. In addition to computers and monitors, phones for each workstation are needed along with networking equipment to provide fast communications and data transfer between the facilities being monitored and the RMC.

Software

Each RMC was equipped with a common set of software, not always of the same brand, but with the following similar functions:

1. Data Historian: used for trending values from operating equipment and investigating the root cause of operating excursions.
2. Operations Displays: remote displays of real-time operating conditions of equipment. This may be a direct view of control system displays or a live view of data sent to the historian through custom displays for the RMC.
3. Advanced Pattern Recognition (APR) Software: all of the RMC's visited agreed that this was the most valuable tool in early identification of operating problems. The APR systems require significant setup. This includes developing models of systems to be monitored and loading of historical data for the APR models to learn what "normal" operating conditions are, based on statistical correlations. For a single unit at a given facility, the installation and 'training' of an APR system can take between 3 and 6

months. A full year of data is normally recommended for the system to contain correlations for all ambient conditions and load ranges.

4. Even with the amount of "training" provided during initial setup, the models often require additional tuning. This year's extraordinary heat waves throughout the Midwest resulted in many additional APR alerts due to the lack of any similar high temperature operation in the data used by the models to determine "normal" operating conditions.
5. Thermal Performance Monitoring (TPM) Software (online): all of the companies visited had installed TPM software at the facilities being monitored, but used it to varying degrees. Significant value was placed on the ability to review operating changes in a model based on physical constants and engineering analysis for comparison with statistical correlations. When the statistical correlations did not agree with engineering analysis, the models for both systems could be reviewed to find the source of the discrepancy. Discrepancies could be related to errors in instrumentation type or location, or to process or flow diagrams improperly setup in the models.
6. Thermal Performance Modeling Software (offline): thermal performance models were built for all of the equipment being monitored with TPM, and those models could then be used in an offline mode for use in "what-if" analysis. The offline analysis was used to support equipment changes and to validate the impact of various changes in operation. Examples include the determination of the long-term impact of plugging tubes in the condenser and replacing condenser tubes with a different material.
7. Alarm Screens: each RMC used one of the larger wall-mounted monitors as an alarm screen. As any system detected an anomaly, an alarm would be posted on the screen for action. The alarm system may be tied only to the APR software or may include TPM alerts as well. The alarm screens were built in various software programs based on the needs and preferences of the RMC. Alarms may include a severity indication, time of excursion, duration since initiation, deferment status, and more.

Personnel

The number of people working in the RMC's visited varied, as did the number available to track problems specific to heat rate. The number of people required depends on the number of facilities and individual units being monitored, as well as the amount of coverage desired (weekday only or around the clock support). One RMC initially utilized in-house personnel for weekday coverage with contract personnel for after-hours monitoring. Once the value of the after-hours coverage was verified, all the personnel were converted to full-time, in-house staff.

The skills of the personnel operating in the RMC also will depend on the priorities of the RMC. The RMC's visited considered themselves as an extension of the control room, and most of the personnel tracking equipment reliability concerns had significant operations experience. Personnel with an Instrumentation and Controls (I&C) background were also highly valued for tracking reliability concerns. Heat rate issues were more often being tracked by personnel with an engineering background, and in some cases they also had significant experience in software modeling and ASME code-level heat rate testing.

Due to the intensity of the software and hardware required to support the people and systems in the RMC, dedicated support from information systems and technology (IT) groups may also be needed. Some of the RMC's visited had full-time IT support available in-house, while others utilized contract personnel.

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COSTS AND BENEFITS

The cost to implement a Remote Monitoring Center will vary, based on the size of the operation and the tools and software selected. A gross estimated cost for installing an RMC, along with APR and TPM software at each facility is $1,000,000 per facility monitored. This is an overall estimate based on the companies visited, where facilities were mostly comprised of one or two coal-fired steam units and a minimum of three facilities were included in the initial RMC installation project. For a company monitoring only simple cycle gas turbine facilities, a lower cost per facility might be expected.

As mentioned earlier in this report, all of the companies included in this project originally setup their RMC's in order to improve equipment reliability. Once the RMC has been built with all the applicable hardware, software and personnel in place, only incremental costs are required to include monitoring with a purpose to improve heat rate. These incremental costs are not large, relative to the rest of the RMC's reliability activities, but the benefits can be significant.

Each RMC visited had various pay-back rates calculated for their operation, but all three recognized the value of the RMC within the first year of operation, often expanding the initial project to include additional personnel and/or facilities. In some cases the payback occurred within 3 months of the *start* of installation – even *before* final system checkout had occurred. For most of the sites, the payback continues to improve year after year. Since the majority of costs are due to software installation during the initial year of RMC operation, the annual investment into the RMC may decline, but the added experiences of RMC personnel lead to improved communications and knowledge of events. The local facilities themselves also learn to utilize the resources available at the RMC more as time goes on, leading the RMC to also serve as a central knowledge database and 'help desk' for all equipment issues.

Additional ongoing costs for the RMC will include the real-estate, computer equipment maintenance, and personnel at the RMC. As part of the implementation of the RMC, additional instrumentation at each facility may also be added to the routine calibration list for facility staff, central support groups, and/or contractors to provide.

At a recent EPRI Heat Rate Conference, the general consensus among the attendees was that there was approximately 4% in heat rate recovery available at each coal fired facility, if one were only to look for it. One of the RMC's visited was able to prove out that assertion. The RMC expanded their operations to include a staff of five engineers dedicated to heat rate monitoring, based on an eventual heat rate reduction of just 2.5% on an annual fleet-average basis. These were mostly older units, so the 2.5% heat rate improvement was intended to return the units to a state closer to new and clean. Since implementation of the dedicated staff of engineers for heat rate monitoring at the RMC, the annual fleet-average heat rate is approximately 4% better than their baseline (the baseline was taken just prior to the RMC installation). It took a few years to achieve the total 4% improvement in heat rate, but the RMC is now able to maintain this improved value year after year, suggesting that the RMC heat rate engineers are not only able to preserve the heat rate improvements made to-date, but are also able to offset normal long term equipment degradation. It should also be noted that the heat rate performance recovery was realized without any capital improvement projects other than the addition of instrumentation for monitoring purposes.

The benefits of the RMC to the company in improved heat rate are significant and well documented at some of the companies. But, there are other benefits to having an RMC. The collective experience of the RMC personnel offer many additional advantages for the generating companies beyond just reliability and heat rate improvements, including the following:

- **A Central Knowledge Database of All Unit Performance Issues.** When issues are resolved with the support of a central group of people who are dedicated to improving the performance of all the units in the company, solutions can be shared across the fleet. In this way steps can be taken to solve problems before they impact performance at more than one unit.
- **Training Resources.** The personnel at the RMC have extensive experience in operations, instrumentation, and plant performance. This information can be organized and presented to new O&M staff for initial training on fleet equipment, and also for existing O&M staff for refreshers or increased heat rate awareness. Where general training is needed, third party groups may be brought in, but for specific unit issues, the personnel at the RMC provide an unsurpassed wealth of information.
- **Abnormal Operation or Excursion Support.** When a control room operator (CRO) is faced with an abnormal operating condition, the personnel at the RMC can be available to walk the CRO through the recommended steps to return the equipment to a safe/normal operating condition. All of the RMC's visited for this evaluation had read-only access to control room data, but the personnel were able to quickly assess situations and support the local facility control rooms by suggesting new setpoints or equipment operating status in the event of an operating excursion. In most cases the personnel at the RMC had more than 10 years of experience (and in some cases more than 30) with plant equipment and may have already experienced the specific excursion which may or may not be the case for the less experienced CRO.

In addition to the above listed benefits of a central RMC, increased monitoring also leads to benefits beyond improvements in equipment reliability and heat rate. The following list is only a sampling of some of the benefits of increased monitoring by RMC personnel:

- Additional planning time for parts replacements, resulting in lower shipping costs (ground versus expedited).
- Well planned outages with fewer surprises lead to shorter, less stressful outages resulting in lower potential for personnel injuries and a higher overall safety record.
- Reduction in overall equipment degradation rates due to a proactive approach to maintaining process conditions and vibration signatures well below alarm limits.

When asked if any RMC had invested in a piece of equipment or software which turned out to not be useful, there were only a few items mentioned. Mostly, installation of software on power generating units which were used only for "reliability-must-run" contracts did not benefit from any additional monitoring (either by software or personnel). Even units operated in short-term peaking capacity were found to benefit from some remote monitoring. For those units, RMC personnel experience was used to monitor the operation of startups and fast ramps, and in many cases were able to shorten the duration of such events. For all the other facilities, the only comment was that additional personnel would be beneficial in using the investments in software and systems to their fullest potential.

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CONCLUSION

Based on the results of this evaluation, improved reliability provides benefits well beyond the costs for the installation and on-going expenses of an RMC. This evaluation also indicates that additional personnel dedicated to monitoring and improving heat rate can also be cost effective. Significant returns, up to and including a 4% recovery (improvement) in heat rate and associated improvements in capacity, easily surpass the costs of additional personnel and equipment. Keys to a successful RMC include:

1. **The right location:** Being close to all necessary support groups in a location large enough to provide space for resources and monitor displays.
2. **The right software:** Both Advanced Pattern Recognition and Thermal Performance Monitoring systems are needed for a complete heat rate and reliability monitoring solution. Communications systems, alarm tracking systems, and access to facility real-time and historical data are also needed for a successful RMC.
3. **The right personnel:** Operations experience, Instrumentation and Control (I&C) experience, and engineering experience are all valuable additions to a successful RMC when tracking heat rate in addition to reliability.
4. **The right hardware:** Computers and monitors are needed for the RMC to get started, but additional instrumentation at the operating facilities may also be needed if certain process lines are not currently instrumented. This is especially true when monitoring for steam cycle alignment, where instrumentation is often not installed during initial construction.
5. **The right procedures:** Having a set of standard operating procedures allows for a smooth transition between shifts and easier training if new personnel are brought into the RMC. Procedures can also become living knowledge documents, capturing methods and rules-of-thumb for determining the root causes of performance losses, and outlining their resolutions.
6. **The right attitude:** All of the companies in this evaluation considered the RMC personnel to be extensions of the facilities' control rooms. The RMC was used in an advisory role, only recommending courses of action. In all cases the local facility personnel were the ones responsible for the operation of the units and were under no obligation to follow the recommendations of the RMC. And also in all cases, the recommendations of the RMC were taken very seriously and acted on in a reasonable amount of time.

Implementing all of the above recommendations may require significant implementation costs, but as one RMC manager said about remote monitoring; "It ain't cheap, but it's worth it."

A

CASE STUDY 1

Remote Monitoring Center Overview

The Remote Monitoring Center (RMC) at Company #1 has been operating in their corporate offices since 2006. The RMC monitors five facilities including 13 coal fired units and 2 gas turbine combined cycle units. They use Advanced Pattern Recognition (APR) software and Thermal Performance Monitoring (TPM) software to trend equipment operating conditions and alert local facility personnel when questions arise or action is needed.

The objectives of the RMC are as follows (in order of priority):

1. Reliability / Availability Improvement
2. Environmental Compliance
3. Maintenance Cost and Schedule Optimization
4. Capacity Improvement
5. Heat Rate Improvement
6. Provision of Ancillary Services

Personnel

Personnel at the RMC include one model maintenance technician and one performance engineer. Future hires in the RMC will place a priority on operating experience. It is felt that significant operating experience is required in order to correctly evaluate alarm indications for severity and recommend courses of action.

The RMC is staffed five days a week during a single 8-hour shift. VPN and Remote Desktop are used for remote off-hours support only when needed. The performance engineer routinely checks on the alarm and event logs at least once over the weekend from a remote VPN connection, but is only rarely contacted by the facilities for support during off-hours.

Hardware and Software

The RMC includes three workstations, each with six separate monitors running from dedicated desktop computers. On one of the workstations, three of the monitors are large flat screens mounted on one wall of the RMC.

Software used includes:

1. APR: SmartSignal's EpiCenter currently, conversion to InStep's PRiSM planned for the near future
2. TPM: General Physics' EtaPro
3. Thermal Modeling: General Physics' Virtual Plant
4. Alarm Screens: Custom software provided by PCS
5. Data Historian: InStep's eDNA
6. Control System Views: Emerson's EDS

Systems and Operation

The RMC's first priority is to monitor alerts from the APR system. A custom alert monitor, or "Annunciator", was added to the system, which acts as an alarm screen for the APR. Every ten minutes the Annunciator software polls the APR system for new events. As an event is identified, it is listed on the Annunciator screen. Each item listed shows information about the event including:

- The facility, unit and asset identifier
- Event description
- Process value
- Minimum and maximum allowable thresholds
- Severity level

The severity level ranges from 1-9 with 9 being the maximum. Events with a medium severity level (4-6) are highlighted in orange. Events with a high severity level (7-9) are highlighted in red.

As new events are listed, the date and time of the initial alarm trigger is highlighted in yellow to indicate an 'unacknowledged' event. This allows the performance engineer to quickly review new items to determine if an action is required. Many of the events are low priority and simply acknowledged, which clears the yellow highlight. If a low severity event has already returned to a normal condition, the event can be cleared off the screen. Higher priority events are reviewed by the performance engineer in more detail, including a review of the history of the sensors involved to determine if the event might indicate a sensor error or problem with the model. If it is a model issue, the model maintenance technician is notified to adjust the model either by adjusting allowable parameters or adding additional data to the APR basis for the sensor(s) involved.

Most events are first investigated through the APR system interface, and then if additional information is needed the TPM system may also be reviewed.

When an event indicates local facility personnel involvement may be needed, the performance engineer will contact appropriate personnel to recommend further action. Phone calls are placed for high priority items; email is used for lower priority items. Personnel contacted may include the control room and/or operations supervisor at the facility or the central system engineer located in the same office as the RMC. An overview of the issue and any recommended action is also placed in a public folder for the facility in Outlook. This allows all personnel to review items and resolutions as they come on shift, even if the item is not of high enough priority to be discussed during shift turn-over.

Information sent by the RMC is for information only and may or may not include recommendations for action. Action on the part of the local facility personnel is not required. The RMC considers themselves an extension of the control room and an additional tool or source of information only. It is up to the facility staff to determine what, if any, action is needed based on current operating conditions at the facility. In most cases, the recommendations of the RMC are acted on within a reasonable amount of time. Since one of the main benefits of the RMC is to provide additional time for planning of maintenance activities prior to equipment failure, most events do not require immediate attention, but can be worked into the existing facility schedules.

In addition to their real-time monitoring functions, the RMC also provides weekly summary reports for each facility to management at both the plant and corporate levels.

Thermal Performance Monitoring

Thermal performance monitoring (TPM) is not the main focus of the RMC, but is an item of interest. Each facility monitored by the RMC does have TPM software installed, which is available to both the RMC and local facility personnel for monitoring of equipment performance. The TPM software at each facility has been configured to print out a shift report two hours *before* the end of each shift. This provides time for personnel to review thermal performance trends prior to shift turn-over. The report includes a list of controllable parameters with their dollar-per-hour ($/hr) impact to operations over the course of the current shift. The top three cost impacts are automatically flagged for operator comments.

At the RMC, the TPM software is used to support events identified by the APR system, and vice versa. Examples of this include the following:

1. Feedwater Heater Performance:
    a. The feedwater heater terminal temperature difference was higher than expected based on the TPM software. The performance engineer used his knowledge of feedwater heater performance to review the trends of appropriate pressures and temperatures in the APR system and based on the information in both systems, it appeared that all data sensors were reading correctly. The performance of the heater indicated there may be feedwater bypassing the heater. The plant inspected the feedwater bypass valve associated with this heater and found the valve to be leaking due to debris caught in the valve seat. Once the valve was re-seated correctly, the feedwater heater performance returned to expected.
    b. Another feedwater heater event which indicated poor performance was determined to be caused by a small vent valve located near the top of the heater's condensing zone that had been inadvertently left open.
2. Condenser Performance:
    a. The TPM software indicated that condenser cleanliness was lower than expected. The plant was alerted that a condenser inspection should be performed during the next scheduled outage. Once the outage inspection was performed, the condenser was cleaned and returned to service. Information provided by the TPM system was then used to show that condenser cleanliness showed significant improvement as a result of the cleaning.
    b. An APR alarm which initiated a review of TPM information led to finding a vacuum pump water seal valve stuck open. The cost in heat rate and capacity loss of the bad seal was determined by the TPM software to be up to $300/hr.
3. Start-up/Shut-down Cycles:

    The RMC monitors unit start-ups and shut-downs and can notify the control room if anomalies occur. Common catches include sticky values that remain open after start-up is complete. Manual checking of the valves for good isolation leads to both improved capacity and heat rate.

In addition to finding short-term events which lead to action recommendations, the RMC is used as an engineering support group for facility performance monitoring. While most of the long-term TPM is performed at the facility level, the RMC provides design support to develop displays and trends for each plant to use. This allows the RMC to leverage information and displays developed for one site across to all the other facilities. Displays of interest include:

1. Steam Turbine Performance: Pressure ratios are trended to provide a visual indication of degradation by section.
2. Steam Cycle Alignment: All drain lines to the condenser with available instrumentation are monitored on a single screen to determine if significant leakages to the condenser are present. The Thermal Modeling software will be used to provide the cost ($/hr) of any leakages based on estimated flows and measured temperatures.
3. Controllable losses: A single screen of all controllable losses is provided on the TPM software displays for the control room operators to monitor. The losses include a dollar-per-hour ($/hr) indication for each item on a bar graph for quick review of significant items of interest.
4. Fleet Dashboard: This display is for use in the RMC, and is currently under development. The intent is to provide a single display of all facilities monitored by the RMC. If a facility has a performance issue an indicator next to the facility's name will be red, otherwise it will be green. This will allow the RMC engineer to quickly determine if any facilities need to be reviewed for thermal performance issues. The facilities on the dashboard will then be linked to additional displays, allowing the engineer to 'drill-down' in to the information and quickly find the performance issues needing attention.

The RMC can also run 'what-if' scenarios through the offline Thermal Modeling software to support the facilities when questions arise about the effect on capacity and heat rate for changes in operating parameters; Examples of this include:

1. Feedwater Heater Bypass Operation: The results of the analysis were used to determine the economic impact of delaying maintenance action until a scheduled outage.
2. Valve Replacement: Results from the TPM software showed that the cost of a leaky valve over the course of a year's expected operation was twice the cost of replacing the valve. The valve was replaced at the next available opportunity.

Additional Information

The RMC fleet operates in a regulated environment. Heat rate savings are passed through to the end-users.

Future plans for the RMC include adding personnel, improving the training materials available within the TPM software displays, and increasing the utilization of the thermal modeling software.

Other System Benefits

Examples of additional system benefits are:

1. Identifying Instrumentation Errors: Use of both the APR and TPM systems have been very valuable in finding problems with instrumentation before errors in measurement lead to either operating at inefficient modes of operation or equipment failures due to missing data indications (for example, if sensors have failed but still send a fixed value to

the control system). While most of the instrumentation issues found are based on information in the APR system, the TPM system does add some additional value by providing an independent evaluation of the data. The first principles indication from the TPM system of a potential problem in the data is used to validate the finding of the APR system and vice versa for problems initially found with the TPM system.

2. The TPM software includes the ability to design troubleshooting flowcharts and links to training materials (such as presentation documents), technical documents from equipment manufacturers, procedures or other material of interest. This ability is being used to provide operators additional equipment information, such as for feedwater heaters. A link to a training presentation on feedwater heaters provides information on the purpose of feedwater heaters, the design of the equipment, how performance parameters are calculated, and common problems and solutions with the equipment.
3. The central knowledge of the RMC is an additional resource for training personnel at the facility level.
4. Personnel Safety improvements are an additional benefit that is hard to quantify. Being able to perform maintenance on a planned, scheduled basis improves personnel's ability to complete activities in a safe manner.

Examples of System "Finds"

Examples of "finds" or "catches" by the RMC include:

1. During a shutdown an alarm indicated an issue on a boiler feedpump used only during unit startup and shutdown. The issue found was resolved prior to the next startup. If the issue had not been identified by the RMC, the feedpump may not have been available for the startup, causing a loss of facility availability.
2. During a routine ID Fan test, a bearing abnormality was identified by the APR system. The bearing problem was found and fixed during a shoulder month, saving $150,000 in potential fan damage if the bearing had failed. Additional costs would have accrued if the fan had failed later in the year leading to lost generation capacity during peak months.
3. An increasing pressure drop on feedpump oil-cooler strainers will be identified in the APR system early, allowing approximately one week to plan for strainer cleanings, versus taking immediate action when the pressure drop climbs to the pre-set alarm condition in the control system.

B
CASE STUDY 2

Remote Monitoring Center Overview

The Remote Monitoring Center (RMC) at Company#2 has been in operation since 2002. The RMC monitors seventeen (17) facilities, including multiple coal fired units, gas fired steam units, combined cycle units, and simple cycle gas turbine units. The facility also tracks the generation of several nuclear units. The nuclear units are not monitored for performance, but their generation levels do impact the other units within the fleet, especially in cases of trips or outages.

The RMC uses Advanced Pattern Recognition (APR) software and Thermal Performance Monitoring (TPM) software to trend equipment operating conditions and alert local facility personnel when questions arise or action is needed.

The overall objectives of the RMC are as follows (in order of priority):

1. Environmental Compliance
2. Reliability / Availability Improvement
3. Maintenance Cost and Schedule Optimization
4. Provision of Ancillary Services
5. Heat Rate Improvement
6. Capacity Improvement

Personnel

Personnel at the RMC include nine operations specialists who work on a two-person rotating shift for around the clock coverage (24x7) of the real-time desks. In addition to the specialists, there is also one manager and one Information Technology (IT) engineer dedicated to the RMC. The nine specialists who staff the real-time desks in the RMC have extensive experience in operations and/or maintenance (specifically Instrumentation and Controls) at the plant level. The IT engineer is a contractor with specific experience in PI and the SmartSignal database engine.

In addition to the personnel who work directly in the RMC, there is one engineer who spends more than half his time on issues which are related to performance and other support projects for the RMC.

The RMC is staffed seven days a week, 24 hours a day. VPN and Remote Desktop are also available for remote support when needed.

Hardware and Software

The RMC includes two full-time workstations, each with at least seven separate monitors running from multiple desktop computers (each computer is able to run three monitors). In addition to the workstation screens, three additional large flat screen monitors are mounted on one wall of the RMC. A third workstation is available with three dedicated monitors for use by visiting plant personnel or for training purposes.

Software used by the RMC includes:

1. APR: SmartSignal's EpiCenter
2. TPM: General Physics' EtaPro, viewed through custom ProcessBook screens which are considered part of the Operations Information System (OIS)
3. Thermal Modeling: General Physics' Virtual Plant
4. Alarm Screens: PI-Alarm View
5. Data Historian: OSI-PI
6. Control System Views: Direct views of control system screens are not used, but screens similar to those used in the control room have been developed in PI-ProcessBook (referred to as the Operations Information System or OIS)

Systems and Operation

There are two operations specialists in the RMC at all times. One specialist is focused on supporting unit operations, including monitoring startups; while the other's primary duty is to resolve system alarms. Depending on the current situation, both specialists may be monitoring startups, or working on alarms, as needed.

The RMC's first priority for daily operations is to monitor unit trips and support orderly unit shutdowns. Secondly they monitor unit startups, which are not modeled in the APR, but are supported by the OIS displays. Third on the list is resolving the alarms on the PI-AlarmView screen.

Most of the alarms are initiated by the APR system, but some do come from the TPM system and all are viewed on the PI Alarm View screens. As alarms come in they are reviewed for significance by one of the two specialists at the real-time desks in the RMC. Alarms may be silenced and deferred for a period of time (ranging from a few minutes to days or weeks) or acted on immediately.

When investigating an alarm, the data behind the event is reviewed in the APR software as well as the performance screens of the TPM/OIS and can also be trended from the data historian (using PI-ProcessBook). Resolutions for alarms may include fixing instrumentation problems, modifying the APR model, and/or involving local facility personnel for additional information and support, such as changing a valve position, modifying fan speeds, or making repairs.

For events where local personnel involvement is needed, the lead specialist for that event will contact appropriate personnel via the phone to discuss the recommend actions. Discussions are often followed by an email which outlines the event and recommended actions, and also includes additional information in the form of data trends and screen shots from the APR system or OIS.

All anomaly investigations are tracked via the Computerized Maintenance Management System (CMMS) (which was built in-house) by work requests assigned to the RMC. When an event requires a longer term resolution, the CMMS work request may be reassigned to facility personnel. The facility personnel can also open work requests and assign them to the RMC. Work requests initiated by the RMC include an identification and description of the anomaly, the time of the event, and a recommended resolution. The work request can be flagged for follow-up to a specific person, group, or may be left 'open'.

During times when there are no critical alarms to investigate or unit startups to monitor, the specialists in the RMC will go through a checklist review for each facility. The checklist includes an in-depth review of APR, OIS, and TPM screens, looking for any abnormal conditions or out of range values in Key Performance Indicators (KPIs). The checklist also includes a review of the CMMS work requests to make sure all issues have been property communicated.

One screen in the RMC is used to monitor the dispatch orders for all the facilities. This allows the RMC to be on alert for unit startups and shutdowns as well as smaller changes in load.

The RMC is viewed as an extension on the control room for each facility. While the specialists in the RMC are not directly responsible for the facility operations, their input is valued and welcomed. But their recommendations for action still remain just recommendations; action on the part of the facility personnel is not required. It is up to the facility staff to determine what, if any, action is needed based on current equipment and operating conditions at the facility as well as potentially conflicting goals for budget, resources and reliability. In most cases, the recommendations of the RMC are acted on within a reasonable amount of time.

Thermal Performance Monitoring

Thermal performance monitoring (TPM) software was installed at every facility in the fleet beginning in the late 1990's to support heat rate improvement in preparation for electric deregulation. At that point, use of TPM was a local responsibility. TPM remains mostly a local facility responsibility, but support is also provided by the RMC and the additional engineers in the corporate offices. The screens originally built for the TPM systems (as a subset of the OIS) have been standardized across the fleet and continue to be improved upon for use at both the local level and by the RMC.

There is also an OIS Project Manager dedicated to maintaining and upgrading the PI systems – including the OIS ProcessBook displays. Examples of some of the TPM/OIS screens are:

1. Controllable Losses Monitor: A single screen can be viewed to see where losses are occurring, including a value for the impact of each controllable loss in $/hour.
2. Transition Monitor: Used to follow startups and shutdowns. Units are monitored closely during startup and shutdown using custom built displays. When startups take longer than expected the displays can point to the location and cause of the delay (such as an extended temperature hold point). Following a startup, steam cycle alignment is monitored for proper drain valve and bypass valve operation. Drain valves left open are quickly found by the RMC and closed promptly by facility personnel when notified.
3. Condenser Performance: Condenser cleaning at the facilities is scheduled based on heat rate and capacity issues. The RMC will notify the facility when a cleaning is warranted. Condenser performance is therefore kept optimized throughout the year.
4. Pump and Fan Advisors: A number of screens are built into the OIS to support optimized pump and fan operation. For example, there is a Circulating Water Pump Advisor screen which recommends the number of pumps which should be running under the current operating conditions for optimal unit capacity and heat rate. The pump advisor screens also show how each pump is operating relative to its performance curve. If the pump drops 10% below its curve, it is recommended to take that pump offline for troubleshooting and/or maintenance.
5. Chemistry Dashboard: A quick overview of the chemistry dashboard indicates in-spec or out-of-spec operation based on EPRI's Action Levels 1, 2 or 3. Refer to EPRI Report 1004188 for information on these action levels.

The RMC support engineer spends more of his time on long-term performance, including quarterly heat rate assessments for each facility and performance tests to demonstrate the Net Dependable Capability of each unit. The heat rate assessments are based on data found in the historian. Due to the current dispatch schedule of the fleet and age of some units, full load, stable data appropriate for a heat rate assessment is not always available. The assessments are done with the best data available, and an acknowledgement that the uncertainties around the reported heat rates are high.

Additional Information

The fleet still operates in a regulated market, but expects to join a different ISO within the next few years. In the current market, ancillary services are often more important than heat rate performance. There are also significant disincentives to improving heat rate. The benefits of any money spent on improving heat rate are directed back out to the rate payers and cost is generally not recovered by the operating company. Projects for system improvement must be justified by reliability, flexibility, or capacity improvements; any heat rate improvements are secondary.

When an event or alarm in the RMC leads to a “find” or “catch”, the value of the catch is estimated as both the difference in maintenance costs due to the early warning, and the impact to revenues from both recovered capacity and improved heat rate. A factor is added to the calculation to account for the probability that the local facility personnel would have found the issue given a certain amount of time.

A limiting factor in monitoring heat rate performance is the current level of instrumentation at many of the plants. The flow meters for feedwater flows and circulating water flows need to be replaced with more accurate metering and also need to be calibrated more often. Costs for new flow metering are currently considered prohibitive, since these instruments do not impact the reliability or capacity of the units. Additional online coal analyzers would also be beneficial for TPM, but due to their high costs are not expected to be installed in the near term.

Future plans that will benefit the RMC include installation of EPRI’s PlantView software; a Condition Based Maintenance (CBM) program that would provide centralized access to additional information such as reports on lube oil analysis, thermography, and vibration reports.

The RMC also hopes to add personnel and expand on the training opportunities provided by the RMC staff to the local facility personnel.

Other System Benefits

Examples of additional system benefits are outlined below:

1. The display screens used by both the facilities and the RMC for TPM are collectively known as the OIS (Operations Information System). The screens were originally built for heat rate improvements in the late 90’s, but have evolved to support facility performance at all levels, including startup and shutdown optimization and equipment condition monitoring. The screens are also available remotely for personnel with a VPN connection to the data servers, providing a complete control system view of the plant conditions (in a read-only environment).
2. The RMC support engineers provide a central location for new and/or updated TPM and OIS screens. Screens requested by one facility can then be provided as a benefit to other facilities as needed.

3. The specialists in the RMC are recognized as system experts by the facility personnel. Their extensive experience is available to be used as a resource to support operations during abnormal excursions and provide both ad hoc and organized training, when time allows.
4. The RMC serves as a central knowledge base for facility O&M information. The value in sharing information across all units in the fleet is significant. The knowledge gained by the RMC staff is also continuously available to the facilities for support of specialty investigations; avoiding 3rd party consultant fees.
5. There are many alarms and equipment indications in the OIS which send automated alerts to specific personnel. Alerts may include when units go on or off-line and other regulatory or critical information as requested by the person receiving the alerts.
6. The facility checklists which are used to monitor equipment in between alarm events at the RMC also support smooth shift turnovers and serve as training tools for new personnel at the facility level, when needed.
7. The RMC has a good reputation with the power dispatch group. In many cases, the dispatcher will call the RMC for information instead of calling the facility. This frees up the facility personnel to focus on real-time operations.
8. The RMC also fulfills from 7 to 20 external data requests every month. Data requests may be used to support management reporting requirements or information required for capital project requests.
9. Equipment needing repair or replacement is often found early, allowing the facility to plan for an outage (if required) and bring in necessary parts on a ground shipping schedule, versus overnight resulting in significant savings in shipping costs as well as minimizing replacement power and fuel costs.

Examples of System "Finds"

The RMC tracks the number and type of "finds" each year in a spreadsheet which includes the date, unit, system, and description of the event. Avoided costs for the event are estimated, including the impact to maintenance costs, capacity, heat rate, and outage duration. They identify approximately 700 finds each year, 20% of which are related to instrumentation. The remainder is split between operational issues and maintenance requirements.

Examples of "finds" or "catches" by the RMC include:

- Oil Leaks. Bearing high temperature alarms, which come in on the APR system, often lead to catching small oil leaks or contamination before they cause equipment damage.
- A turbine thrust bearing high temperature alarm in the APR resulted in an inspection by the facility personnel. They found the front standard expansion tracks needed additional grease.
- Superheater spray was in use following a startup after it was no longer needed. The control room operator was notified and the spray was reduced to normal operating levels, improving unit heat rate. The amount of improvement was not captured, since there is no incentive to demonstrate heat rate improvements.

C
CASE STUDY 3

Remote Monitoring Center Overview

The Remote Monitoring Center (RMC) at Company #3 has been operating in their corporate offices since 2005. The RMC monitors 10 facilities for reliability and heat rate, including 12 coal fired units, 8 gas fired steam units, and 2 nuclear units. They use Advanced Pattern Recognition (APR) software and Thermal Performance Monitoring (TPM) software to trend equipment operating conditions and alert facility personnel when questions arise or action is needed. In addition to the facilities monitored for heat rate, there are multiple simple cycle gas turbine units which are monitored by the RMC for reliability only.

The overall objectives of the RMC (not just the heat rate team) are as follows (in order of priority):

1. Reliability / Availability Improvement
2. Maintenance Cost and Schedule Optimization
3. Capacity Improvement
4. Heat Rate Improvement (Management and Recovery*)
5. Provision of Ancillary Services

While environmental compliance was not ranked in the above list, it is expected to be high on the list at either #2 or #3, since units which are not run within environmental permit limits will not be allowed to run. The current RMC management also places a high value on managing emissions to ‘best in class’ standards.

* Due to the potential of heat rate “improvements” to impact utility rate cases, the RMC considers its goal to be “heat rate management and recovery” – which means they are actively working to maintain each unit’s heat rate as close to new and clean conditions as possible and to minimize the effects of equipment degradation. They are not working to improve heat rate beyond the original design basis.

Personnel

Personnel at the RMC include a team of five thermal performance engineers dedicated to heat rate monitoring and recovery, supervised by one engineering manager. Each week a single performance engineer is dedicated to the RMC real-time desk during a normal weekday shift (40 hours a week). The remaining performance engineers work from their offices on heat rate improvement projects, including investigations into issues identified by the real-time desk. Each week the performance engineer at the real-time desk is rotated, such that each engineer spends one week in five at the real-time desk.

VPN and Remote Desktop are used for remote off-hours support by the performance engineers only when needed. Requests for off-hours support are infrequent.

In addition to the performance engineering staff, the RMC is also staffed with two operations experts around the clock and one reliability / equipment manager on a day shift basis.

Hardware and Software

The RMC includes eight workstations, two of which are staffed continuously and two of which are staffed during day shift only. The other four stations are available for additional support during high activity times (such as during the heat of summer or when the local power grid declares a state of emergency). Each workstation includes at least three separate monitors running from a desktop computer. In addition to the workstation screens, eight large flat screen monitors and two extra-large projection screens are available on the front wall of the RMC.

Software used includes:

1. APR: SmartSignal's EpiCenter
2. TPM: General Physics' EtaPro on coal units; EPRI's PMW on gas units; Westinghouse's EnergiTools on Nuclear units
3. Thermal Modeling: General Physics' Virtual Plant and Encotech's Ebalance
4. Alarm Screens: Siemens' Cockpit
5. Data Historian: OSI - PI
6. Control System Views: Siemens' Cockpit

Plant Instrumentation

During the initial startup of the thermal performance recovery program, additional instrumentation was added at the plant level in several key locations. The new instrumentation was added using wireless technology in order to minimize installation costs. While the instrumentation does have higher maintenance costs due to wireless issues and battery replacements, they have found the wireless systems to be very cost effective. Access to the additional information has been very beneficial in identifying additional heat rate losses, especially around steam cycle alignment issues.

Systems and Operation

There are two operations leads monitoring multiple screens for APR and control system (static) alarms in the RMC at all times. During the daytime shift there is also one equipment manager supporting the reliability desk and one thermal performance engineer at the heat rate desk.

The two operations desks monitor both APR and control system alarms for all the facilities. As an alarm comes in and an issue is identified which needs further investigation, the issue is passed either to the reliability desk for an equipment issue, or the heat rate desk for a thermal performance issue.

When there are no active thermal performance alarms requiring the performance engineer's attention, the engineer at the real-time desk will conduct an in-depth thermal performance analysis of one of five different coal facilities (some of which include multiple units); with a different facility being placed under review each day of the week. Using this rotation, each coal facility is subjected to an in-depth analysis weekly, and each engineer reviews each of the plants' performance in depth once every five weeks. The nuclear plants undergo a similar in-depth analysis once every two weeks. The gas plants, being peaking units only, are not subject to these periodic reviews.

As issues are identified during alarm investigations or the in-depth review, potential causes and resolutions for the issue under investigation are determined. In support of issue resolution, a diagnostics manual is available which offers information on known issues for various pieces of equipment. The diagnostics manual was developed in house and is a living document; being added to as new issues are identified and resolutions found.

The resolution of issues may include any (or all) of the following:

1. Contact the control room for immediate concerns, such as closing startup valves or rectifying a steam cycle alignment issue.
2. Contact the facility maintenance manager for valve work or other equipment issues which need to be handled locally but do not require immediate attention.
3. Initiate an Action Request in the communication system for further investigation by the "back office" engineers (the thermal performance engineers not currently manning the real-time desk). The Action Request may also lead to a Work Order at the facility level. One to six events from the real-time desk are sent to the "back office" each day.

Issues, resolutions, communications, action requests, and findings of the in-depth reviews are all logged in the online log system (eLog) for future reference along with any alarms from the real-time desk. The eLog entries are reviewed at the end of each month and a report is generated and distributed to the stakeholders. An estimate for the dollar impact of the RMC is made and presented to management on an as-requested basis.

In addition to the monthly report, certain factors are noted and reported to the RMC team daily during their morning meeting. Daily indicators include: a quality assurance (QA) factor for the data used by the TPM software (the percentage of "bad" inputs and calculations), heat rate tracking values, and dispatch gas use "gap" (difference versus actual and expected based on dispatch heat rate curves).

Thermal Performance Monitoring

Thermal performance monitoring (TPM) is only one of the functions of the RMC, but it is the specific focus of the thermal performance engineering group. Each facility monitored by the RMC does have TPM software installed, which is available to both the RMC and facility personnel for monitoring of equipment performance.

At the RMC, the TPM software is used to trend the performance of all turbine sections, feedwater heaters, condensers, feedwater pumps, air preheaters, and major steam cycle alignment valves. Key Performance Indicators (KPI's) are trended and reported quarterly. The TPM software also provides input into the weekly in-depth performance reviews and often identifies issues requiring further investigation.

Examples of issues identified include:

1. Steam Cycle Alignment. The RMC maintains a very close watch on the steam cycle alignment at each facility. Many heat rate issues are found to be due to improper cycle alignment. In some cases valves are left open after start-up; in which case the control room is notified such that action can be taken quickly. In other cases valves are leaking by and require offline maintenance or replacement. A significant portion of the heat rate recovery found by the RMC can be attributed to the priority placed on monitoring each facility for steam cycle alignment. Given that approximately 35 valves are monitored at each of 12 facilities (for a total of 420 valves). On average, four or five valve issues are identified each day.

2. Feedwater heater pass partition plate failures are found easily with the data and tools in the RMC.
3. Condenser performance issues are often identified, leading to timely cleaning and other maintenance. TPM is also used to support material options when condenser re-tubing is necessary.

Additional Information

The business case for installing the RMC initially was that payback could be attained within three years by improving heat rate by approximately 2.0% from the 2005 baseline (based on a 12-month rolling average heat rate, to incorporate seasonal variances), with a long-term goal of maintaining heat rate 2.5% better than baseline. The RMC was paid for within one year with reliability improvements, and the long-term goal of 2.5% heat rate improvement was achieved by the RMC within the first three years.

The RMC operated in a weekday shift mode for the first 4 years, and then went to around the clock operations with contract employees to test out the additional benefits of fulltime operation. The RMC is now operated with permanent company employees after determining there was significant benefit for full-time (24x7) operation. Note that the personnel on off-hours shifts (nights and weekends) are focused on operations issues and not heat rate issues. The real-time heat rate desk is still only manned 40-hours a week during the normal workday shift.

Currently, the fleet average heat rate is operating at 4% better than the original baseline (on a 12-month rolling average basis). The value of the 4% heat rate recovery is approximately $35 million annually. It is understood by upper management that were the RMC to go off-line, the heat rate would eventually climb back to baseline levels, or worse.

When originally questioned about the ability of the RMC to find more than 2% in heat rate recovery, the thermal performance engineers were able to show the potential for up to 4% heat rate losses if just the main steam drain valves were left open following startup.

Prior to the first year of operation, the RMC completed an analysis of each valve on the steam cycle for each facility. Approximately 35 valves at each facility were found to be significant sources of potential heat rate losses. These valves were instrumented with additional (wireless) temperature sensors when needed to facilitate the estimation of leakages using near real-time data.

One of the limitations for heat rate monitoring is the lack of accurate metering, especially for the final feedwater flow. Most of the units do not have ASME nozzles for feedwater flow measurements. Condensate flow meters, where available, are more often calibrated instruments, and may be used as the “official” flow value within the TPM software for determining the cycle mass balance.

The RMC operates as an independent source of information and support for each of the generating facilities. The personnel in the RMC can view control system screens and all alarms (control system and APR) but all changes in operation occur at the local facility control room level. The RMC can recommend actions to the local staff, but it is up to the facility personnel to decide which recommendations to act on.

Personnel from the facilities are periodically rotated into the RMC to support the operations desk. This allows the facility personnel to understand first-hand what happens in the RMC, as well as learn about the amount of support available for their operations once they return to their facility. The facility personnel normally need only a single 3-5 day visit to gain an understanding and appreciation for the RMC. Sending personnel to the RMC is at the discretion of the facility management.

Members of the RMC's heat rate team also visit the facilities periodically. Many times it is just to maintain the wireless instrumentation, but the engineers enjoy reconnecting with the facility personnel and seeing the equipment first hand.

The RMC fleet currently operates in a deregulated market, but is still subject to federal new-source-reviews if any significant changes are made to the units. Due to this issue, the thermal performance group is considered a heat rate management and recovery operation – keeping each facility operating as close to new and clean as possible while minimizing equipment degradation.

Future plans for the RMC include bringing all power generation stake-holders into a central location, such that all marketing, dispatch, operations and maintenance activities can be automated and coordinated to the maximum extent possible.

Other System Benefits

Examples of additional system benefits are:

1. The RMC performance engineering group is working with the company's field performance test group to automate the periodic performance testing of the units. Currently, the performance tests are run by the test group utilizing a trailer full of calibrated instrumentation which is installed temporarily, specifically for each performance test. The RMC performance engineers are building analysis screens for the TPM software to automate the test analysis utilizing permanent plant instrumentation. Additional instrumentation may be added (using the wireless technology mentioned earlier) as needed. The performance test group and facility personnel would be responsible for instrument calibrations prior to executing the performance test. It is understood that the uncertainty of the test results would increase using the TPM/automated method due to the reduced accuracy of the instrumentation available, but the gains in test execution efficiency are expected to outweigh this downside.
2. The RMC thermal performance engineering group provides additional engineering support for equipment operating issues. For example, when a condenser operating with sections in parallel (A/B side) shows exit conditions from one side differ significantly from the other. The RMC engineering group can open a task for the "back office" (non-real-time) staff to investigate the performance issue and provide recommended resolutions.
3. The TPM software displays are very helpful at identifying instrumentation failures.
4. The TPM software is used to provide analysis before and after outages. The changes in heat rate are provided in an Outage Effectiveness Report. The first startup after an outage is also monitored closely to verify valve line-ups and steam cycle alignment.
5. When an issue is identified at one facility, the other facilities are investigated to see if the same issue is evident. Resolutions can then be applied fleetwide, as needed.
6. The RMC supports the economic dispatch and marketing group by tracking the heat rate dispatch "gap" for the operating units. This is essentially how close the unit is operating per the dispatch expected heat rate (for the given load).

7. The RMC thermal performance engineering group also provides updated heat rate curves for economic dispatch on a quarterly basis for all the facilities. The curves identify the impact of operating at different loads. When there are changes in the curves, sources of the changes may flag investigations into facility performance. In some cases the changes may be due to changing operating profiles such as caused by increased load following due to wind or other renewable entering the generation mix.
8. The RMC provides a central location for engineering excellence. By using this central sharing of information and experiences as a training center, new personnel at both the facility level and RMC can be brought up to speed quickly.

Examples of System "Finds"

Examples of "finds" or "catches" by the RMC include:

1. Turbine seal damage was identified early allowing for a planned maintenance event versus a forced outage.
2. HP steam turbine efficiency trended down approximately 1% over a two week period. During the next boiler outage, soft deposits were identified and removed from the HP section. Post outage analysis showed a return to higher HP section efficiency.
3. When comparing performance before and after an outage, the steam turbine calculated LP section efficiency was found to have shifted down, leading to the finding of a steam cycle alignment issue.
4. During a demonstration of the TPM system, a Hot Reheat drain valve solenoid failure was found.
5. Real-time information led to finding a leak in a boiler feedpump recirculation valve before it caused a forced outage.
6. Monitoring the feedwater heater drain cooler approach led to an investigation which found the thermocouple being used in the analysis was in the wrong location. The instrument was moved to allow for a more consistent and more accurate analysis.

D
SURVEY QUESTIONS FOR THE EVALUATION OF REMOTE MONITORING FOR HEAT RATE IMPROVEMENT

Q1. What is the size of your remote monitoring organization?

1. No. of Facilities and Units being monitored:
2. Remote Monitoring Center hours of operation (24x7, 8x5, etc.):
3. No. of Personnel
   a. Engineers:
   b. Operators:
   c. Managers:
   d. Other:

Q2. How many of the following types of facilities do you monitor?

1. Traditional fossil
   a. Coal:
   b. Gas:
   c. Biomass/Other:
2. Gas turbine based
   a. Combined Cycle:
   b. Simple Cycle:
3. Nuclear:
4. Hydropower:
5. Wind (farms):
6. Other:

Q3. Rank the following based on priority within your organization (1 being highest priority):

___ Ancillary Services

___ Availability / Reliability

___ Capacity

___ Emissions / Environmental

___ Fuel Efficiency / Heat Rate

___ Maintenance Optimization (Cost and/or Schedule)

___ Other / ______________________

Q4. Which of the following software is used in the monitoring center?

1. Advanced Pattern Recognition Software (SmartSignal, PRiSM, PdP, etc.):
2. Thermal Performance Monitoring Software (EtaPro, PMAX, EnergiTools, etc.):
3. Thermal Modeling Software (GateCycle, VirtualPlant, PEPSE, etc.):
4. Other (please specify):

Q5. How do you communicate issues requiring follow-up to the appropriate personnel (phone, email, instant messaging, custom software/log tool, etc.)?

Q6. Can you share any data and/or examples of problems identified and/or solved which resulted in heat rate improvements?

Q7. Based on your experiences, rank the expected benefits of the following (with the goal of heat rate improvement):

___ New software tools

___ Additional personnel

___ More personnel training

___ Better communication tools

___ Other / _____________________

Q8. What do you see as your biggest obstacle to improving heat rate across your fleet? (Human resources, physical resources, operating profile requirements, management practices, etc.)

Q9. If you had an unlimited budget, what improvements to your central monitoring facility would you make? What benefits would you expect to see from these changes?

Q10. If you would be available for follow-up questions to any of the information you've provided, who is the best person to contact:

Name: ______________________

Phone: ______________________

Email: ______________________

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