COMPARATIVE ANALYSIS OF HVAC SYSTEM AND ENERGY ANALYSIS

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ABSTRACT*: The energy consumed by heating, ventilating, and air conditioning (HVAC) systems has been Increasing over the last decades. Thus, improving efficiency of HVAC systems has gained attention of industry and academia. This concern has posed challenges for modeling and optimizing HVAC systems. The traditional methods, such as analytical and statistical approaches, usually involve assumptions that may not hold in practice since HVAC systems are complex, nonlinear, and dynamic. Data-mining is a novel science aiming at extracting system characteristics, identifying models and recognizing patterns from large-size data sets. It has proved its power in modeling complex and nonlinear systems through various effective and successful applications in industrial, business, and medical areas. Applications of classical data-mining approaches, such as neural networks and boosting tree have been reported in the HVAC literature. Evolutionary computation, including swarm intelligence, have rapidly developed in the past decades and then applied to improving the performance of HVAC systems. This analysis focuses on modeling, optimizing, and controlling HVAC systems. Data-mining algorithms are utilized to extract predictive models from experimental data sets provided by the Energy Resource Station located in Ankeny,. In the optimization process, two set points of the HVAC system, supply air duct static pressure set point and supply air temperature set point, are controlled aiming at improving energy efficiency and maintaining thermal comfort. However, for some special projects, due to the specific design and control of the HVAC system, conventional settings may not be necessarily energy-efficient in daily operation. The HVAC system design and equipment selection for a commercial building (376 TR) is included as a case study in this paper. The outcomes of this paper are efficient design of HVAC system with minimum energy consumption and equipment selection based on operating.

INTRODUCTION

Heating Ventilating and Air Conditioning (HVAC) systems are designed to control the indoor environment including indoor air quality and thermal comfort for occupants. HVAC systems are used in residential and commercial buildings worldwide .Figures 1.1 -1.2 illustrate schematic diagrams of a typical air handling unit (AHU) system and a typical single-room variable-air-volume box. According to the literature [1, 2], HVAC systems account for over 60% of the energy consumed by buildings and this number is likely to grow in the future.

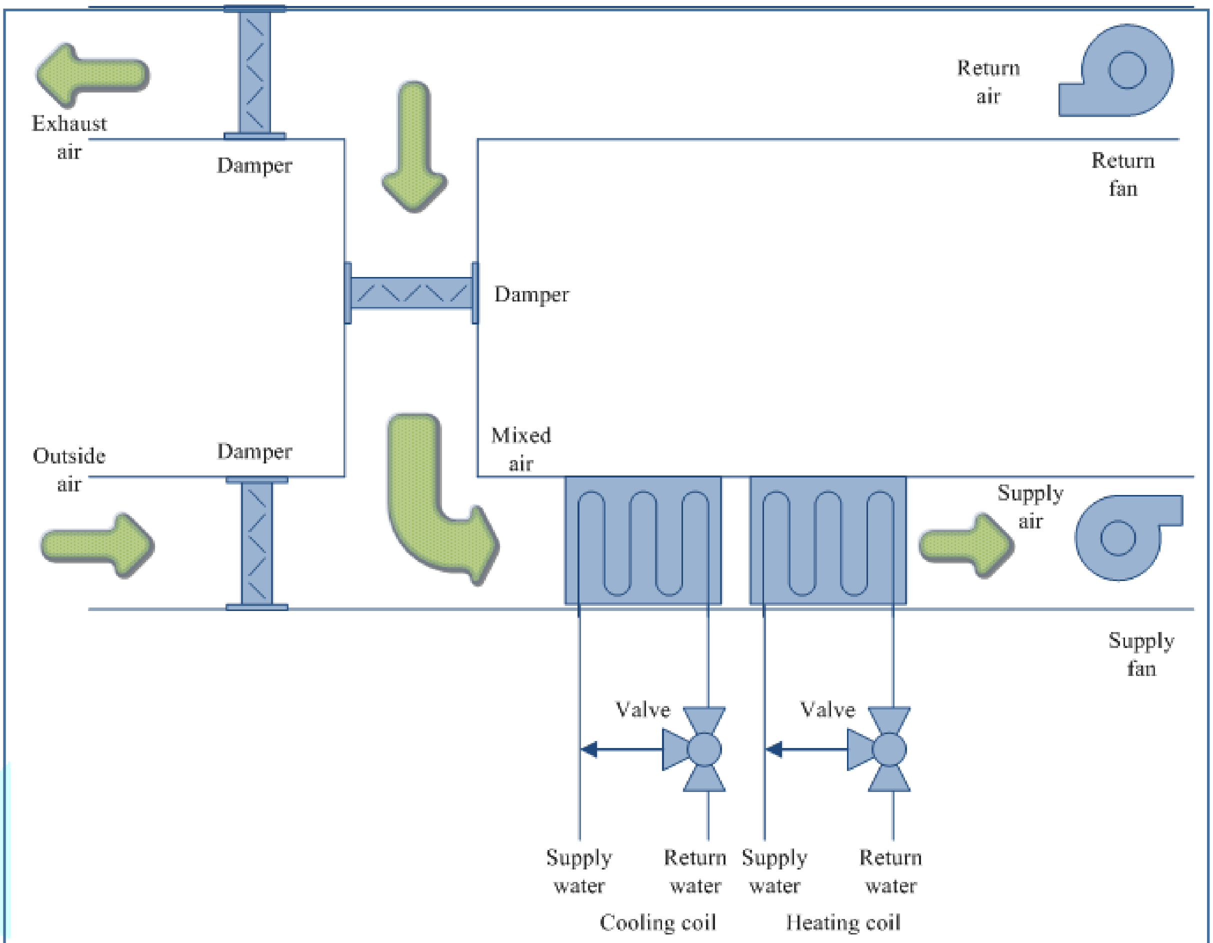


Figure 1.1 Schematic diagram of a typical air handling unit system

From the efficiency perspective, it is crucial to maintain a healthy and a comfortable indoor environment for occupants since people spend large portion of their time in buildings. Therefore, balancing the energy efficiency and effectiveness of HVAC systems has drawn attentions of the research community

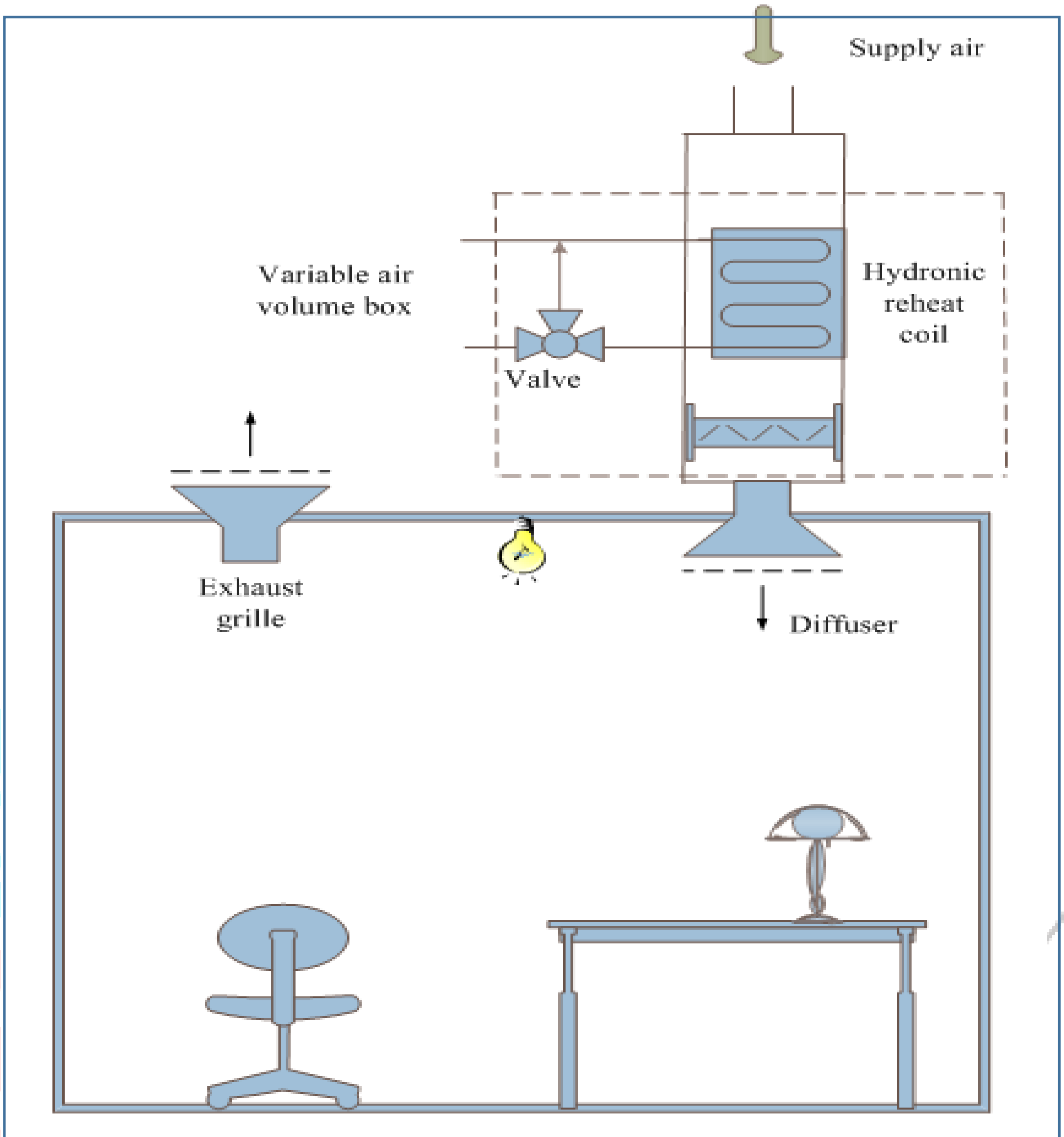


Figure 1.2 Schematic diagram of a typical single-room variable-air-volume box

Previous research has introduced numerous simulation models for analysis of different operational scenarios of HVAC systems. A typical commercial HVAC system includes a large number (hundreds) of variables with static and dynamic characteristics most of which are neglected by simulation models. Therefore, simulation models cannot be used in practical to control the HVAC systems, especially when a rapid response needed. Analytical or mathematical models of HVAC systems have been extensively investigated in the literature. Although such models can accurately describe the physical properties of HVAC systems, they could be computationally expensive due to the complex, nonlinear, and dynamic characteristics of the system. Analytical models can only be reliable and practical when appropriate assumptions or simplifications are made.

Data-driven models have gained attention in the recent years and applied to modeling HVAC systems. The data-driven models are derived from empirical behavior and heuristic searching process. They have proven to be powerful in capturing complex, noisy, and imprecise data collected from various nonlinear and large-scale systems.

An optimization model is developed from the predictive model to minimize energy consumption while maintaining the indoor air temperature within a desirable range. The supply air static pressure and the supply air temperature set points are generated by this optimization model by applying a nonlinear interior-point algorithm to solve it. The interior-point method was originally developed for linear programming optimization and then extended to non-convex nonlinear programming. A case study is presented to validate the effectiveness of the proposed approach.

OBJECTIVE

The goal of the analysis reported in this Chapter is to minimize the total energy consumption, while maintaining the indoor temperature (thermal comfort) at a desirable level by adjusting two controlling set points: the supply air static pressure and the supply air temperature set point. In this analysis , the indoor humidity is not considered since the relevant data in the experimental building cannot be obtained. Another reason is due to the average humidity in our experimental location that falls in the desirable range most of the time. Therefore, humidity is not necessary to be considered in the model proposed in this analysis. Thus, in constructing the energy consumption predictive model and the indoor temperature predictive model, it is necessary to include the two set points as parameters

The internal heat gain has a significant impact on the HVAC energy consumption. In commercial buildings, the number of occupants is a random variable. Thus, it is necessary to model activities of the occupants. In this analysis, considering its successful application in simulating discrete occurrences, a Poisson process is applied to model arrival of the occupants, and a uniform distribution is used to model their departure.

ENERGY ANALYSIS

In addition to facilitating daily performance tracking, it is possible to use the simulation to evaluate longer-term energy use in the monitored system. This section compares the energy use of the system and Shows the energy inputs of the three subsystems in the air-handling unit. The figure shows that all subsystems have higher heat-transfer rates in the real system than in the simulation. The most noticeable difference is the amount of energy transferred to the supply air in the mixing-box, with significantly more energy transferred in the real system than in the simulation. As explained previously, this was most likely due to leakage through the return air damper. Lists the potential savings in the real system, based on the assumption that the simulation represented an optimum level of performance.

SUB SYSTEM	ANNUAL ENERGY INPUT (MWh)		POTENTIAL SAVING BY OES	
	Simulation	System	MWh	%
Cooling coil	128	128	18	12
Heating Coil	571	679	108	16
Mixed coil	24	201	177	88

In order to establish the effect of the leakage in the mixing-box on the heating and cooling energy, the simulation was re-configured to use the simulated mixed air conditions as inputs to the coils. lists the results from re-running the simulation in this way. These results show that the leaking mixing-box reduced the load on the heating coil, but increased the load on the cooling coil. Hence, although a reduction of 16% in the energy use of the heating coil subsystem was possible by improving its control and operation, these savings reduce to 6% by eliminating the leakage in the mixing-box. Conversely, energy savings from improving the cooling coil subsystem increase from 12% to 46% by fixing the mixing-box. Since cooling energy is more expensive than heating energy, these potential savings are economically significant

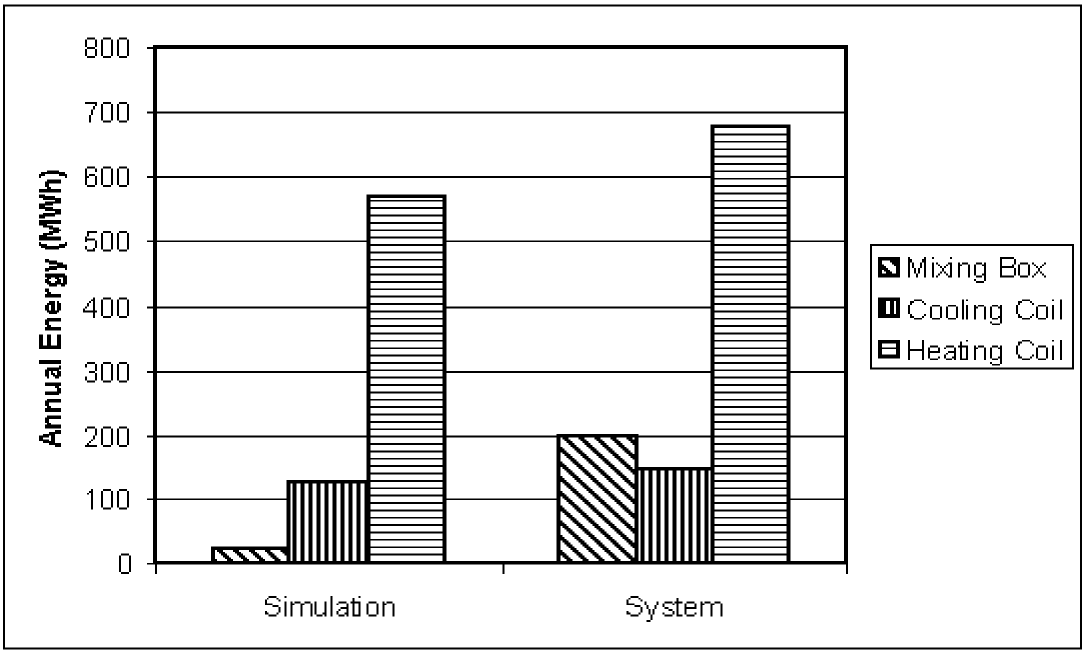
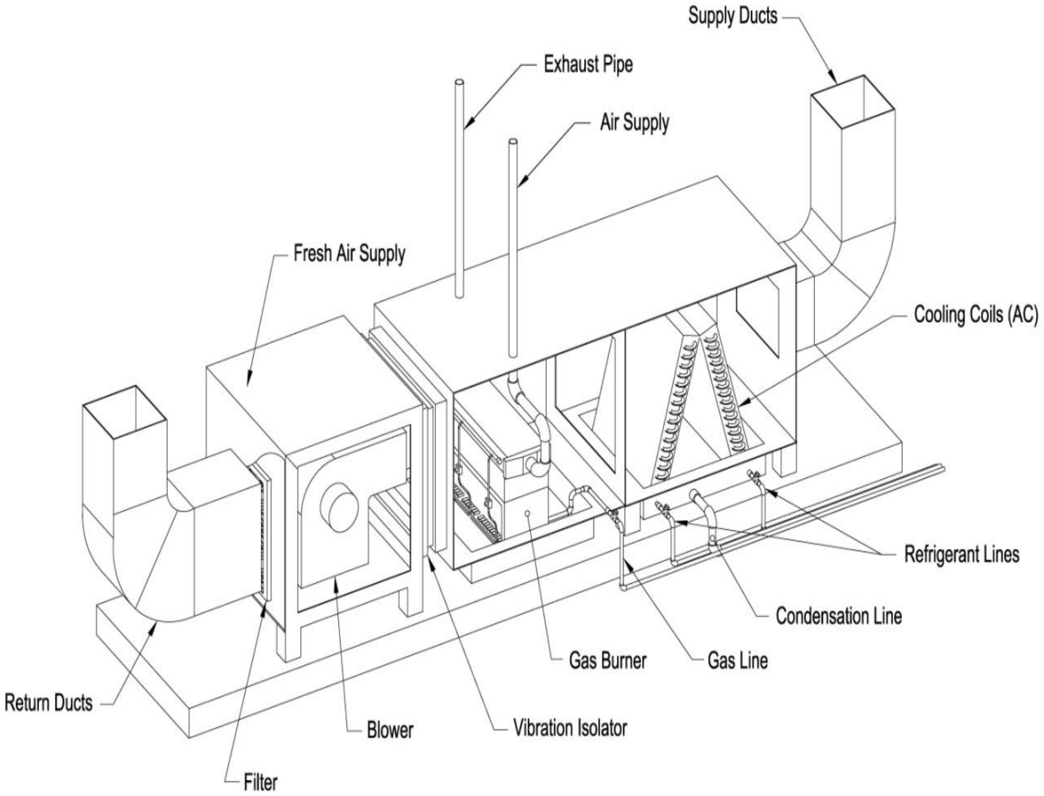


Figure : Annual energy comparisons in simulation and system subsystems.

HYPOTHESIS

In this section we study the design of the components of HVAC system and how to control it.
Most new homes have forced-air heating and cooling systems. These systems use a central furnace plus an air conditioner, or a heat pump. Figure 7-1 shows all the components of a forced-air system. In atypical system, several of these components are combined into one unit. Forced-air systems utilize a series of ducts to distribute the conditioned heated or cooled air throughout the home. A blower, located in a unit called an air handler, forces the conditioned air through the ducts. In many residential systems, the blower is integral with the furnace enclosure.



Component of Forced - Air Systems

HEAT PUMP EQUIPMENT

Heat pumps are designed to move heat from one fluid to another. The fluid inside the home is air and the fluid outside is either air (air-source), or water (geothermal). In the summer, heat from the inside air is moved to the outside fluid. In the winter, heat is taken from the outside fluid and moved to the inside air.
Heat pumps use the vapor compression cycle to move heat (see Figure 7-2). A reversing valve allows the heat pump to work automatically in either heating or cooling mode. The heating process is:
1. The compressor (in the outside unit) pressurizes the refrigerant, which is piped inside.
2. The hot gas enters the inside condensing coil. Room air passes over the coil and is heated. The refrigerant cools and condenses.
3. The refrigerant, now a pressurized liquid, flows outside to a throttling valve where it expands to become a cool, low pressure liquid.
4. The outdoor evaporator coil, which serves as the condenser in the cooling process, use outside air to boil the cold, liquid refrigerant into a gas. This step completes the cycle.
5. If the outdoor air is so cold that the heat pump cannot adequately heat the home, electric resistance strip heaters usually provide supplemental heating.

SIZING

When considering a HVAC system for a residence, remember that energy efficient and passive solar homes have less demand for heating and cooling. Substantial savings may be obtained by installing smaller units that are properly sized to meet the load. Because energy bills in more efficient homes are lower, higher efficiency systems will not provide as much annual savings on energy bills and may not be as cost effective as in less efficient homes .Not only does oversized equipment cost more, but also it can waste energy. Oversized equipment may also decrease comfort. For example, an oversized air conditioner cools a house but may not provide adequate dehumidification. This cool, but clammy air creates an uncomfortable environment.

AIR HANDLING UNIT

The air handler is normally constructed around a framing system with metal infill panels as required suiting the configuration of the components. The metalwork is normally galvanized for long term protection .For outdoor units some form of weatherproof lid and additional sealing around joints is provided. Air handler is a type of device used to regulate and circulate air as part of a heating, ventilating, and air-conditioning for HVAC systems. An air handler is usually a large metal box containing a blower, heating or cooling elements filter racks or chambers, sound attenuators, and dampers. Air handlers usually connect to ductwork ventilation system that distributes the conditioned air through the building and returns it to the
AHU. Sometimes AHUs discharge [supply] and admit [return] air directly to and from the space served without ductwork.

COMPONENTS OF AHU

Filters - Air filtration is almost always present in order to clean dust-free air to the building occupants and to the core areas and manufacturing areas of pharmaceutical firms. Filtration is typically placed first in the AHU in order to keep all the downstream components clean. Depending upon the grade of filtration required the types of filters used are G-4, F-6, F-9 and H-13 hence, G-4 filter is cheaper to replace and maintain thus saving other expensive filters from getting replaced within short interval of time. The span of a filter maybe assessed by monitoring the pressure drop through the filter medium at design air volume flow rate. This is done by means of a visual display using a pressure gauge. Failure to replace a filter may eventually lead to its collapse, as the forces exerted upon it by the fan overcome its inherent strength, resulting in collapse and thus contamination of the air handler and downstream ductwork.

Heating & Cooling coils - Air handling units requires providing heating, cooling, or both to change the supply air temperature, and humidity level depending on the areas and the application. Such conditioning is provided by heating and cooling coils within the air handling unit air stream; such coils are directly influenced to the medium providing the heating or cooling effect.

Coils are typically manufactured from copper for the tubes, with copper or aluminum fins to assist heat transfer. Cooling coils will also employ eliminator plates to remove and drain condensate water. The hot water is provided by hot water generator and the chilled water is provided by chiller. Downstream temperature sensors are typically used to monitor and control "off coil" temperatures, in conjunction with an appropriate motorized control valve prior to the coil. Dehumidifier is required, and then the cooling coil is used to over-cool so that the dew point is reached and condensation occurs. A heater coil placed after the cooling coil re-heats the air to the desired supply temperature. This has the effect of reducing the relative humidity level of the supply air. During colder climates, where winter temperatures regularly drop freezing point, then heating coils are often used as a first stage of air treatment to ensure that downstream filters or chilled water coils are protected against freezing. The control of the chilled coil is such that if a certain off-coil air temperature is not reached then the entire air handler is shut down for protection.

Humidifier - Humidification is often necessary in colder climates where continuous heating will make the air drier, resulting in uncomfortable air quality and increased static electricity.

Air-mixing Plenum - In order to maintain indoor air quality, air handlers commonly have provisions to allow the entry of outside air into through fresh air filtered opening regulated by a manual damper, and the exhausting of air from the building. During moderate climates, mixing the right amount of cooler outside air with warmer return air can be used to approach the required supply air temperature. A mixing chamber is therefore used which has manual dampers controlling the ratio between the return, outside, and exhaust air.

Blower fan - Air handling units generally employ a large squirrel cage blower driven by an AC induction electric motor to suction the air. The blower is driven by a Variable Frequency Drive to allow a wide range of air flow rates. Flow rate is controlled by inlet vanes or outlet dampers on the fan. These are driven using high efficiency EC (electronically commutated) motors with built in speed control. It is placed behind G-4 filters starting form fresh air opening damper

Vibration isolators - The blowers in an air handling unit can create substantial vibration and the large area of the duct system would transmit this noise and vibration to the occupants of the building situated in the core and manufacturing areas of pharmacy plant. To avoid this, vibration isolators or damper block are normally inserted into the duct immediately before and after the air handler and often also between the fan compartment and the rest of the AHU. The rubberized canvas-like material of these sections allows the air handler components to vibrate without transmitting this motion to the attached ducts. The fan compartment is further isolated by placing it on a spring suspension, which will palliate the transfer of vibration through the floor.

BMS - It can be abbreviate as Building management system in HVAC control simulation. BMS is a computer-based control system installed in buildings that controls and monitors the building’s mechanical and electrical equipment such as ventilation unit, Air handling unit of HVAC systems. A BMS consists of software and hardware; the software program, usually configured in a hierarchical manner, can be proprietary, using such protocols as C-bus, Profibus, and soon.

CONCLUSION

• HVAC is one of, if not, the most important utility in health product manufacturing operations. • HVAC systems are critical and represents increased risk as the complexity and cleanliness of the operation increases.

• Validation of HVAC systems is necessary.

• HVAC systems must be properly designed for the intended application, qualified, and their operation monitored continuously to complete the validation.

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