Building Automation Systems

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Abstract

Building automation systems (BAS) provide facility managers with the ability to monitor, track, and respond to the performance of facility assets. Round the clock monitoring ensures that all systems function optimally. Appropriately managed building automation systems increase facility assets reliability and reduce maintenance costs. Large organizations can achieve economies of scale by centralizing facility asset monitoring.

Introduction

The ability to detect impending faults and to minimize energy usage associated with facility assets will increase reliability and reduce cost. Therefore, building owners and managers should consider global networking technologies to optimally manage their buildings and building equipment. Finch (1998) argued that global networking technology requires a new mindset for facility managers. It also requires a new mindset for facility owners. He also noted that building solutions should tie manufacturers and suppliers into the total life-cycle performance of the building. In essence, monitoring and monitoring responses may be outsourced to those with specific expertise: manufacturers, suppliers or service providers. Environmental concerns, safety issues, and cost reduction are other reasons for viewing facility maintenance with a new mindset: as a strategic organizational component (Tsang, 1995).

Organizational view of facility assets

In reviewing a 1994 survey conducted by Arthur Andersen Consulting to assess how 160 European businesses view their property assets, Loe (1996) noted that many European businesses were under-exploiting the financial and strategic benefits of effective property management. For instance, over half of the respondents viewed property merely as a cost of doing business; and, under half had no formal strategic property plan, as well as no significant performance measurements- facility maintenance goals. However, clearly defined actionable facility maintenance goals that cascade from the organizational mission and vision to individuals are necessary to determine performance (Cable & Davis, 2004).

The European view of property assets is not unique, many U.S. businesses and government agencies behave in a similar fashion. However, without monitoring and fine-tuning facility assets, modern buildings tend to degrade; the settings of the buildings will diverge from the changing requirements of occupants (Finch, 1998). According to Finch, facility managers are unlikely to have all the expertise necessary to monitor the many different types of assets within a facility. Thus, lack of facilities managers’ expertise is a strong justification for integrating and centrally monitoring embedded systems so they do not operate as inefficient islands. For instance, in many buildings lighting systems operate independently from the security systems.

Intelligent buildings (IB)

Intelligent buildings are facilities in which building automation systems

(BAS) facilitate a productive and cost effective environment by optimizing structure, systems, services, and management and the interrelations between them (So, Chan, & Tse, 1997). So et al. noted that two of the most intensely used building services are lighting and heating, ventilation, and air conditioning (HVAC). Thus, BAS can be programmed to minimize HVAC and lighting energy usage, and to detect other parameters of interest.

An article in Air Conditioning Heating and Refrigeration News, June 27, 2005, reported that Thomas Jefferson University in Philadelphia saved $600,000 in energy as a result of BAS equipment scheduling. Equipment scheduling is the ability to turn equipment on and off. Improving equipment scheduling is one of the most common and effective measures for saving energy in commercial buildings. BAS can also perform an array of other functions, such as data logging, trend logging, energy assessment, etc. (So et al). Moreover, users can issue commands to manipulate certain building systems to affect temperature set points, chilled water flow rates, illumination levels, etc.

Wal Mart Stores, Inc. has used an energy management system (EMS) since 1988 to monitor and control all HVAC, lighting, and refrigeration systems at each Wal Mart or SAM's locations. (Wal Mart Good Works). Moreover, each location is controlled centrally by their 24 hours a day, 7 days a week facility monitoring team. Accordingly, round the clock monitoring ensures that all systems function optimally, thereby maximizing energy efficiency at each store.

NSTAR (2004), the largest Massachusetts electric and gas utility, indicated that energy management systems saved an average of 10 percent in overall building energy consumption. Curtis (2003), Aprilaire manager, (Aprilaire supplies automation systems) believes that energy savings could be as high as 33% based on occupancy.

The benefit of tracking asset performance

Wood (1999) argued that preventive maintenance (PM) often failed to maximize the service life of each component; in many instances the components were being replaced with many hours of useful life remaining. PM tasks, based on hard time intervals, waste a lot of resources (Tsang, 1995); that is, often the plant or building is over-maintained (Mann, Saxena, & Knapp, 1995).

According to Bloch and Geitner (1983), certain signs, conditions, or indications precede 99% of all machine failures. Therefore, by monitoring an asset, action can be taken prior to it having a serious effect on the performance of the organization. Thus, condition-based monitoring offers an alternative to the PM assumption of age-related failure mode. Moreover, with condition-based monitoring, managers can focus on just-in-time (JIT) replacement. According to Wood, JIT replacement maximizes the life of each component and is facilitated by BAS or intelligent buildings.

Condition-based monitoring involves intermittent or continuous collection and interpretation of data from components of critical equipment, determining when a failure mode has been initiated, predicting the time to complete failure, and making decisions on the appropriate maintenance response (Mann et al., 1995).

Wilmeth and Usrey (2000) noted that United Airlines studied documented failure histories in the airline industry and determined that only 11% of all nonstructural components experienced an aging characteristic, while 89% failed for reason other than fatigue. Based on this study, PM replacements were reduced from 58% in 1964 to 9% in 1987, while conditioned-based monitoring increased from 2% in 1964 to 51% in 1987. These changes reduced maintenance cost. Likewise, the Electric Power Research Industry (EPRI) conducted a similar study for utility equipment and, like airline equipment, found that, more often than not, utility equipment failures were not age-related.

Moubray (2001) indicated that these finding contradict the belief that there is a connection between reliability and operating age, which has led to the common belief that frequent asset overhauls reduce the likelihood of failures. However, he argued that overhauls are extraordinarily invasive undertakings that massively upset stable systems. Therefore, overhauls are risky and are likely to introduce infant mortality and cause the very failure that they seek to prevent (Moubray, 2001; Tsang, 1995).

A study on fossil power plants revealed that 56% of forced outages occurred within one week after invasive maintenance had been performed (Tsang, 1995). Therefore, Moubray (2001) noted that the main reason for conditioned-based maintenance is to reduce or eliminate the consequences of failure.

Monitoring systems

BAS control energy usage and monitor the performance of building assets, they are also known as EMS. Finch (2001) noted that BAS have been narrowly defined to EMS, security and environmental control. However, Buswell, Haves, and Wright (2003) believe that these systems should detect more than abrupt changes HVAC equipment. BAS should offer fault isolation, diagnostic information, and detect degradation in system performance. According to Merritt (2004), currently available wireless sensor networks allow fault detection and diagnosis (FDD).

Wireless sensor networks

Wireless sensor networks are ideal, because they eliminate wiring and are self organizing. These networks contain tiny processors called dust, motes, or sensor nodes. The wireless sensors send information to central wireless processors that convert data from up to 12 sensors and transmit it to a personal computer (PC) that runs asset management software (Merritt, 2004). A mote is a tiny battery operated wireless processor made by Intel, a dust is smaller and solar-powered versions have been used to monitor temperature, humidity, and other parameters.

Building automation systems, which consist of sensors, controllers, actuators, and software, can monitor and track the status of multiple building assets. Furthermore, direct digital controls (DDC) allow for building control and information flows to be centralized at a single location. As a result, operators can view and control all building systems from a single computer terminal. Additionally, most BAS offer remote Internet monitoring and control, which means that virtual monitoring is possible. DDC systems offer two major communication choices: proprietary and open communications. Open communication allows communication between equipment from different manufacturers

Large organizations can achieve economies of scale by monitoring, tracking, and responding to the status of multiple building assets from centralized or regional locations. Organizations can strategically locate in-house, or contract, response teams to address anticipated multi-site challenges that result from fault detection and diagnosis. Regional response teams will improve the organization's ability to respond to facility challenges, reduce resource allocation, and hence minimize facility maintenance cost.

Using RCM to determine critical functions

Organizations can use reliability-centered maintenance (RCM) as a tool to sort out critical components of facility equipment that may affect the reliability of facility assets (Wilmeth & Usrey, 2000). RCM is a structured methodology for determining the maintenance requirement of physical assets (Tsang, 1995). Tsang noted that the primary objective of RCM is to preserve the functions of an asset. Therefore, once the dominant and critical failure modes of an asset are identified through RCM or a mini-RCM, sensors (hard-wired or wireless motes or dust) could be used to track abnormalities, such as unwanted vibration associated with rotating equipment. Vibration is a significant parameter for reflecting the condition of rotating assets (Rao, Zubair, & Rao, 2003). For instance, high vibration and temperature on fans can be correlated to bearing, shaft, or wheel abnormalities. RCM recognizes that overhauls or preventive replacement cannot prevent random failures.

False alarms

A key requirement for successful implementation of BAS is low incidence of false alarms and quick and reliable detection of faults (Buswell & Wright, 2004). Buswell and Wright noted that an International Energy Agency (IEA) project indicated that abrupt faults could be easily detected; degradation faults, on the other hand, had to be quite large before detection was unambiguous. The study also noted that it is possible to balance robustness and sensitivity. Increasing sensitivity results in early warning of faults, but may increase the incident of false alarms (Knapp, Javadpour, & Wang, 2000). However, condition-based monitoring industry leaders have applied quality control type techniques in the detection of machine faults; thus, providing increased protection from false alarms, as well as from missed faults (Mann et al., 1995).

The future

Tiny processors called dust, motes, or sensor nodes are the main components of wireless sensor networks. Merritt (2004) predicted that in the near future all rotating equipment would be equipped with these sensors. He further noted that in spite of the need for better hardware-to-software integration, organizations could presently equip their critical rotating equipment with these sensors.

Conclusion

The need for equipment reliability and cost minimization should lead organizations to incorporate BAS as a central component of their maintenance strategy.

References

Block, H. P. & Geitner, F. K. (1983). *Machinery failure analysis and troubleshooting*. Houston: TX. Gulf Publication, Co.

Buswell, R. A., Haves, P., & Wright, J. A. (2003). Model-based conditioning monitoring of a HVAC cooling coil sub-system in a real building. *Building Services Engineering Res. Technol*, 24 (2), 103-116.

Buswell, R. A., & Wright, J. A. (2004). Uncertainty in model-based conditioning monitoring. *Building Services Engineering Res. Technol*, 25 (1), 65-75.

Cable, J. H. & Davis, J. S. (2004). Key performance indicators for federal facilities portfolios. *Federal Facilities Council Technical Report #147*. Washington, DC: National Academy Press.

Curtis, G. (2003). Building automation made simple. *Heating/Piping/Air Conditioning Engineering,* p. 70.

Finch, E. (1998). Remote building control using the Internet. *Facilities,* 19 (12/13), 356-360.

Finch, E. (2001). Is IP everywhere the way ahead for building automation? *Facilities,* 19 (11/12), 396-403.

Knapp, G. M., Javadpour, J., & Wang, H. (2000). An ARTMAP neural network machine condition monitoring system. *Journal of Quality in Maintenance Engineering*, 6(2), 86-105.

Loe, E. (1996). Providing the benefits - justifying the cost of intelligent systems. *Facilities*, 14, 17-25.

Mann, L., Saxena, A., & Knapp, G. M. (1995). Statistical-based or condition-based preventive maintenance? *Journal of Quality in Maintenance Engineering*, 1 (1), 46-59.

Merritt, R. (2004). Mighty motes. Retrieved September 27, 2005 from http://www.plantservices.com/articles/2004/108.html.

Moubray, J. (2001). Maintenance Management – A new paradigm. *CIM Bulletin*, Issue 1055, 78-86.

NSTAR (2004). HVAC: Energy management systems. Retrieved September 27, 2005, from http://www.nstaronline.com/your_business/energy_advisor/PA_36.html.

Rao, J. S., Zubair, M., & Rao, C. (2003). Condition monitoring of power plant through the Internet. *Integrating Manufacturing Systems*, 14(6), 508-517.

So, Albert T. P., Chan, W. L., & Tse, W. L. (1997) Building automation system on the Internet. *Facilities*, 15, 125-133.

Tsang, A. C. (1995). Condition based maintenance: Tools and decision making. *Journal of Quality in Maintenance Engineering, 1(3)*, 1-17.

Wal Mart Good Works Our pledge to our planet: Recycle. Conserve. Beautify. Retrieved September 27, 2005, from http://www.walmartfoundation.org/wmstore/goodworks/scripts/Environment.jsp?oid=-10264&coid=-10307.

Wilmeth, R. G., & Usrey, M. W. (2000). Reliability-centered maintenance: A case study. *Engineering Management Journal,* 12(4), 25-31.