Development of Remote Monitoring/ Predictive Diagnosis Service "exiida" for Air Conditioning

Air conditioners are found in many different types of buildings, including homes, offices, stores, hospitals, schools, and factories, having in recent years become an essential part of the infrastructure. For reasons that include preventing heat stroke, they are relied on to operate without interruption. Refrigeration systems are likewise vital for cooling and for the supply of chilled water in the cold chains found in a wide variety of manufacturing and food distribution operations. Here, too, unexpected faults or shutdowns can be very costly and inconvenient for customers. In response, Hitachi Global Life Solutions, Inc. has launched the exiida IoT solution for the remote monitoring and predictive diagnosis of air conditioning that uses the collection and analysis of large amounts of operational data from air conditioning and refrigeration equipment to identify the warning signs of potential faults so that remedial action can be taken before they happen. Rather than simply supplying equipment to customers, this delivers economic value in forms that include maintaining a comfortable environment and reducing business losses. It also delivers social value by minimizing the release into the atmosphere of freon coolant (thereby reducing the environmental load), and by addressing staff shortages by leveling maintenance workloads that would otherwise happen mainly during the summer.

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1. Introduction

Air conditioning (for maintaining the health and productivity of the people concerned) and refrigeration (for maintaining quality) are among the more important items of equipment for customers. While there is already demand for ways of detecting the warning signs of faults or shutdowns before they happen, with attempts having been made to automate this by setting thresholds for particular sensor measurements, such automation is complicated by the variability of equipment status under different operating conditions. As a result, users have come to rely instead on alarms and monitoring of when faults occur and their diagnosis by experienced staff. In response, Hitachi Global Life Solutions, Inc. (Hitachi GLS) has embarked on development work that seeks to apply to air conditioning and refrigeration systems the predictive diagnosis techniques that have already proven successful in electric power generation, an application that shares the same complex variability of equipment status depending on operating conditions.

2. Challenges for Air Conditioning and Refrigeration Systems

2. 1 Challenges for Keeping Equipment Running

Keeping air conditioning and refrigeration systems running reliably is an important challenge for customers, who require such equipment to be repaired promptly and correctly. Past practice for preventing faults has been to undertake regular inspections and to perform maintenance if any anomalies are found. These inspections, which depend on the skill of the person performing them, involve: (1) recording the values of particular sensors, (2) checking whether each sensor reading is within its permitted range, (3) checking whether the correlations between sensor readings are normal, (4) checking equipment for abnormal noises or vibration, and (5) visually checking the equipment for oil or coolant leaks. Regular inspections like these can detect anomalies before faults or shutdowns occur if the person undertaking them has the necessary experience, so although they are an effective way to keep equipment running, they are also problematic because they involve a lot of subjective judgment.

Meanwhile, systems have been developed that shorten the time taken for repair work by installing equipment that can send alarm output and operational data to facility devices, and monitoring alarms, identifying different types of alarms, issuing repair instructions, and reviewing the data at a control center or other such facility when a fault occurs. However, while these systems are good at shortening outage durations, the alarms are not output until a fault or shutdown actually occurs, so the problem remains that they do nothing to prevent such outages from happening in the first place.

2. 2 Societal Challenges in Management of Air Conditioning and Refrigeration Systems

With heat sources accounting for more than 40% of energy consumption in office buildings[1], air conditioning systems and equipment are directly involved in the issue of global warming. As most air conditioning and refrigeration systems use freon coolant, a gas with a much higher global warming index than carbon dioxide, Japan's F-Gas Law for minimizing fluorocarbon emissions mandates inspections to prevent leaks and the recovery and destruction of freon when equipment is upgraded.

At the same time, a shrinking national workforce is making it difficult to recruit staff for the reliable operation and maintenance of equipment. This staff shortage is particularly severe at peak times as requests to undertake repairs on air conditioning and refrigeration systems tend to occur most often in the summer. Other challenges include how to pass on the inspection work skills of aging staff. Together, these factors are driving demand for establishing maintenance work practices for air conditioning and refrigeration systems that do not depend on the expertise of individuals.

3. Improvement through Predictive Diagnosis

3. 1 Technology Development Background

Operational data from air conditioning and refrigeration systems is subject to complex changes. If an air conditioner is suffering from poor cooling performance, for example, it can be difficult to tell simply by measuring the temperature of the compressor whether a temperature rise is due to a heavy load or an equipment problem (such as a faulty heat exchanger or lack of coolant). Instead, such a diagnosis requires a comparative assessment of the system parameters such as the coolant pressure and temperature and the compressor current and load. Unfortunately, the correlations between these are complex, and can confuse even experienced staff in the absence of symptoms or changes in operational data that clearly indicate the problem.

Furthermore, these correlations are influenced by a wide variety of factors. Along with differences between individual items of equipment, these include installation conditions such as the length of piping, pipe diameters, and elevation changes; differences in cooling load due to outdoor and indoor temperature and humidity, number of people present, and heat given off by equipment; and differences in incoming heat in the form of air flows or sunlight. Because it is so difficult to express these correlations in a graphical or mathematical formula, it became apparent that new diagnostic techniques based on large amounts of operational data would be needed.

Accordingly, Hitachi GLS came up with the idea of adopting an algorithm previously used with power generation equipment, which is subject to similar challenges of operational data varying in complex ways, using it to develop a predictive diagnosis technique for air conditioning and refrigeration systems in collaboration with the Center for Technology Innovation – Production Engineering and Center for Technology Innovation – Mechanical Engineering, both of which belong to Hitachi's Research & Development Group. The algorithm performs machine learning on training data obtained by collecting certain sensor readings at regular intervals during a period when the equipment is operating normally. It then compares the feature vectors for this training data and the data being evaluated. A large distance between two vectors indicates that something is wrong.

3. 2 Development of Technique Using Operational Data

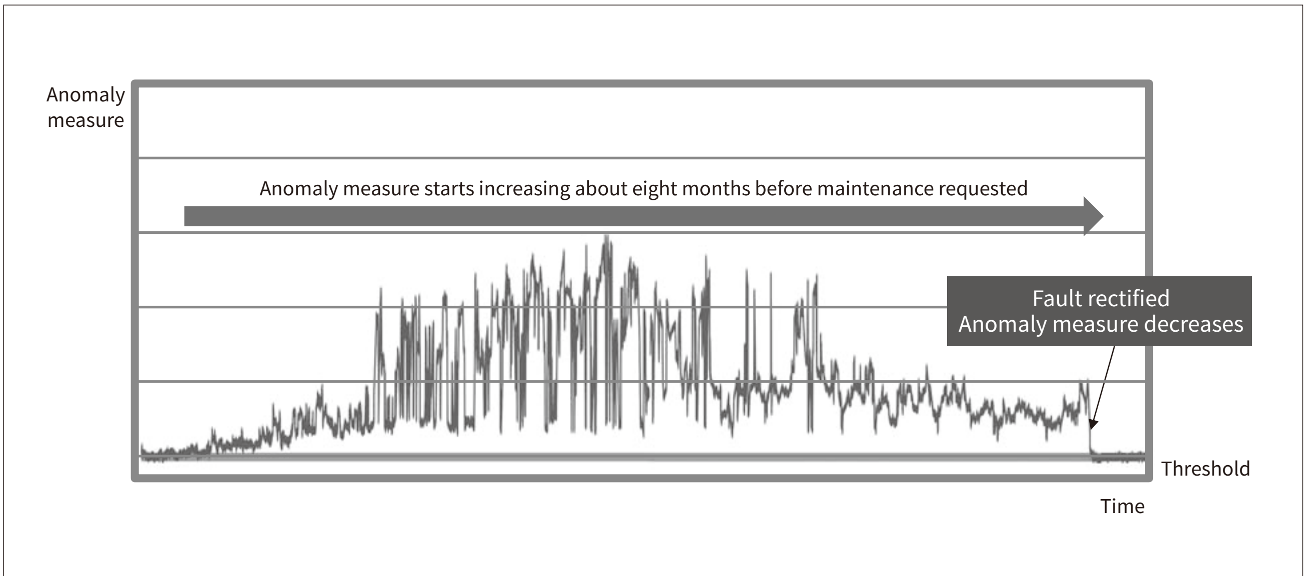
The algorithm was tested using operational data from a fault in an air chiller unit. This included a study of how long to perform training, the best collection interval for the sensor data, and how best to "clean" the data (process it prior to use in the algorithm). It was concluded that, because of seasonal variations, a training period of one year should be used despite the large amount of data involved. **Figure 1** shows the results of this work.

The data used for training covered one year during which no faults occurred, excluding the year prior to the repair request. The algorithm was then used to evaluate the data for the year leading up to the fault. The numbers detected a potential fault, with the anomaly measure gradually increasing from the beginning of the evaluation period and exceeding the threshold automatically calculated at that time. The anomaly measure then decreased in the latter half of the evaluation period when the repair was made, demonstrating the viability of predictive diagnosis. The actual fault was a coolant leak that was too small to be detected by the air chiller unit itself. That the anomaly was evident so far in advance (eight months) indicates that the slow leak of coolant had been going on for a long time.

In addition to this test, the development project also trialed the system on operational data from 309 chillers and freezers and 415 package air conditioners for office or retail premises. This testing demonstrated

Figure 1 — Trial of Predictive Diagnosis Using Chiller Operation Data (for RCUNP500AV Air Conditioner)

After first training on data for a one-year period during which the equipment was believed to be operating normally, the technique was then used to evaluate a year of data covering the time before and after the maintenance call. The comparison against normal operation indicated that the change (increasing anomaly measure) began about eight months earlier, with a return to normal operation (decreased anomaly measure) after maintenance was carried out.



the viability of the diagnostic algorithm and data cleaning techniques by pre-emptively detecting all 11 instances of faults in these systems without false positives (identification of anomalies in systems where no faults occurred).

As predictive diagnosis does not in itself reveal the reasons for the increasing anomaly measure, a function was added to identify automatically which sensors are driving the result. An indication of what sort of maintenance is required can be obtained from this sensor behavior and work can be undertaken accordingly to resolve the issue. It was possible in the example described above to identify which sensors were behaving differently from normal.

However, the sort of problems that this technique can identify are mechanical faults of a sort that take a comparatively long time to repair and that impose high costs on the customer. Technical challenges still remain with regard to faulty electrical components and these are not covered by the technique.

3. 3
exiida Service for Remote Monitoring and Predictive Diagnosis

Figure 2 shows a diagram of the system described here. System installation involves connecting a panel equipped with a remote monitoring adapter to the customer's air conditioning and refrigeration equipment*. Training data is generated by collecting one year of data for normal operation, covering all four seasons. Once training has been performed, the system continues the routine collection of equipment operation data and evaluates it against the training data. The system works by raising an alarm if more than a certain level of variation from the training data is detected so that maintenance can be performed.

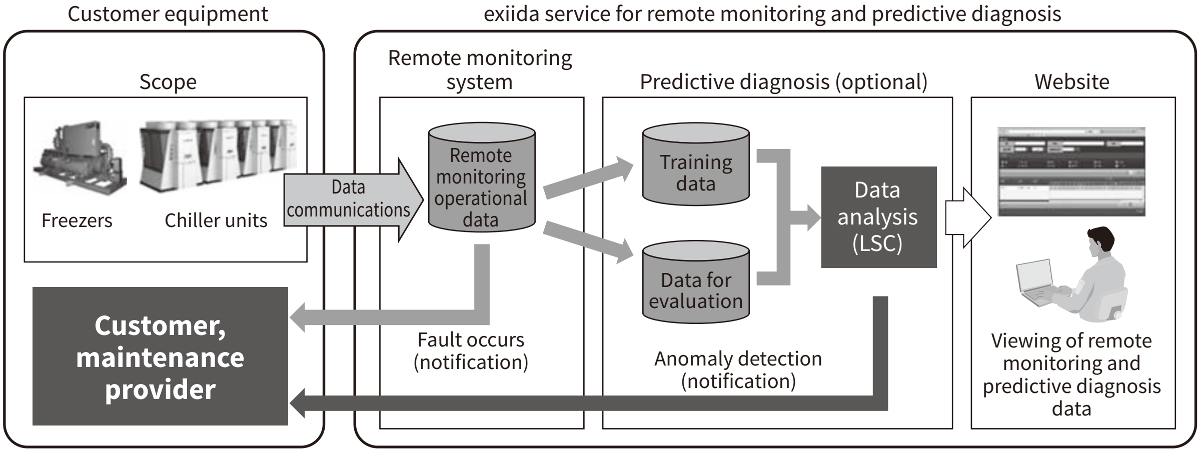
3. 4
Improvement through Predictive Diagnosis

By reducing extended outages caused by faults in air conditioning and refrigeration systems, undertaking maintenance based on predictive diagnosis allows customers to maintain productivity and keep their premises comfortable during hot weather. Moreover, the ability to provide early warning of coolant leaks and to detect reduced equipment efficiency caused by problems such as clogged heat exchangers means that predictive diagnosis can also help protect the global environment, minimizing the release into the atmosphere of freon (which has a high global warming index) and keeping systems running efficiently to avoid unnecessary energy consumption.

* Products manufactured by Hitachi-Johnson Controls Air Conditioning, Inc. that support the H-LINK protocol.

Figure 2 — Diagram of exiida Service for Remote Monitoring and Predictive Diagnosis

A remote monitoring adapter is connected to the air conditioning and refrigeration equipment and data collected in the remote monitoring system via a Long Term Evolution virtual private network. The training data is generated from the required period of collected data and then an LSC is used to compare it against the data for evaluation so that anomalies can be detected and notified.



LSC: local sub-space classifier

Predictive diagnosis both augments inspections by experienced staff (excluding legally required inspections) and provides a way to assess how well work has been performed by re-assessing performance after maintenance has been carried out. As maintenance work prompted by early detection can be done in a planned manner, it can also boost efficiency by shifting workload away from the busy summer period, meaning the service is likely to be a valuable one for equipment maintenance companies concerned about their aging workforce. In the future, Hitachi intends to utilize the exiida service for remote monitoring and predictive diagnosis both to keep customer equipment operating reliably and to help overcome societal challenges.

4. Conclusions

The predictive diagnosis service for chiller and freezer units was launched in April 2018 and extended to package air conditioners for office or retail premises in April 2019. Hitachi had contracts to provide remote monitoring services for approximately 7,000 such systems as of March 2019. By expanding the number of systems covered, the service will also continue helping to overcome the societal challenges of environmental protection and depopulation, with a further expansion to cover multi-room air conditioners for large buildings planned for December 2019.

References

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