HVAC Fault Detection

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A significant amount of energy is wasted by malfunctioning or ill-maintained building systems.

Faults relating to HVAC systems represent between 1% and 2.5% of total commercial building consumption. Owners/operators are often unaware when units are malfunctioning and wasting energy.

The average commercial AC unit has an evaporator airflow 15% to 25% less than optimum commissioned values,[1] 34% of residential air conditioners are undercharged and 28% are overcharged,* 35% of commercial rooftop units' dampers fail within several years of installation,[1] and 50% to 67% of air conditioners (residential and commercial) are either improperly charged or have airflow issues.[2,3]

Despite the performance seen when a system is first commissioned, efficiency over time decreases. Though scheduled maintenance is purported to maintain a system at its peak performance level, the typical maintenance person cannot do the in-depth tests required to deliver this performance without lengthy service calls. Such calls are often prohibitively expensive.

Automated fault detection and diagnostics (FDD) systems attempt to address these issues by identifying faults when they occur and, if they are of sufficient severity, communicating the fault to the owner or maintenance personnel. This can eliminate scheduled maintenance costs, reduce diagnostic labor, reduce wasted energy, reduce peak electricity demand, and minimize downtime.

Residential and commercial HVAC systems are excellent systems for application of FDD. Units that tend to be under-maintained (such as many small-and medium-sized commercial/industrial building's rooftop or other packaged air conditioners) have the potential for the shortest payback periods.

Technology

Generally FDD works by measuring a subset of temperatures, pressures, and humidity levels in several stages of the HVAC system. Automated comparison of what these values should be for a given system with what they actually are can provide strong indicators of fault conditions.

Targeted faults include:

- Low refrigerant charge;
- Refrigerant overcharge;
- Noncondensable gas in the refrigerant;
- Liquid-line restriction;
- Compressor valve leaks; and
- Condenser and evaporator fouling.

Several types of HVAC FDD devices exist.

First, embedded FDD in each device's controller can be convenient and accurate, with the algorithms specifically tailored to the model by the manufacturer. This requires additional sensor and communications hardware beyond what is traditionally fielded, and therefore, adds to the system's upfront cost. Embedded FDD offers continuous, dedicated monitoring allowing it to record and report faults as they occur, allowing repairs to be performed in a timely manner.

The National Institute of Standards and Technology (NIST) has developed a set of algorithms for detecting faults in air-handling units (AHUs) and variable-air-volume (VAV) boxes that has been integrated into some control units.[4] These higher-end units give alarms for a number of conditions such as fouled coils, incorrect damper positions, and leaking valves.

Next, software as a service (SaaS) FDD systems offer continuous monitoring and feedback on system faults by sending sensor information to a data server that continuously monitors connected systems and reports faults. The FDD algorithms on the server can be continuously updated independent of the data coming from the sensors.
In addition, the server's increased computational power provides the potential for more complex and accurate diagnostic capabilities. Generally, SaaS FDD systems require a monthly fee, but can provide more personalized service.

Finally, handheld or in-field FDD units can be carried by maintenance personnel to their sites and set up on individual systems. By running the system through several testing conditions and inputting system parameters/characteristics, a fault/performance profile can be determined.

An FDD system of this kind minimizes the upfront capital cost to the owner and can be used on a variety of systems. It is prone to operator error, either through incorrect sensor placement or through incorrect manual input of the system parameters. Also, since it must work on many system types, its accuracy on any one model is not maximized.

This type of system is only beneficial when a service or maintenance call is scheduled and the maintenance personnel are physically at the unit, where as other FDD systems can monitor continuously with no one onsite.

For this reason, we focus only on the two types of FDD that provide continuous monitoring.

Energy Savings Potential

Roughly half of all packaged commercial HVAC systems have significant faults, and 60% of cooling energy for commercial buildings is consumed by these units. A fault can degrade the system's efficiency by roughly 20%, causing the unit to run longer to meet space cooling load demands. Rough estimates make the overall energy savings between 0.1 to 0.2 quads with significant implications for reducing peak electricity use.[1]

Market Factors

Though FDD does result in reduced electricity use, these savings are small compared to typical monthly operating costs of a business on a commercial site. FDD provides several other significant monetary benefits that also amortize over the life of the system. These benefits, beyond reduced electricity use, include elimination of preventative maintenance services, increased system lifetime, and reduced repair labor and parts.
FDD systems are designed to catch many of the faults that preventative maintenance addresses. Typical preventative maintenance visits cannot find many of the faults an FDD system can, so preventative maintenance can be discontinued, saving $2,000 to $3,000 over the lifetime of a moderately sized unit.[5]
If the owner/operator has repairs performed when they are alerted to faults, runtime is reduced relative to the runtime of a unit not running at peak efficiency, thereby achieving similar comfort levels and extending the lifetime of the unit. This can be quantified as some percentage of the unit cost, roughly $500 to $1,000 for a typical installation.

Reduced maintenance and repair labor is another key benefit. Generally, labor costs are high, while replacement component costs are low. If the FDD system can diagnose the problem, repair personnel can more quickly and efficiently address these faults. Emergency service calls should also be minimized by catching evolving faults before they become severe, allowing the owner to schedule service calls at typical nonemergency rates.

At an estimated additional cost of $80 to $500 per integrated unit, the savings figures are promising for market adoption, and policy-making bodies have taken notice.

The California Energy Commission's Title 24 now provides credits for the use of FDD in packaged rooftop units. Other regulations will likely include FDD as well as it becomes more widely studied and recognized.

Many owners purchase their HVAC systems based on performance ratings achievable when the systems are first installed and commissioned, not for the long-term efficiency in the presence of fault conditions. This has resulted in manufacturers targeting best-case performance numbers while keeping costs down relating to other systems, such as FDD.

Some high-end units have basic, yet important, FDD capabilities, but these have not been sold in significant enough numbers for large-scale impact, continuing to make underperforming HVAC units a common occurrence and a major source of wasted energy.

The FDD subcommittee of ASHRAE TC 7.5 and NIST have been working toward integration standards, protocols to verify system benefits, system ratings, and labeling conventions.

Education of the consumer about the long-term benefits of FDD systems will be important for their long-term success.

References

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