How Automated Fault Detection and Diagnostics Can Empower Today’s Building Operators
ENTROPY, DOES IT OFTEN RUIN YOUR DAY?

It’s 8 pm, near closing time, the night before black Friday – one of the most lucrative days of the year. And just like last year, and the year before that, you get a call from one of your store managers. “The HVAC is broken and it’s only been in the low-60’s all afternoon”. Entropy has struck again!

Entropy, defined by the Second Law of Thermodynamics, is about the natural order of things to decay, to become more disorderly.

Unfortunately, we would argue heating ventilation and air conditioning (HVAC) rooftop units (RTUs), the work-horse of small to medium size commercial buildings, are more susceptible to entropy than other building systems because of neglect. They sit on a roof, unsupervised and out of mind until something breaks. To make matters worse, RTUs typically don’t have the highest quality components. Their low cost is the very reason they condition over 69% of the nation’s commercial floor space.¹

As a building operator, the responsibility of dealing with that RTU the night before black Friday falls to you. You call the service provider and they say they can fix it tomorrow around 9 am. That’s too late! Your company needs that store comfortable when the doors open for business. Despite your loathing of it, you are at the mercy of needlessly high HVAC repair. Adding insult to injury, RTUs in disrepair can drastically increase your energy bills. Unfortunately, ignoring your HVAC system isn’t an option because uncomfortable customers and employees is simply not acceptable for a successful business. So does your relationship with your HVAC assets always need to be reactive and stressful?

¹ http://www.eia.gov/consumption/commercial/
Born from a 30-year-old commercial HVAC service firm, we understand your dilemma. Many building operators look to us to address what, at face value, appears to be unpredictable, unavoidable issues. Yet based on our experience working on thousands of rooftop HVAC systems each year, we’ve determined that many of these issues could have been clearly identified before they turned catastrophic and some avoided all together through cost effective, preventative maintenance.

Some building operators have turned to generic Building Automation Systems (BAS) as their front-line solution to becoming more proactive. Unfortunately, these BAS solutions do not provide enough visibility into the inner workings of these metal boxes. They oversee the thermostat calls but not much else. While generic BAS solutions can be successful at maintaining consistent thermostat set points, they provide limited insight into how the rooftop's individual components are operating. This level of detail is critical to identifying issues before or immediately when they happen instead of waiting until the space gets uncomfortable and you begin to get complaints.

If you currently have a BAS solution that alarms you when something is wrong, how detailed is the information? Is it inferring a fault based on thermostat calls? Is it directly monitoring your supply fan and knows when the belt is starting to slip? Is it looking at outdoor air, return air and supply air temperatures to know when one of your cooling stages isn't performing properly? RTUs may be inexpensive but they are still complex machines.

Generic BAS solutions applied to RTUs is like trying to fit a square peg into a round hole. To empower a building operator to better manage their rooftop assets, Automated Fault Detection & Diagnostic (FDD) solutions need to be customized for these machines. They need to monitor individual components and use both real-time and historic data to recognize patterns, deducing maintenance issues without inundating users with false alarms. It's important to combine both passive and active fault evaluation, where passive means it is always working behind the scenes and active gives you a virtual run-down of current system performance.

We, along with several other companies, saw an opportunity to meet these challenges. Fortunately, the timing was right with the proliferation and reduced cost of smart, connected devices and sensors. While each company has different approaches, all built a BAS from the ground up that focused on two improvements for rooftop HVAC units. First, advanced control to run equipment more efficiently such as multi-speed fan control instead of energy-guzzling constant speed. Second, Automated FDD that directly measures individual components (e.g., fans, compressors, outdoor air damper, etc.) rather than inferring issues based on the limited information solely from a thermostat.
WHAT IS AUTOMATED FAULT DETECTION & DIAGNOSTICS?

Before we dive into how it can empower you from being at the mercy of your HVAC equipment, we want to give you some background on what Automated FDD is all about. Breaking the term apart, let’s start with ‘fault detection’ – identifying that something is wrong. It could be anything from a loose fan belt to something less obvious like low refrigerant charge. So the first part of Automated FDD is using embedded sensors (e.g., temperature, power, refrigerant pressures, etc.) to monitor the components of your RTU in real-time and process the data to provide automated notification of potential faults.

The second part is ‘diagnostics’. Just like when you get sick and go to the doctor, your physician investigates your ailments and determines the cause. The same logic applies for HVAC equipment, or any building system for that matter. More difficult than fault detection, diagnostics requires domain expertise and automated logic to process the sensor data and narrow down to a single or short list of causes. In some cases, these diagnostics means automatically controlling your RTU outside its standard operation to help troubleshoot the issue. This could mean opening the outdoor air damper for 5 minutes during unoccupied hours to check whether it is actually opening or if it is stuck.

The third part of Automated FDD is ‘automating’ the fix. In many ways, it is mirroring the same troubleshooting thought process a service technician currently uses when they are on your roof. By automating this process in the background, you will have the benefit of real-time oversight, 24/7.

While Automated FDD will never be able to completely replicate an experienced technician’s eyes, ears and intuition, its capabilities today can detect and diagnose most faults down to their cause and even make adjustments to the system or adjacent systems to work around the deficiency until a repair can be made.

Automated FDD doesn’t look to replace your technician. It looks to enhance your current operation, shifting you from reactive to proactive. Leveraging Automated FDD enables you to become aware of issues right as they happen. There is even a predictive maintenance element as it is now possible to know when your fan belt is loose before it fails completely. Automated FDD can empower your service provider with access to these powerful remote tools. Used properly, it will enable them to show up at your site with the right equipment and replacement parts in hand. It also reduces a technician’s troubleshooting time, giving them more time to address other issues.

Minimizing truck rolls by deferring maintenance for issues that can be solved later is another advantage. Have a compressor that needs replacing? Use these tools to lock that compressor out and leverage your other compressors to handle your building’s comfort needs until your next scheduled maintenance. These examples highlight how you can integrate Automated FDD into your day-to-day operation to reduce your operational expenses and improve your HVAC system’s energy efficiency.

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FEATURES YOUR AUTOMATED FDD SOLUTION SHOULD HAVE

For many of you, Automated FDD is not new. You’ve heard colleagues talk about it, and likely even complain about it. Just like any industry, some solutions are pragmatic, user-friendly, and have been proven to improve operational performance and energy efficiency. And there are solutions that are cumbersome to use, not intuitive, and inundate you with senseless nuisance alarms. This next section outlines the features of an Automated FDD solution that achieves what we call ‘intelligent accountability’.

Accountability is the key word here. At the end of the day, someone has to physically fix a maintenance issue. But that comes at the end of a multi-step process. There are many decisions and actions that need to happen prior. Adding to the complexity are the involvement of different types of people who process information differently. So by ‘intelligent accountability’, we are defining an Automated FDD framework that starts with intelligently detecting and diagnosing an issue. Not stopping there, it then provides accountable oversight through the entire ‘fix it’ process. You, the building operator, are empowered to ensure each responsible party does their part from detection and diagnosis, to the service visit and final confirmation that the issue was indeed fixed.

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1. MAKING SMART SIMPLE

First and foremost, the user interface needs to be clear and concise. When BAS dashboards started coming out for Automated FDD systems, they were often too complex and driven solely by tabular data. You could say they were for engineers, by engineers. The feedback on user interaction by building operators and service technicians was that the systems were too burdensome. Iterations of dashboards have continued to strive for simplicity, as shown by the tabular view of multiple RTUs at a site in Figure 1. Despite using intuitive icons like green lights for confirming everything is okay or warning symbols indicating a potential issue, the feedback from users was still ‘information overload’!

So we listened and revamped to what’s shown in Figure 2. These orbs only display the salient points. Here it is clear that Unit01 has a damper failure. You have the option to dive down deeper to see details such as possible causes (e.g., broken actuator, stuck damper, etc.) and when the fault occurred. Yet for most busy building operators, this is all the information you need. You may decide to pay a service technician to get on site and address it immediately. More likely, since you want to reduce your operational expenses, you decide to wait until the next scheduled maintenance because this issue will not lead to a catastrophic failure and wont impact thermal comfort much - unless the damper is stuck at 100% open. Here you can see how Automated FDD, configured as simple smarts, can clearly notify you of what is happening to your HVAC assets so you can address issues in a less stressful, proactive way.
2. GET YOUR INFO QUICKLY

As we stated previously, there are different types of people involved from initial fault detection to final verification that “yes”, the problem was indeed fixed. The user interface of an Automated FDD platform must let each stakeholder get to the information they need to make a decision quickly. The level of detail for each user varies. Building operators want high-level information to make fast determinations. ‘I want a service technician to investigate’ or ‘I want someone from technical support to diagnose further before rolling a truck’. Before they head over to a site, service technicians want more detailed information to ensure they bring the correct equipment and replacement parts.

The graphic below provides an example of quickly accessing information by minimizing the number of mouse clicks for the different types of users. Building operators who oversee a portfolio of buildings are the most overwhelmed in our industry. The first graphic shows them a list of stores with existing issues. When we think of faults, we typically focus on something is broken and needs fixing. Yet, a fault could be a comfort issue – perhaps an employee left a side door open and the RTUs are not able to keep up. Energy faults are becoming an increasing concern as companies look to reduce utility bills and meet energy goals. Here, portfolio managers can quickly garner where their attention is needed. With one mouse click, managers are brought to the building level, looking at each unit’s orbs. Here they glean that Unit01 has a damper failure. At this point, most building operators often don’t have the time to dial down further. They quickly send an email with a screen shot to their service provider.

The service technician can then dive deeper such as looking at the unit view and historical data. For some faults, they'll want to remotely control the unit. As an example, in the case of a cooling fault, they'll want to remotely turn each compressor on to see which cooling stage is causing problems.

For more comprehensive Automated FDD solutions on the market, some building operators will have access to a technical support team. This typically comes with the software’s annual licensing fee. A quick click within the dashboard sends a note from the facility manager to the technical support team for further diagnosis. Using the Automated FDD provider’s technical support can often be more effective than passing faults through to a service provider for further inspection. The technical support team is comprised of the most skilled users of their own system. And they are incentivized to prevent truck rolls while, depending on your service contract, some service providers are incentivized to roll a truck to troubleshoot on site rather than remotely.

With all of these different stakeholders, user credential management is important in an FDD solution. Limiting access to certain sites for individuals can prevent confusion and narrow their focus. Administrative versus read-only access ensures that only those with proper permission are able to adjust system settings. And finally, the ability to track changes in the system provides accountability for any and all modifications made, from steps taken to troubleshoot a fault to leaving notes on the results of the investigation.

Figure 3. Different Levels of Visibility Provide Information for Various End-Users
3. PERSONALIZED NOTIFICATIONS, NOT ALARM FATIGUE

Automated FDD solutions need to acknowledge how only focusing on automated alarms can quickly cause fatigue and eventually apathy in building operators. Psychological studies have measured increased heart rates from stress – feelings of angst – when people look at work email. Unfortunately, many providers of Automated FDD use automated alarm emails as the main form of resolution.

We mention in the previous section how a more comprehensive offering of an Automated FDD solution paired with technical support can be a powerful package. However, this technical support shouldn't just be sitting around, waiting for your email after you receive an automated fault notification. A strong technical support team should be proactively combing through the new and outstanding faults on your systems.

While we are a big proponent of using automation to identify and diagnose faults, nothing beats a well-crafted, actionable notification from the technical support team. These personalized communications should include the fault and its diagnosis. They should also cover other potential faults on site. Therefore, you are able to quickly understand when a fault is of probable concern and action needs to be taken. Wouldn't you prefer a single notification identifying and diagnosing all the current faults at a site instead of a separate email for every bell and whistle that goes off?
4. MINIMIZE FALSE ALARMS WITH MORE SENSORS

A quick way to lose confidence in an Automated FDD solution, for both building operators and technicians, is false alarms. Remember, fault detection is based on processing sensor data according to some pre-programmed logic. Sometimes those algorithms mistake a deviation in expected system operation as a fault. Or sometimes the fault says it’s one thing – a cooling fault – and it turns out to be another – damper is stuck at 100% open. False alarms initially cause fatigue to you and your service providers. And fatigue quickly translates to apathy.

Many Automated FDD solution providers have found that increasing the number of embedded sensors can reduce these nuisance alarms. When you are investigating a solution, make sure the solution provider gives you full transparency of the sensors they use and their algorithms. At the very least, make sure they monitor outdoor, return, and supply air temperatures as well as power, because a lot can be confidently garnered from these data points.

While some providers look to keep it simple and minimize the number of sensors on each RTU, the chances of false alarms increase tremendously. The simple reason is that they are trying to infer individual component issues (e.g., fan belt slippage, stuck outdoor damper, etc.) from minimal measurement points such as whole unit power. The more they infer, the greater the likelihood their algorithms misinterpret the data.

Our experience has been that multiple data points per unit (e.g., temperatures, power, relative humidities, operational commands, etc.), are crucial to confidently identify common faults within these machines. We need to keep in mind that packaged RTUs, albeit inexpensive, have the same components as much larger, higher quality built-up systems. These are still complex machines and failures can happen in many ways, each from various causes.

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When you implement an Automated FDD solution, make sure that it enhances the best practices of your service provider. Adding a controller and changing some of the low-voltage control wiring on an RTU can confuse and frustrate service technicians. First, they need to better understand what the new equipment does. Then, they need to know how to interface with the unit as they normally would. For instance, technicians usually like to override the unit’s operation into cooling mode or heating mode while troubleshooting.

If the Automated FDD solution makes their job more difficult, there is a good chance they will bypass the new equipment. You are then left with paying for a solution that has been disconnected. We see this often when an Automated FDD technology did not account for the role of service technicians.

One way to make a service technician’s job easier is the device in Figure 4, called a Service Switch. Connected directly to the controller on each unit, it empowers a technician to override the automated control and command the unit into different operational modes. In this way, they can quickly interface with the RTU without having to reconfigure any of the low voltage wiring. And the full functionality of the Service Switch also exists on a web-based dashboard as seen in Figure 5. The technician can override the unit virtually. The ability to remotely override a unit’s operation and watch how it performs over the web can minimize truck rolls. Keep in mind, just like you don’t want to be bothered with issues at odd hours, holidays or weekends, neither do technicians. Give them a feature that can make their day-to-day easier and they will incorporate it into their best practices.

A less complex but equally powerful feature for service technicians is enabling users to document service notes or questions within the Automated FDD dashboard. This is also very useful for building operators. Once the note has been logged, it is tied to the equipment, not some independent service report or email trail that gets lost over time. If the service provider changes or there is a shift in personnel at a company, these notes or questions logged on the dashboard are still there and provide insight for future maintenance issues.
Automated FDD solutions should provide full transparency on the algorithms used to process the sensor data when identifying and diagnosing faults. As a building operator, you should have the ability to know how the fault algorithms work. Greater openness improves your ability to digest fault notifications and then act upon them.

Unfortunately, there are Automated FDD solutions that use a black box approach in which you don’t have access to their algorithms. Your company is paying for these solutions; therefore, you should have full knowledge of how they slice and dice the data. You should be able to provide input on how these algorithms are configured and be able to change the limit on a fault such that you can customize these solutions to your specific building and RTU assets.

Another argument for transparency is that Automated FDD is rapidly becoming complex in this quickly progressing industry. For instance, look at the outdoor air damper dashboard view (Figure 6) which is used to comply with the new economizer requirements for California’s Title 24. The green or red dots in the lower right are really the main indicator a building operator would focus on. Yet when a building operator sees a red dot for the first time signalling that the damper is not economizing when it should, you may want to know how this determination was made.

Finally, this information should be available on their web-based platform, not just their owner’s manual which can get lost. Online access makes it available 24/7 for you, others within your organization, and your service providers. It is also helpful to have a troubleshooting page covering the algorithm behind the fault, best practices for diagnosing the root cause and helpful tips on how to fix it, as seen in Figure 7.
1. COMMUNICATE CLEARLY WITH YOUR SERVICE PROVIDER

Your Automated FDD solution can improve your communication with your service provider and the outcome of identified faults. Better connectivity to your Automated FDD solution helps in two ways.

First, you are able to convey much more detailed information regarding the fault detected and potential diagnoses. For example, instead of telling your service provider that the space is getting warm, you can tell them that unit05 has a cooling fault because its supply air has been above 65°F despite a 40-minute call for second stage cooling. Within the web-based dashboard, you should be able to relay a message including a screenshot of the issue to your service provider.

Ideally, your service provider has some level of access to the Automated FDD platform. They can then log in and view the operation in real-time. Mimicking what they would do if they were physically at the site, they have the ability to remotely override the unit into different operational modes and watch the data histories to have a better understanding of the issue. They can send you screen shots of what they are seeing for your final decision on whether to have a truck roll or not. Automated FDD improves your and your service provider’s level of knowledge regarding a fault and lets you have a more constructive conversation on the best way to address it.

The second benefit is reducing your operational expenses with less truck rolls. By having a greater understanding of the fault, you may decide that the fault is of low priority and can wait until the next scheduled maintenance. Remember, your busy times typically coincide with when your service provider is busy – such as cold snaps or heat waves. They must prioritize sites where high priority issues need addressing, and hefty fees may apply during peak periods of demand.
2. BE PROACTIVE NOT REACTIVE

You should think of Automated FDD as a stress reliever. Your platform shouldn’t do the opposite by overwhelming you with alarms, especially false ones. With the right solution in place, you should expect notifications of issues as they happen. Instead of waiting until a space is extremely hot, you can work with your service provider to diagnose the issue before a technician heads to the site. Once you have a better understanding regarding the cause of the fault, you can be proactive and determine if it is worth paying for a service visit. Perhaps not and you let your provider know to take care of the issue on the next schedule maintenance. Along these lines, the Automated FDD platform should send FDD reports to you and your service provider according to scheduled maintenance visits. This way all the outstanding issues are addressed while the technician is already there on site. It is all about taking action before you get any comfort complaints.

3. ENSURE YOUR REPAIRS ARE DONE CORRECTLY

Real-time oversight of your equipment enables your service provider to have better feedback on whether they were able to address a fault. It can take a while for some problems to be properly identified and then corrected. After fixing something on site, the technician can keep an eye on the unit’s performance in the following days to ensure that they eliminated the fault. It is a great tool to ensure equipment is properly fixed.

4. QUANTIFIABLE IMPACTS TO YOUR ENERGY BUDGETS

So far, we have mainly focused on how Automated FDD impacts your operational performance, empowering you to have greater oversight of maintenance issues. Yet it can have positive impacts to your energy budgets as well. This is actually one of the largest growth areas in the FDD industry. Automated FDD solutions are starting to incorporate fault notifications when RTUs begin using uncharacteristically high amounts of energy, indicating something is wrong. For instance, your outdoor air dampers may be stuck such that they cannot economize properly and you are using more compressor-based cooling. With energy related faults, you are shown how much additional energy you are using because of improper operation; therefore, you can directly translate that to increased energy budgets. Knowing how much a fault is impacting your bottom line gives you the information you need to make a decision on whether to address it immediately or defer until the next maintenance visit.
CONCLUSION

If you are a building operator who often feels overwhelmed by the entropy of your rooftop HVAC systems, you should look into how an Automated FDD solution would impact your day-to-day reality. Several companies are providing Automated FDD solutions that specifically focus on RTUs. Compared to generic BASs that only monitor thermostat calls, these solutions dig well below the surface. They monitor individual components such as fans, compressors and outdoor air dampers. They apply intuitive fault logic to the real-time and historic data to recognize patterns and notify you of potential issues before they happen or immediately when they do happen.

In this eBook, we've summarized 6 features that are critical to an effective Automated FDD solution. We then covered best practices on how you can implement one of these solutions within your organization. Automated FDD can shift your day-to-day reality from the stress of constantly having to react to HVAC issues toward being proactive, improving your working relationship with your service providers. No longer will you need to wait until your building gets uncomfortable before you know there is an issue. And you can reduce your operating expenses by minimizing emergency calls to a technician. By knowing exactly what is broken before a technician comes out, you can decide to defer addressing the issue until the next scheduled maintenance. Finally, by ensuring your HVAC is operating properly, you'll also see a reduction in your energy bills. With the right Automated FDD solution, your lower operating expenses and energy bills help you improve your company's bottom line while reducing the stress of managing your HVAC systems.

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ABOUT TRANSFORMATIVE WAVE

Transformative Wave is a leading energy efficiency innovator in HVAC retrofit and building automation solutions, developing and bringing to market a growing line of game-changing technologies that are transforming the commercial building energy landscape.

Validated by the Department of Energy (DOE) to save an average of 57% in energy savings, Transformative Wave's CATALYST is a complete HVAC energy efficiency upgrade and retrofit kit that converts RTUs into smart machines. More than just a variable frequency drive, the CATALYST delivers advanced economization and demand controlled ventilation capabilities, while also enabling RTUs to become Smart Grid and Demand Response enabled assets.

The CATALYST provides live interaction via the eIQ Platform, a completely wireless solution that allows real-time monitoring and building automation control over the Internet using computers, laptops or smart phones, along with advanced fault detection and diagnostics, troubleshooting capabilities, remote notifications, and performance reporting.

For more information on our revolutionary products, including the CATALYST and eIQ Platform, visit www.transformativewave.com.