Ormat Plants: From Remote Monitoring to Remote Operation

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Abstract
Ormat operates geothermal and recovered energy generation power plants in 22 countries. The engineering and customer support teams require process and equipment data in order to respond quickly to events of upsets, malfunction and failures. Not long ago, technology allowed monitoring limited data with slow transmission rates and unreliable connections. True valuable support was only achievable by spending time and money traveling to site. Today, Ethernet technology, Wide Area Networks and the Internet bring abundance of online plant data achieving fast, reliable and secure remote activities: from basic support to complex plant tests and experiments; from simple troubleshooting to advanced diagnosis and problem solving. Ultimately, with the ability to place plant operator workstations at any distance from the plant, full remote operation of unmanned power plants has become a reality.

The benefits of the remote control system become evident through the presentation of Ormat’s Steamboat complex in Reno, NV. From the complex’s control center, unmanned plants are remotely controlled, among them ten recovered energy units, located thousands of miles away along the Northern Border gas pipeline. Operations optimization is pursued by clustering power plants’ supervision into central control locations.

Monitoring rotating equipment is crucial to understand and prevent developing of problems in the machine. Especially, vibration analysis is the key diagnostic tool in evaluating a rotating machine’s condition. A machine’s vibrations signature together with the process data allow for a comprehensive analysis and diagnostic of the machine condition. With the ability to access online plant data at the click of a mouse, rotating engineers sitting at their office desk can perform valuable data monitoring and analysis on daily basis. The case study of a 5.5 MW power unit turbine located in the plains of South Dakota, US, monitored from Ormat engineering headquarters sheds more light on the advantages of remote monitoring and diagnostics.

Using its own plants as test benches, Ormat continues to expand its remote monitoring and diagnostic capabilities, offering improved products and services to its customers.

Introduction
The first part of this paper presents an overview of the evolution of remote operations. Discussion points range from when the first programmable automated control systems were introduced to innovations from the present days: from limited data acquisition capability to full remote operations of unmanned plants.

The second part details as an example the online vibration monitoring system implemented in Ormat plants, which collects real-time vibration data from the rotating equipment (i.e. turbines, pumps and generators) and automatically sends it to Ormat headquarters for storage, analysis and diagnostics.

Ormat Technologies, Inc. manufactures and sells power generation equipment for geothermal and recovered energy generation power plants located around the world. Ormat also operates its own worldwide power plants serving as an independent power producer (IPP).

Ormat has manufactured and supplied more than 80 power plants (1430 MW) of which it owns and operates 20 facilities totaling 556 MW. Over 30 years of development and accumulated experience operating geothermal power plants, Ormat uses the same equipment and services offered to its customers.

One of Ormat power plants’ key features is their ability to be unmanned and remotely operated. Many Ormat-owned and third-party-owned power plants, as well as most recovered energy generation units, are unmanned. Plant operations’ efficiency is improved by clustering power plants’ supervision into central control locations. Many control centers are already in operation and others are planned.

A central goal of Ormat’s engineering department is to professionally accompany and support every project during its working life and not only for the short interval following the commissioning phase.
To facilitate sustainable solutions for any problem, all relevant data must be available to Ormat’s engineers for correct analysis. With the added fact of today’s production, down time and power generation costs, a minimum delay between problem occurrence and solution is critical to success.

To achieve this success Ormat is implementing control systems with the following main integral capabilities:

- Safe and reliable full automated systems ensuring optimal performance during normal operation and safe shutdown in case of emergency situation or failure.
- Extensive use of process instrumentation and machine condition monitoring equipment.
- Fast, reliable and secured communications system to allow monitoring and data collection for plant supervision and analysis of plant equipment and thermodynamic process.

Besides the obvious benefits of allowing unmanned and remote operations, this approach has the following main advantages:

- The ability to diagnose and provide a solution to a problem before a support crew arrives on site.
- Continuous equipment monitoring allowing for condition evaluation and preventative actions, as required.
- Dedicated engineering experience to address one or more specific problems simultaneously.
- Gather and store field data for future development.
- Correlation between machine condition and thermodynamic process variables allows a more inclusive picture for root-cause analysis.

Remote Power Plant Operation

For more than 30 years, Ormat has designed, manufactured, constructed and operated geothermal and recovered energy generation power plants in 22 countries. The engineering and customer support teams located hours, even days away, require as much process and equipment data as possible in order to respond quickly to events of upsets, malfunction and failures. Ormat has worked to implement the remote operation system to circumvent the time spent traveling during the days when only offline data was achievable. With the improvement bringing plant data available online, the company achieves fast, reliable and secure operation. With the abundance of online data attainable at the click of a mouse, a wide range of remote activities, from basic support to complex plant tests and experiments are possible from afar, allowing not only a robust problem solving capability but also the ability to verify a diagnosis or benchmark development changes from the engineer’s design desk. This is of great importance to Ormat’s progressive approach. Ultimately, with the ability to place plant operator workstations at any distance from the plant, full remote operation of unmanned power plants has become a reality.

Evolution of Data Acquisition and Monitoring

In the first years of automated programmable control, special communications systems were developed to acquire and transmit data from local control systems to central remote control rooms. These systems, called SCADA -Supervisory Control and Data Acquisition- were usually vendor specific, i.e., applicable only to specific equipment, very expensive and limited in range. True remote (e.g., overseas) monitoring was exceptional. All this changed when Ethernet networks and the Internet were developed.

The first control systems in Ormat plants had limited remote monitoring support, mostly a thin replication of the local graphic displays. Data were transmitted through a phone line modem making rather slow transfers of small amounts of data possible. In order to connect, the remote user needed dedicated software installed in the computer. Due to slow data lines prone to frequent disconnections, remote sessions were typically used for monitoring and, to the extent possible, for support.

Improved data transfer and better connections were possible when Ethernet networks and then the Internet became available, first through slow modem connections and then through fast broadband. With faster data transfer and more reliable connections, remote users were able to get a more comprehensive look at the plant, sustain longer sessions without interruption and able not just to give verbal support to fix problems but to fix the problem themselves.

These days, remote connection is straightforward and seamless through the Internet using either a standard Web Browser or off-the-shelf, -even freeware,- Remote Access software and can be accessed easily and securely by computers connected to the network either physically or through a virtual private network connection (VPN). Using fast and reliable Internet connections, remote users get almost the same feel of operability as local operators do, making possible fruitful sessions of monitoring and analysis, remote support and programming as well as remote operation of unmanned plants.

Ormat Plants From Remote Monitoring to Remote Operation

Figure 1 shows a typical Ormat Energy Converter (OEC) screen used in Human Machine Interface (HMI) systems two decades ago. The remote user gets a thin replication of the screen with selected data.

Figure 2 shows a typical OEC screen in a modern HMI system. The remote user gets exactly the same software environment as the local operator.
Using a standard graphic scheme across the plants fleet—same objects, same colors, similar menu bars—gives the operator a familiar graphic environment facilitating easy monitoring and fast control. The user has just to take a quick glance at the screen to verify no alarms are present (no yellow color onscreen), all equipment needing to be running is running (red) and values are well within their operating range. To assist the user finding a certain process value there’s a standard color code: orange background is for pressure values, cyan for temperatures, light brown for vibrations, black for valves, etc.

Fast, reliable and secure connections make remote control of unattended plants possible. Remote operators supervise plants located at distances ranging from a few to thousands of miles away from their control room.

Typical next door cases are expansion plants and generating units—most typically REG (Recovered Energy Generation) - built in the vicinity to existing plants where a new control room and operations staff is already available. When intervention is needed at the unattended plant, operators can get onsite after a short walk or drive. Many plants built by Ormat are operated in this fashion. In New Zealand, the Te-huka power plant is operated from Wairakei plant located a few miles away; KA-24 unit in the Bay of Plenty is operated from the main plant Kawerau; an additional unit in Ngawha power plant is controlled from the main Ngawha plant; new 100 MW Ngatamariki plant, now in construction, is designed to be remotely operated.

But with WAN (Wide Area Networks) and Internet technology distance is no longer an issue. Remotely operated plants can be, and are, located thousands of miles away. Roaming operations and maintenance staff located nearby, usually responsible for the operation and maintenance of a number of unmanned sites, are called to the plant as required by the remote operators or automatically summoned by the HMI through SMS, email or paging systems.

Figure 3 shows the central control room in Ormat’s Steamboat geothermal power plant complex, Reno, NV. Operators in the control room supervise not only the power plants located at Steamboat complex, but also additional plants in northern Nevada and REG units in Montana, the Dakotas, Minnesota, Nevada and Colorado.

Figure 4 depicts Steamboat center Wide Area Network. A state of the art, robust WAN infrastructure, dual redundant communications links and HMI servers, along with complex hardware and software security measures, enables operators at the central control room, as well as roaming operators and engineering staff, to gain access to the network allowing full supervision and control of the remote power plants.

Figure 5 shows an HMI screen of Ormat’s REG units along the Northern Border gas Pipeline. The screen presents an overview
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of the units with basic data allowing
the operator at Reno, NV, monitor the
general status of the units at a glance.

Supervisory operations are clustered in central control rooms, thus
centralizing and optimizing manpow-
er and resources. While Steamboat
control center is in charge of Reno and Northern Nevada plants and REG
units, many other centers are already
operating or at planning stage. Among
others, a control center in Heber, CA,
supervises a group of power plants in
the Imperial Valley, CA, while a con-
trol center in Elko, NV, is planned for
supervision of Ormat’s power plants
in Eastern Nevada.

**Remote Power Plant Vibrations Monitoring**

The rotating equipment in the
plant does not operate at a steady
state; it could be affected by many
parameters such as flow, pressure
and temperature changes, and power
generation requirements. Some
phenomena only occur under certain

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**Figure 4.** Steamboat complex wide area network.

**Figure 5.** Monitoring Ormat REG (OREG) plants along Northern Border Pipeline.
process parameters that could even be the cause of a machine’s problem. Monitoring data through the HMI is critical for the evaluation of a machine’s condition and for understanding the reason for a developing problem. Together with the process data, a thorough monitoring of the machine vibration signature allows for a comprehensive analysis and diagnostic of the machine condition.

**Remote Vibration Monitoring System**

Vibration analysis is a key diagnostic tool in evaluating a rotating machine’s condition. Regular vibration monitoring can detect deteriorating bearings, misalignment, unbalance, bent shafts, structural problems and flow-related issues.

Vibration data are acquired by accelerometers and proximity probes mounted on various locations on turbines, generators and other rotating equipment in Ormat’s plant. The raw data from the sensors is transferred through cables to a vibration monitoring device which has FFT capability and can transform the raw data to: acceleration and velocity spectrums, enveloped spectrum, time waveform and overall vibration levels. The device then sends the data through the Internet to a dedicated server (Figure 6), where it is analyzed by a trained engineer.

The remote vibration monitoring system is successfully implemented in over 30 power plants and has already proven its value as described in the next example.

**Case Study - Ormat REG Turbine**

The turbine is part of a 5.5 MW unit located in the plains of South Dakota, U.S. The unit utilizes waste heat from a pipeline compression station, it is unmanned and controlled and monitored remotely. In September 2011, four years after its commissioning, abnormal vibrations measurements started to appear. On the vibration spectrum (Figure 7), frequencies that relate to bearing defects appeared and their amplitudes started growing. At that moment, a diagnosis was made to determine that bearing condition was deteriorating and it was decided to ship replacement parts for the turbine to be available for turbine overhaul. Five months after the initial diagnosis, the bearings reached their end-of-service life and were replaced.

**Detailed Diagnostics**

Figure 7 presents two vibration velocity spectra, the first (red color) was taken on January 23, 2012 and the second spectrum (blue color) was taken on February 25, 2012, a short period after the turbine overhaul. The vertical axis shows vibration amplitude in mm/s while the horizontal axis shows the frequency in Hz. The frequencies apparent on the spectrum equal to BPFI (Ball Pass Frequency Inner (Ring)) and its harmonics, which means a defect is present on the bearing’s inner ring. In addition to the bearing’s defect there was also high amplitude at 30 Hz frequency which relates to unbalance issues. During the overhaul, the turbine was balanced and the bearings
were replaced. The results are apparent in the blue spectrum; the amplitude at 30 Hz decreased and bearing defect frequencies disappeared (400-950 Hz).

Figure 8 was taken during the turbine’s disassembly. It shows the inner ring and cage of the disassembled angular contact roller bearing. The damage on the inner ring is noticeable (red box).

The advantages of remote monitoring and diagnostics in the presented example are evident:

- It allowed for minimal downtime and costs as all the replacement parts were on site ready for the overhaul and personnel assignment for the job could be planned ahead.
- During the winter months, the climate in South Dakota gets extremely hazardous for work of that kind, regular monitoring of the turbine's condition allowed to postpone the turbine's overhaul to a warmer and more suitable climate.
- It increased the ability to operate the unit unmanned for long periods of time.

**Automated Fault Detection**

In addition to the system’s ability to process and send vibration data, it is also able to send warning and alarm emails regarding a possible machine fault. Since Ormat gained experience in monitoring its rotating equipment, a lot of the fault frequencies are known and can be stored in the system with an appropriate alarm threshold.

Once a vibration in a certain frequency is increasing and crossing its threshold, the warning is sent to the supporting engineers and alerts them to analyze the vibration measurements of the machine. This ability creates an even more reliable monitoring procedure.

**Enhancing and Broadening the Capabilities**

Additional rotating equipment is being connected to the remote vibration monitoring system, which means more machines are being studied and Ormat can be even more prepared to deal in case problems occur.

Various vibration frequencies and fault frequencies of each machine are being learned, which leads to better understanding of system performance and enhances the automated fault detection ability.

The diagnostics of turbine and pump problems today integrates software with advanced capabilities such as natural frequency and modal analysis, lateral and torsional analysis and strength analysis. Ormat is continuously implementing new cutting-edge tools.

**Conclusions**

Ormat continues to expand its remote monitoring and diagnostic capabilities using its own plants as test benches, offering improved products and services to its customers:

- Power plant remote control and monitoring is now a standard in Ormat plants and additional existing plants are being connected and monitored.
- With fast, reliable and secure communication, remote monitoring enables ongoing supervision, problem analysis and solving, process and equipment testing and, ultimately, remote operation of unmanned plants.
- Access to power plants’ data by the engineering staff in Ormat’s headquarters make possible supervision, commission and training during the plants’ lifecycle facilitating exploration and analysis of the process and equipment performance thus extending the engineering know-how and knowledge base.
- Operations, engineering support and other many relevant teams benefit from the acquired data accessible at the click of a mouse.