SUPERVISORY AND CONTROL OF HVAC SYSTEMS

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Abstract. *HVAC (heating, ventilating and air conditioning) systems are used for controlled maintenance of indoor ambient characteristics in optimal manner, with regards to outdoor ambient characteristics. The objective of these systems is to achieve comfortable and pleasant sensation of people staying in the conditioned area. To accomplish the established requests, understanding of intensity and dynamic of thermal effects on objects, physical characteristics of objects and requirements for heating and cooling energy are needed. Climate chambers and chillers are the base element of ventilating and conditioning system where air is prepared to reach purity, temperature and humidity of air. It is accomplished by filtering, heating, cooling, mixing and wetting/drying of the air. In this paper, basic elements (industrial climate chambers and chillers), working principles of HVAC systems with control and monitoring configurations based on PLC and SCADA are presented.*

Key words: *HVAC, air conditioner, chiller, PLC, SCADA, communication protocol*

1. INTRODUCTION

Pleasant sensation of people residing in a certain area are provided by constant bringing of fresh air into that space, where at least three air exchanges within one hour are required. Fresh air, which is used for ventilation, is also a carrier of heat for local regulation of ambient temperatures in winter and summer conditions. Ventilation with 100% fresh air is energy efficient only in case of realization based on device equipped with feedback sensors of air temperature and humidity, especially at low outdoor air temperature. The air conditioner, in cooling mode, decrease humidity of inflowing air to make better condition in residing area during extreme summer temperatures.

Implementation of HVAC system and efficiency evaluation need data about the degree and dynamics of thermal effects on objects, as well as insulation characteristics and needs

for heating and cooling. The majority of modern commercial and public buildings are fully or partially air conditioned. Typically, there is central preparing of heating and cooling energy conveyed by water thermal exchangers for a particular area and air systems for bringing fresh air conditioned in air chambers.

2. AIR CONDITIONING CHAMBER

Air conditioning chamber is installed at the beginning of air channel installation i.e. at the entrance of fresh air, along with equipment for heat recovery from wasted air used for fore heating of fresh air from the outside. The heat originates from recuperators (sensible heat) and regenerators (sensible and latent heat). Air conditioning chambers are used for ventilation and air conditioning of shopping and business centers, hospitals, industrial halls, storerooms, banks, post offices, sport facilities, indoor swimming pools, public areas, telecommunication and computer centers and other buildings. HVAC system is equipped with heating generators, refrigerators, air conditioners, air conveyers and control devices.

Heating energy originates from boilers running on heavy oil, oil, gas or biomass. The use of groundwater heat (the heat pump effect), which has a temperature of 10°C to 13°C during winter, increases the efficiency of these systems. A heat pump utilizes the heat of groundwater to heat a heating medium. In cooling mode, the heat pump role is changed to cool rooms. Cooling water temperature in the installation is 20°C, so that the sensible heat is maintained at a level that makes the room comfortable to stay in.

For the sake of energy saving (significant decrease required heating capacity) heat recuperators are used to transfer waste air heat to fresh air.
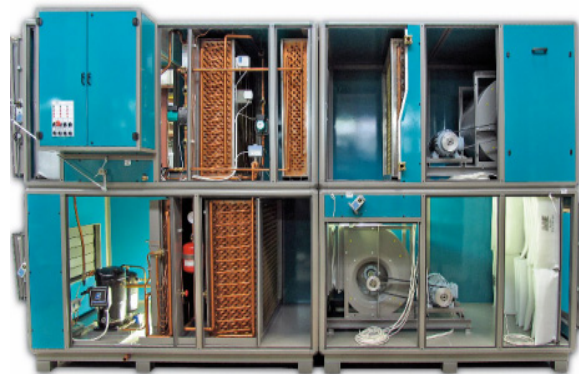

Fig. 1. Photo air conditioning chamber of domestic producers "Soko"

Air Chamber is one of the key elements of the HVAC system. This complex device provides:

– Temperature and humidity regulation of the air – conditioned space with limitation of maximum and minimum temperature (temperature and humidity sensors – spatial type and channel type),

− Damper control (fresh and recirculation air with the damper actuator) with options "free cooling" and "free heating",

− Exhaust and pressure ventilator with a two – speed motor, or with frequency regulation of the number of revolutions,

− Water heater or electric heater with pre – heating control,

− Regulation of the valves of coolers, heaters and recuperators,

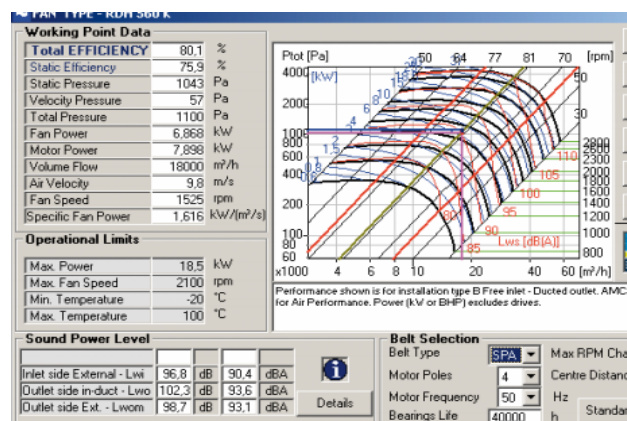Regulation of the pump of cooler, heater and recuperator,

Fig. 2. Choice of fan characteristics

− Cooling with direct expansion: multi – stage regulation of the compressor, regulation of the condenser ventilator and electronic thermal expansion valves,

− Adiabatic/isothermal moisturizing with ON/OFF or continuous regulation.

− The device has the following security features:

− Monitoring of the exhaust and pressure ventilators with a differential pressostate,

− Monitoring of the filter with a differential pressostate,

Freeze protection of:

− heater of the heating pipe system (with frost thermostat positioned in the air stream) and

− plate recuperator with by pass shutters,

− overload of electric heater.

The main objective of an air conditioning system is to fulfill the requirements in terms of air quality (temperature, humidity and air purity degree) to create the comfort and suitable conditions for living and working in an air conditioned environment. This is achieved by a combination of basic air processing, different options for managing air and using the related elements of automation and control laws. Control block diagram of industrial air chamber is shown in Fig. 3. Two channels are evident: the input channel – fresh air supply (by fan VI1) and the output channel – polluted air exhaust. On the way through the air chamber, air passes through a filter (F1), then through the heating system - H1 (in winter) or cooling system - C1 in summer mode. Heating is done with regulated electric heaters (rarely) or by using hot water that is already prepared in the boiler room. Water is supplied by pump P1.

Fig. 3. Control block diagram of Air conditioning chamber

Fig. 4. SCADA screen of Air conditioning chamber
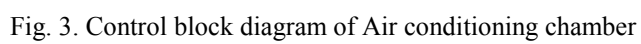
Regulating the temperature of this water is done with electro-magnetic three way valve - YV1, which stirs hot water (the boiler) and cold water, in suitable proportions, providing the necessary heat for heating intake air. In summer, when it is necessary to cool the supply air, electric valve - YV2 is used, which lets cold water (prepared in the chiller, or water delivered by the heat pump) through a system of cooling air. The air continues through the system for drying/wetting - D/HU and finally brings in air conditioned area. The polluted air is drawn from the room by exhaust fan - VO1 (initially pass through the filter - F2). The polluted air heat, via the recouperator – R, is used for heating fresh air which increases the efficiency of the system. Fans VI1 and VO1 have frequency converter control. Contamination of filters is registered by built in pressure sensors - SP1 and SP3, by a symptom of pressure drop. The measurement of inlet air temperature is carried out by Pt100 element - BT1, and the air temperature at the beginning of the output channel is measured by Pt100 element - BT2. The temperature at the end of the output channel is measured by Pt100 element - BT3. The frost thermostat - ST1 is installed to protect the installation from freezing. As security elements in the input and output channels, limit thermostats ST2 and ST3 are installed. Measuring humidity in channels is done by sensors BTH1 or BTH2.

In addition, the status of switches in an electrical closet of air chamber and the status of fire stations, which closes the shutter dampers in the ducts in case of fire, are monitored. In the lower part of Fig. 3, in a table form, all the digital and analog input and output signals that the process (the air chamber) connect with the control unit are shown. Monitoring and tuning of relevant parameters and values is done on the SCADA (Fig. 4) computer, which is installed in the control room. Managing air chamber is done by PLC controller, which is installed in the switch cabinet.

3. CHILLER

Chiller is a cooling device. A simplified scheme of a chiller is shown in Fig. 5. It is a complex system of exceptional performance in terms of efficiency, especially the new series, which can be used by low ambient temperature throughout the year.

They provide high reliability in housing, technological and industrial applications. Chillers are used in the ceramics industry, food industry, printing industry, machines for plastic injection and extrusion, shopping and business centers, sports facilities and so on.

These systems can operate in free-cooling mode (the diagram in Fig. 8), exploiting the temperature of the outside air for cooling water that is used. A special control valve turns a certain amount the feedback water from the system. In this way, appropriate conditions of temperature of the outside air cool the water before its return, resulting in delayed activation of the cooling device.

3.1. Free cooling

Free – cooling control exploits the temperature of the outside air to assist in the cooling of the utility water (Fig. 7). Special valve deviates a certain quantity of return water from the system. The favorable outside air temperature conditions thus cool the water prior to its return, and the activation of the cooling devices is therefore delayed.

Free-cooling is envisaged for air/water units in internal free-cooling mode, that is, the free-cooling coil housed inside the unit near the condenser coil/coils, with which it shares the control of the condenser fan/fans.

LEGEND:
1 - COMPRESSOR
2 - OUTDOOR EXCHANGER
3 - INDOOR EXCHANGER
4 - FAN
5 - THERMOSTATIC VALVE
6 - DRYER
7 - FAN SPEED REGULATOR
8 - SHUT OFF VALVE

9 - SUPPLY COCK
10 - SIGHT GLASS
11 - SERVICE VALVE
12 - PRESURE SWITCH
13 - PRESURE SWITCH
14 - GAUGE
15 - TEMPERATURE PROBE
16 - ANTIFREEZE PROBE
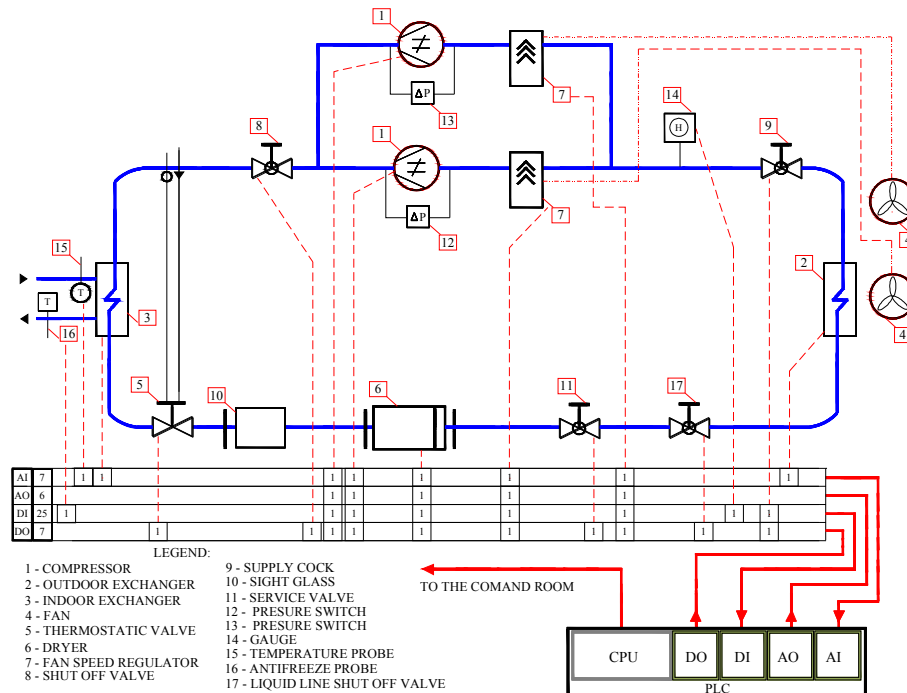17 - LIQUID LINE SHUT OFF VALVE

TO THE COMAND ROOM

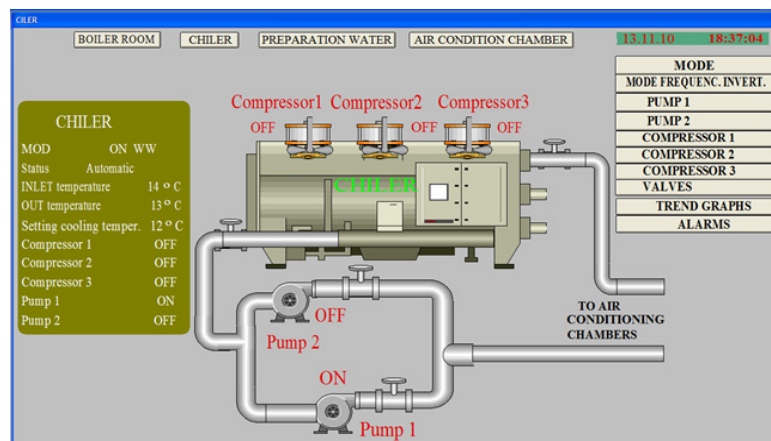Fig. 5. A simplified scheme for refrigeration equipment – chiller

Fig. 6. SCADA screen of Chiller

3.2. Activation of the free-cooling function

The free-cooling function is based on the relationship that compares the temperature measured by the outside temperature probe, the temperature measured by the temperature probe located at the free-cooling coil inlet, and the set free-coiling delta.
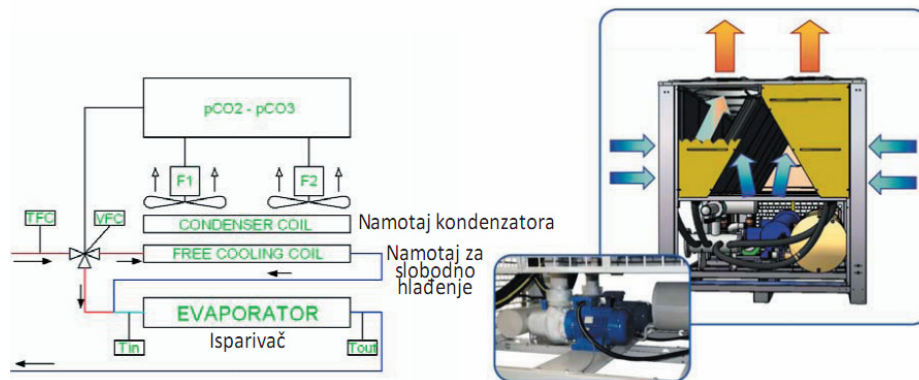

Fig. 7. Scheme of free cooling

Legend:
TFC – Free-cooling coil inlet temperature, B5 – Outside temperature
VFC–Free-cooling valve, Tin – Evaporator water inlet temperature
Tout – Evaporator water outlet temperature, F1, F2 – Condenser fans
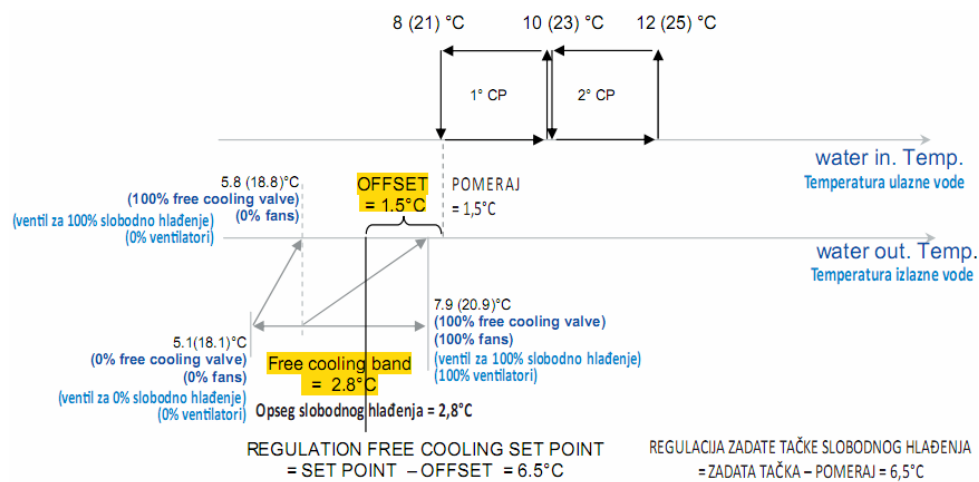pCO2 – Control Unit (PLC)

Fig. 8. Graphical display of the free cooling mode

4. COMMUNICATION PROTOCOLS

A very important issue in the design of a system for building management, and therefore the management of HVAC systems, is the choice of communication protocols. The dilemma is whether to choose an open protocol or protocol with limited access. Previous experience shows the advantage of open protocols. Here again the question of what to choose arises: LonWorks (Local Operating Network) or BACnet (A Data Communication Protocol for Building Automation and Control Networks). The leading companies, which among other things, are engaged in the production of building management systems, such as Siemens, Honeywell, Invensys, Johnson and TAC are the main sponsors of LonWorks. On the other hand, the BACnet is supported by ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers - Association of Engineers in America, dealing with issues related to HVAC systems).

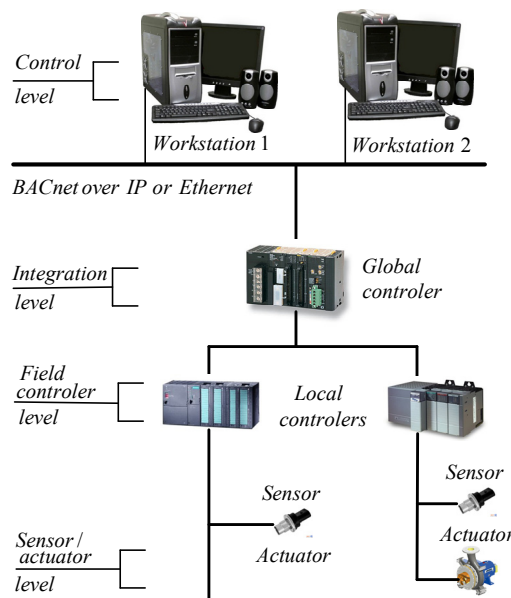BACnet is a generally accepted world standard in building management systems.

Fig. 9. BACnet Functional Levels

This protocol has become the standard with the support of the Association of ASHRAE and ANSI (American National Standards Institute) in North America in 1995, and in Europe through CEN (European Committee for Standardization). The standard was approved in 2000. It is designed for transmission of complex information, such as plans, calendars, monitoring devices and equipment, signal failures and so on. BACnet is applied to all systems which can be found in the construction of modern facilities, such as HVAC systems, electrical installations, telecommunications, fire protection, intrusion protection, access control, video surveillance, etc. This flexible platform for data transfer is based on object-oriented programming. The link between BACnet and LonWorks is implemented over TCP/IP protocol. Functional levels of BACnet protocol are shown in

Fig. 9. In the BACnet terminology functional connectivity (interoperate) means that two or more BACnet computer systems can share the same communication network on peer-to-peer basis (like LonWorks). Although BACnet does not require that each system has equal capabilities, for designers of system components at each level of complexity, it is allowed to access the other equitable system (peer). In the world of BACnet, there are no differences in importance between large and small controllers, sensors, workstations or the main computer. To understand BACnet it is necessary to be familiar with two basic ideas. The first idea is the fact that BACnet is applicable to all types of systems that could be found in one building or a facility: HVAC, security systems, access control, fire alarm system, power supply and so on. Mechanism, which provides BACnet with flexibility, has two good qualities: independence from the supplier and compatibility with future generations of systems. This was accomplished by using object-oriented approach in presenting all the information within each controller. Another key idea is that BACnet uses any combination of several types of local networks, the Internet or LAN technology for transfer BACnet application messages. This choice of several different types, offers the designer the possibility of considerable flexibility in choosing the best option in terms of scale and cost performance in every situation. Since BACnet is based on standards, it provides maximum satisfaction to both manufacturers who designed BACnet and the users or owners of the system.

BACnet provides a sophisticated model for describing systems of all types of automation. This model is based on the assumption that systems are truly mutually functional (interoperable). BACnet is a model organized with the following elements:

Objects, for the presentation of information and databases, along with a universal method for access to standardized and proprietary information.

Services, which allow BACnet devices to perform various functions in a standardized manner. Local area networks provide transport mechanism for message interchange through various types of networks and communication media.

Internetworking rules, allow construction of large networks created by different types of LAN. Adjustment rules, which define standardized ways to describe systems BACnet terminology and standard forms for the description of optional BACnet features that a particular system allows. Each of these elements provides an important advantage for vendors and users of BACnet system. BACnet supports the following communication protocols: RS232-point-to-point communication between devices or systems, RS485 - using MS/TP, LonTalk - LonWorks BACnet over LonWorks - as a mechanism for data transfer, but there is no interoperability with Lonmark devices.

ARCNET-BACnet. ARCNET is ANSI standard. Its advantages come from its deterministic response, the diversity of the media (coaxial cable, UTP, fiber optics) and the possibility of scaling speed. The disadvantage is the problem related to large distances. Ethernet is used for high speed communication (10-100Mbps). The advantages of Ethernet are that it is an international standard, already installed infrastructure in many buildings and facilities, great speed and a variety of media transmission (coaxial cable, UTP, fiber optics). The disadvantages are non-deterministic response, the problem of large distances and relatively high price. TCP/IP, IP standard is used to connect a BACnet media over any TCP IP network. Therefore, it is possible to control access to the building (facility) from any place that has Internet access; however, its weak point is security violation on the Internet (hackers break into the system, etc.).

5. CONCLUSION

The exploit of modern materials and equipment with the implementation of appropriate algorithms, produce modern HVAC systems that belong to the ENERGY SAVING systems, i.e. systems with maximum performance, which save energy and protect the environment. A system for monitoring and control provides management and visualization of the object and display the current value of significant parameters in the form of appropriate tables and graphics, the acquisition of relevant data and archiving, statistical data processing, data transfer to distributed locations in the network, linking with other programs in real time (DDE, ODBC, OLE, etc.) and generating various reports.

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NADZOR I UPRAVLJANJE KGH SISTEMIMA

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KGH su sistemi za grejanje, hlađenje i ventilaciju. Oni služe za kontrolisano održavanje određenih karakteristika ambijenta zatvorenog prostora u granicama optimalnih vrednosti, imajući u vidu promenljive uslove spoljnje sredine. Zadatak ovih sistema je da obezbede komforan i ugodan osećaj ljudi koji borave u datom prostoru. Da bi se ispunili postavljeni zahtevi neophodno je poznavanje veličine i dinamike termičkih uticaja na objekat, fizičke karakteristike objekta, potrebe za toplotnom i rashladnom energijom. Klima komore i čileri su osnovni elementi sistema ventilacije i klimatizacije u kome se vrši priprema vazduha sa ciljem da se obezbedi odgovarajuća čistoća, temperatura i vlažnost vazduha. Ovo se postiže pomoću filtriranja, grejanja, hlađenja, mešanja i vlaženja/sušenja vazduha. U radu su dati osnovni elementi i princip rada sistema klimatizacije i nadzorno upravljačka konfiguracija, na bazi PLC i SCADA sistema, za HVAC elemente kao što su industrijska klima komora i uređaj za rashlađivanje - čiler.

Ključne reči: *KGH sistemi, klima komora, čiler, PLC, SCADA, protokol komunikacije*