Technical Description
and
Demand Side Management
Utility Implementation
of the

ADRES

Automated Demand Response

and Energy Savings

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1.0 Introduction

The ADRES Energy Management System is a flexible microprocessor based intelligent and programmable energy management system with the following capabilities:

- Control of HVAC systems.
- Electric, gas and water meter reading and data storage.
- Remote control, monitor and programming using a variety or communication technologies.
- Local and remote alarm reporting.
- Local or remote Demand Side Management control.

The ADRES system produces a high rate of internally verifiable energy savings in commercial and residential applications. Designed for packaged air conditioning units of 2.5 to 40 ton capacity and up to 500,000 BTU heating furnaces. The ADRES system optimizes HVAC energy efficiency by causing the equipment to operate in an energy recovery mode for a significant portion of each cooling or heating cycle, without impacting the comfort zone of the affected facility. It further reduces energy consumption and demand by programming the HVAC equipment to cool or heat the facility on an optimum schedule. The ADRES has a built-in testing mode for verification of actual energy consumption and savings. The system is remotely accessible for programming, control, and energy analysis using the embedded Wireless Cellular service operating on a virtual private network (VPN) with advanced encryption technology for state-of-the-art secure and reliable communications for utility demand side management control. The ADRES hardware will operate with the OpenADR 2.0 protocol.

The ADRES Energy Management System produces energy and cost savings through improved efficiency, operational and maintenance savings while allowing a utility to implement real time auto demand side management on a local or remote basis through the OpenADR 2.0 protocol.

1.1 Utility Demand Side Management

Utility demand side management (DSM) is first achieved by programmed efficient loading and operation of the HVAC equipment. Real time DSM is achieved by allowing a utility to control the setpoint temperature used for either air conditioning or heating on a local level, remote basis through two way modem communications or optionally with an easily accessed radio frequency paging system. The setpoints can be proportionally or continuously controlled and changed by the utility as the demand for electrical power increases or decreases. The ADRES can be programmed to raise the cooling setpoint temperature or heating setpoint temperature in small increments, cycle units on a timed

operational basis or shut units off. The ADRES automatically advises the consumer of these changes and can report DSM load shedding to the utility via modem communications. Several types of DSM scenarios can be configured to be implemented at the local level based on preset peak demand limits being read and calculated from the electric meter.

1.2 Consumer Electrical Demand Savings

Consumers with single or multiple HVAC systems can achieve electrical demand savings by the programmed use of the ADRES and by the ADRES sequencing the operation of multiple air conditioning systems to limit the number of air conditioner compressors operating at any one time. The utility / consumer can also place setpoint limits on the amount the room temperature can rise during DSM load shedding control in cooling and establish priorities for unloading each HVAC system.

1.3 Energy Conservation

Energy conservation is achieved by programming the ADRES for more energy efficient temperature settings for heating and cooling at all times and especially when a commercial building or residence is vacant. This type of setpoint control has been widely accepted by the U.S. Department of Energy, utility commissions, and utilities as an effective means of conserving energy. The ADRES goes beyond typical setback thermostats by being able to program holidays, vacations, and complex work schedules in commercial applications and produces all of the energy savings provided by larger, more expensive computer controlled energy management systems.

In addition to the programmable thermostat energy savings, the ADRES conserves additional energy by operating the HVAC system in its most efficient mode by monitoring output or supply air temperature, return air temperature, room temperature and outdoor temperature. This allows the ADRES to make complex decisions about compressor, indoor fan, economizer and gas valve / burner operation.

Some new and more expensive air conditioning systems are furnished with a time delay relay (TDR) that keeps the indoor fan operating 30 to 60 seconds at the end of a cooling call to salvage the cold stored in the mechanical system. American Refrigeration Institute (ARI) has recognized this technique for improving energy efficiency and has provided an additional 0.15 to 0.25 improvement in the SEER rating of the equipment.

The ADRES performs this function for equipment that does not have a TDR (most equipment in the field) and goes beyond the simple TDR function. The

ADRES monitors the temperature of the supply air and keeps the indoor fan operating until the BTU output has dropped to 25% of its normal output. This is done by monitoring the temperature drop across the indoor coil (return air temperature-supply air temperature). At the 25% level, the BTU output from the system is about equal to the power required to operate the indoor fan to recover the BTU's.

1.4 Monitors and Alarms on Performance

The ADRES monitors the performance of the HVAC equipment and even its routine maintenance schedule to assure the equipment is continuing to operate at its most efficient level. The ADRES accumulates records and stores the energy consumption and run times of each component in the HVAC system. Analysis of this data determines normal system efficiencies and identifies any degradation or deficiencies occurring in the system. The ADRES will generate alarms on a number of temperature and operation parameters of each HVAC unit. These alarms can be reported on a local and remote basis using the modem communication back to a central monitoring computer.

2.0 Description of Hardware

The ADRES system consists of the ADRES HVAC Control Module(s) and individual Room Temperature Sensor(s). There is at least one ADRES Control Module that has the embedded cellular gateway modem for local or remote operation with a PC Computer, smart phone or tablet with an Internet connection. The ADRES Control module has the ability to communicate directly with a utility Demand Response Automated Server (DRAS).

2.1 ADRES Master Control Unit (Optional)

The ADRES Master Control Unit is shown in Figure 1. This unit, which provides a local control interface, can control from one to eight ADRES HVAC controllers through a wireless local area network using an embedded local RF module in each ADRES controller. The keyboard and LCD display are used for entering control parameters, program data, operating modes and is used to display the same data, as well as energy usage, demand and energy efficiency of each system. The ADRES controllers communication to the utility DRAS server using the OpenADR2.0 protocol to receive DR commands from a utility. All critical program and energy data is stored in non-volatile memory within the ADRES in EEprom memory to assure the data is not lost in case of a power failure. The display is a LCD type with 2 lines of 16 alphanumeric characters. Programming the ADRES is a tutorial process where the ADRES displays information on the LCD and the user need only answer yes or no or press a key to increase or decrease a parameter.

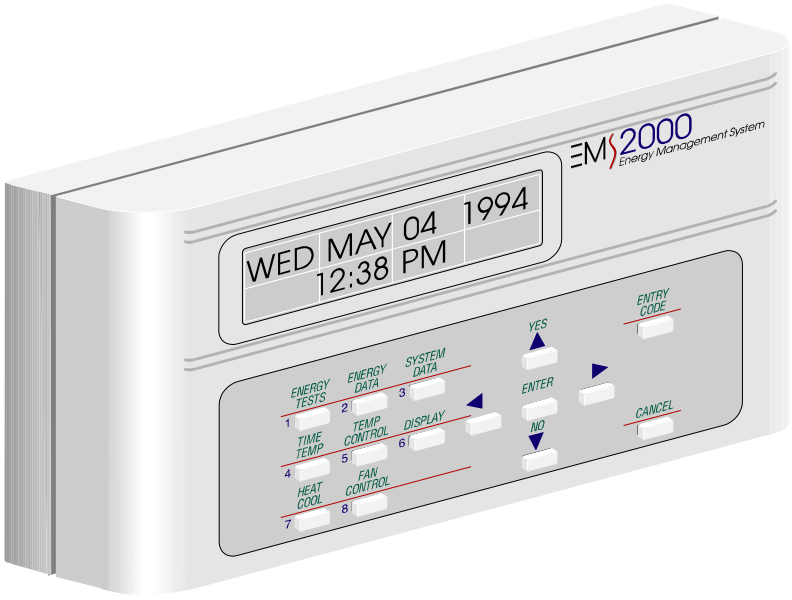


Figure 1. ADRES Master Control Unit (MCU)

2.2 ADRES HVAC Control Module

An ADRES Control Module (Figure 2) is installed on each HVAC system. This module receives data from the Master Control Unit across the local wireless network and is continuously updated with temperature setpoints and operating instructions. The ADRES Control Module also informs the Master Control Unit of the status of the systems so that it can monitor alarm conditions, energy usage and energy efficiency. The ADRES Control Modules are available in a variety of configurations for different types of HVAC systems (condensing air conditioners, heat pumps and gas furnaces, etc.). The ADRES Control module uses relay contacts rated at 10 amps to control the 24VAC controls within the HVAC system.

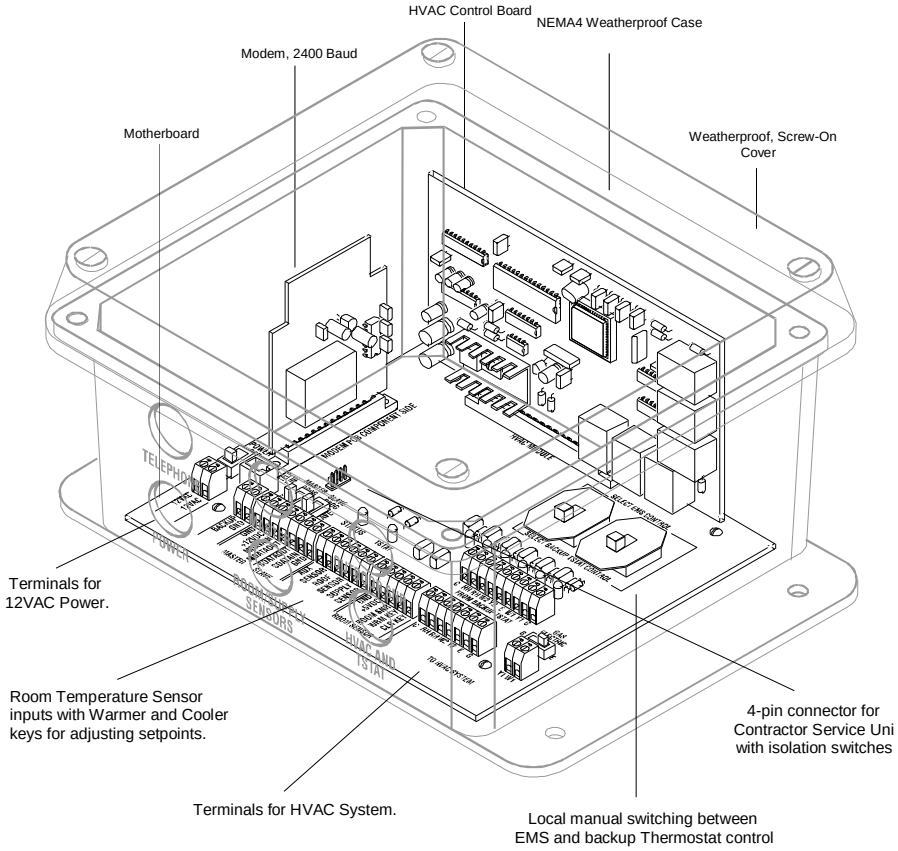


Figure 2. ADRES HVAC Control Module (CM)

2.3 Room Temperature Sensor

In multiple HVAC installations, a thermistor-type Room Temperature Sensor (Figure 3) is placed in each area where a thermostat was previously located and is connected to the HVAC control module using the existing thermostat wires in the walls. The sensor also has a WARMER and COOLER push-button switch on it that allows the occupant at each remote location to adjust the room temperature setting over a pre-set limited range. If the system is in a night economy setting, pressing the WARMER or COOLER key returns the system to the comfort temperature for an 8-hour period (adjustable within the EnergyPro software. This provides a simple way of overriding the programmed temperature.

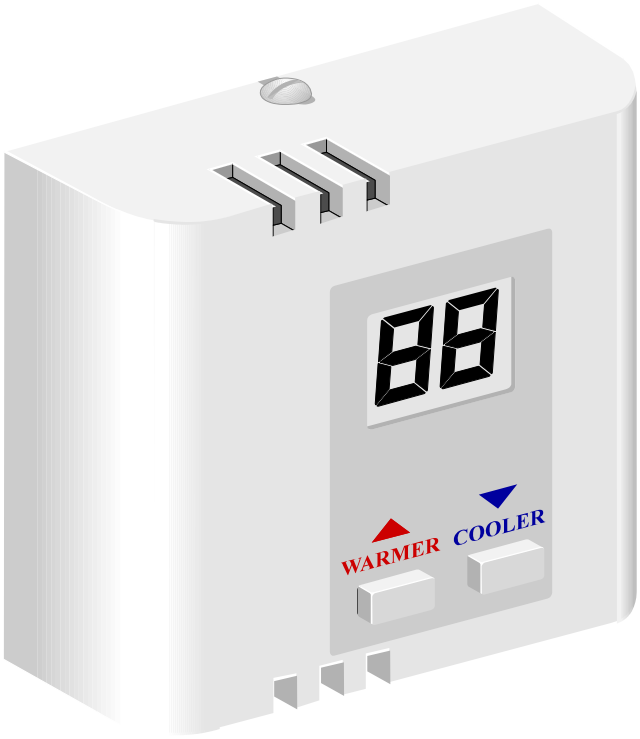


Figure 3. ADRES Room Temperature Sensor (with LCD Display)

3.0 System Configuration

Figure 4 shows an ADRES system controlling a single Master Control Unit and eight HVAC systems with an optional PC Computer and telephone modem interface. Figure 5 on the following page shows the ADRES controlling sixteen different HVAC systems through two Master Control Units, single Communications Multiplexer with built in modem. Utility meter reading is accomplished via pulse counter input or wireless communication into a Control Module. Data is collected in 15 minute increments, date and time stamped and recorded in non-volatile memory.

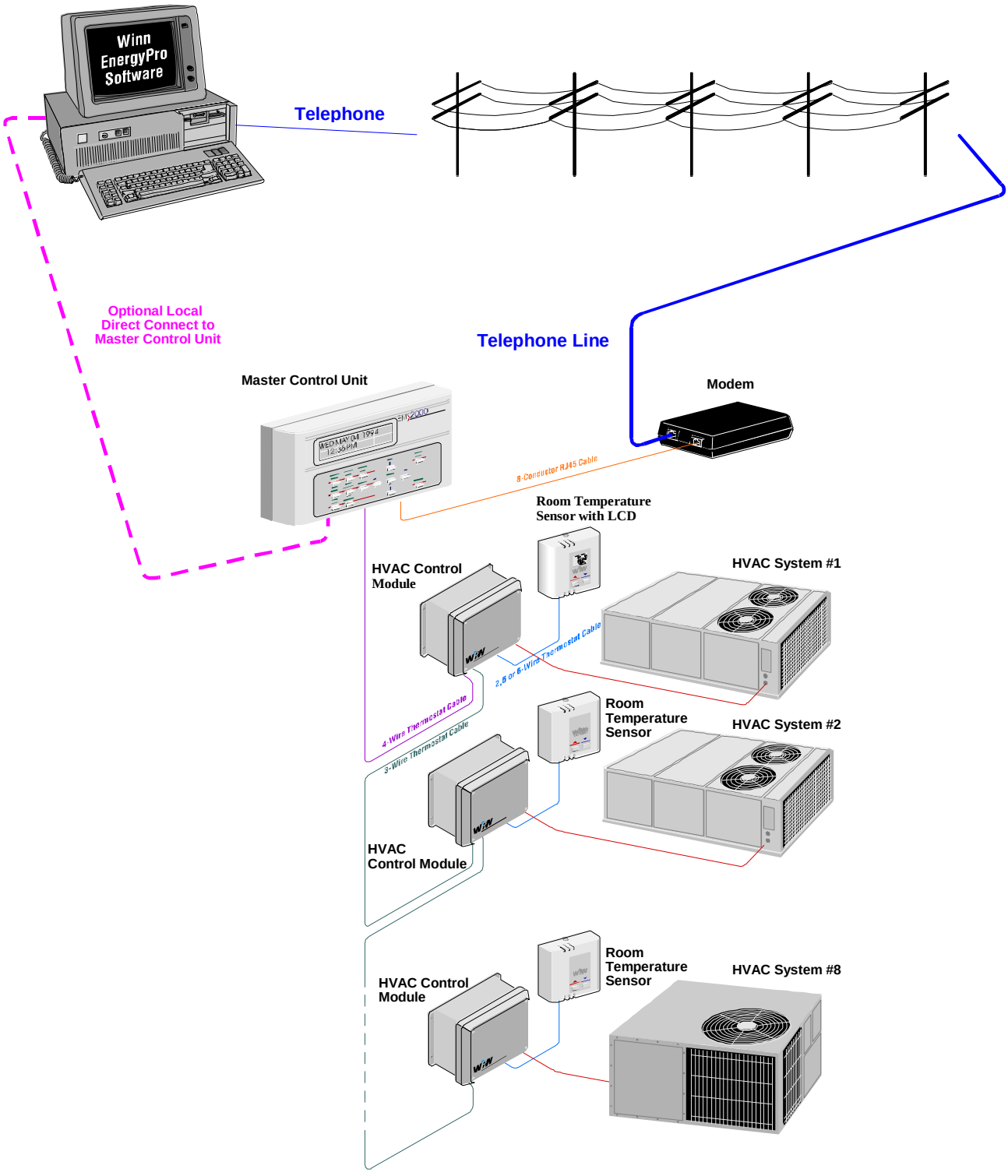


Figure 4. ADRES controlling eight HVAC systems

Typical 16 System Application with Master Control Units for Local Control and PC Computer for Off-Site Control and Reporting

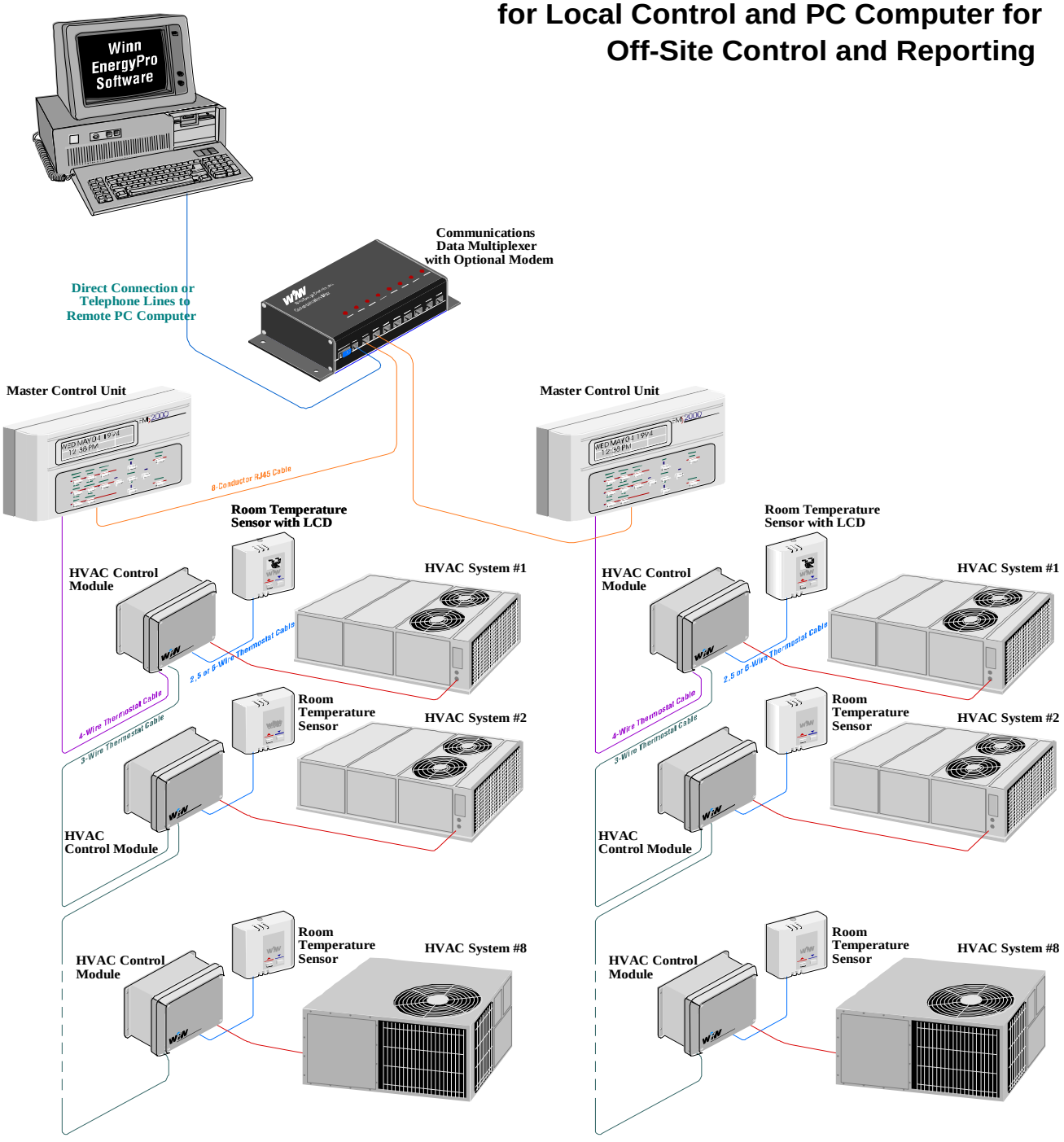
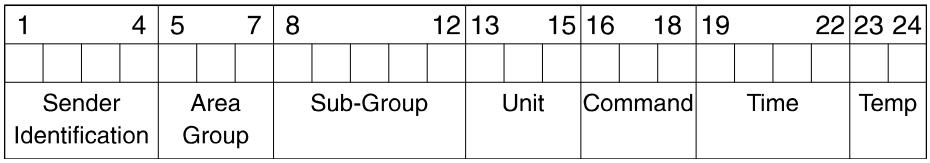


Figure 5. ADRES controlling sixteen HVAC systems

4.0 Utility Demand Side Management

The ADRES allows a utility to access any HVAC system it is controlling and raise the cooling setpoint so that electrical demand and energy consumption is reduced as might be required during peak demand periods. It has been widely accepted that raising the cooling setpoint by 5^{o}F for a period of eight hours would lower the average energy consumption by 15% to 30% depending upon geographic location. The energy reduction during the period the setpoint temperature is setup is in addition to the energy savings produced by the ADRES during normal system operation.

The utility can control any ADRES Master Control Unit or group of ADRES Master Control Units through the RF paging system and raise the cooling setpoint or lower the heating setpoint by 1^{o}F to 15^{o}F. This can be accomplished by an optional RF paging receiver built into the ADRES Master Control Unit. The new setpoint is activated by dialing the paging number corresponding to the Master Control group selected and entering a code in the same manner as entering a telephone number when paging someone. As an alternative, the paging could be automated using a PC Computer with the EnergyPro software program. The number entered contains a Verification Code, an Area Group Number, a Sub-Group Number, a Unit Number and a Command with both Time and Temperature instructions to the Master Control. This command structure allows up to 999 Area Groups with up to 99,999 Sub-Groups in each Area Group and up to 9,999 ADRES Master Control Units in each Sub-Group.



4.1 Sender Identification

The Sender Identification Number prevents unauthorized or accidental accessing of the ADRES systems. There are three access codes available for entering commands into the ADRES and each of these access codes have restrictions. The utility will have a code that allows it to set the heating and cooling setpoint temperatures remotely. The consumer's management will have an access code that allows it to completely program and control the ADRES Master Control Unit remotely. The store or facility manager will have a code that allows the cooling or heating setpoints to be adjusted within a limited range.

4.2 Area Group Number

The Area Group Number can be used to identify a city or area within the utility service area so that it can selectively reduce load as demand rises in a specific area.

4.3 Sub-Group Number

This allows a utility to access up to 99,999 individual customers within the Area Group. The Sub-Group Numbers combined with the Area Group Number provides addressing to over 99 million customers.

4.4 Unit Number

The Unit Number allows up to 99,999 individual HVAC systems to be addressed at a customer location. It is not envisioned that a utility would address specific units within a facility.

4.5 Command, Time and Temperature

The command structure provides a means of controlling the cooling and heating setpoints as well as programming the ADRES remotely. Some of the typical commands are described below.

CMD 001 0000 02

A utility command that raises the cooling setpoint 2 degrees higher than the present room temperature and maintains that setpoint until released by the utility.

CMD 002 0000 03

A utility command that lowers the heating setpoint 3 degrees lower than the present room temperature and maintains that setpoint until released by the utility.

CMD 001 0015 04

A utility command that raises the cooling setpoint 4 degrees higher than the present room temperature and maintains that setpoint for 15 minutes.

CMD 999 0000 00

An internally generated command within each ADRES Control module will return the system to normal operation after an adjustable timer has timed out. The setpoints and all operating conditions are returned to those that were used before the utility took control in order to reduce demand consumption.

4.6 DSM Priority

Whenever the utility takes control of the setpoint for heating or cooling, all other control is restricted to assure the setpoints are not changed. If the ADRES was in consumer control, before the utility took control, the ADRES reverts to consumer control. Otherwise, it returns to local control at the Master Control Unit.

4.7 DSM Status Display

Whenever the utility takes control of the setpoints to reduce energy consumption, a message is displayed on the LCD as shown below. This prevents the consumer from wondering why the room temperature is changing and calling his HVAC service company.

4.8 Comparison to Other DSM Control Used By Utilities

Earlier approaches to DSM by utilities used an external control, a “Duty Cycler,” that was installed at the HVAC system and was activated by an AC carrier signal imposed on the AC power lines. The control was normally wired to open the control wired from the thermostat to the contactor controlling the compressor. This turned the compressor off for varying periods of time to reduce energy consumption. Each facility would respond differently to the loss of compressor cooling and there was no control over the indoor temperature. Typically, the user had no idea the utility had turned the air conditioning off. This resulted in confusion and sometimes caused the user to call their HVAC service contractor because they believed the HVAC system had failed or malfunctioned.

The ADRES solves these problems by providing the utility with proportional and continuous control over the cooling and heating setpoints. This allows the setpoints to be changed as demand rises. By using a smaller change in the setpoint over a larger number of customers, the impact on any one customer’s comfort is minimized and demand is still reduced. In addition, the customer can

see from the LCD display on the thermostat that the utility has modified the setpoint and is in control of the thermostat.

4.9 Tamper Proof

The DSM control is an integral part of the ADRES Master Control Unit and, therefore it cannot be bypassed or disabled by the customer. Often the external controls or duty cyclers supplied by utilities have been bypassed or simply removed by HVAC service contractors at the request of the consumer due to sudden and extreme changes in the consumer's comfort zone.

5.0 Consumer Electrical Demand Savings

Consumer electrical demand savings is produced even without the intervention or control of the ADRES system by a utility. This is accomplished by programming the ADRES to sequence the different air conditioning systems to minimize the number of compressors operating at any one time on a local basis. Each 5-ton air conditioner that can be kept off-line, can reduce demand by 6 to 7.5KW. This can be done during the utility peak demand period by programming a starting date, ending date, and the start and stop times each day.

5.1 Intelligent Control

During the peak utility demand periods, provided the customer has agreed to utility demand side management, the ADRES will periodically turn air conditioning compressors off to control the number of compressors operating at any one time. Before turning a compressor off, the ADRES looks at the setpoint temperature and the room temperature and selects those systems that have been running the longest and closest to the setpoint or satisfying the call for cooling. The ADRES also considers the priority of each system, the amount of temperature rise allowed for each system, and the number of systems that are allowed to operate at any one time.

5.2 Priority Levels

A priority level is assigned to each system so that the systems with the lowest priorities are turned off first. Some systems, such as those used in laboratories and computer rooms will have a priority that prevents them from being considered during demand times.

6.0 Energy Conservation

The ADRES conserves energy by minimizing the amount of time the HVAC system operates, monitoring the performance of the HVAC system to assure that all components are operating efficiently and together in the most efficient mode for the application. Each of these techniques is discussed in detail.

6.1 Time/Temperature Programming

The ADRES can be programmed so that each day may have a different time and temperature schedule with up to four temperature changes per day for cooling and heating. Each program or schedule can use different temperatures for cooling and heating.

The energy savings achieved by raising the cooling setpoint 5^{o}F for an eight-hour period are widely stated as 15% to 30% depending upon the geographic location. Similarly, a 10^{o}F setback in heating for an eight-hour period can reduce energy consumption by another 7% to 15% depending on geographic location.

6.2 Just-In-Time Temperature Programming

The ADRES monitors the outdoor temperatures and computes when it should turn on the heating or cooling to assure that the temperature programmed will be reached at the proper time and not too early. Starting a heating or cooling call 30 minutes early can increase the energy consumption by 6% in eight hours of call time.

6.3 Vacation / Holiday Programming

The ADRES can be programmed at the beginning of the year for up to twelve vacation or holiday periods. These days are entered by date to program holiday temperature settings for both heating and cooling. In a commercial application, this results in significant energy savings.

6.4 Alarm Reporting

The ADRES can be programmed to report alarm conditions of peak demand or energy consumption. The alarms will be reported locally on the Master Control Unit or PC Computer and dialed out to report the alarms to an off site PC Computer for notification and action.

7.0 Energy Conservation By Improved System Efficiency

The ADRES conserves energy by operating the HVAC system in its most efficient mode by monitoring output or supply air temperature, return air temperature, room temperature and outdoor temperature. This allows the ADRES to make complex decisions about compressor, indoor fan, economizer and gas valve / burner operation.

7.1 Energy Recovery at the End of a Cooling or Heating Call

Some new and more expensive heating and air conditioning systems are furnished with a time delay relay (TDR) that keeps the indoor fan operating 30 to 60 seconds at the end of a heating or cooling call to salvage the residual hot or cold energy stored in the mechanical system. American Refrigeration Institute (ARI) has recognized this technique for improving energy efficiency and has provided an additional .15 to .25 improvement in the SEER rating of the equipment with this control.

The ADRES performs this function for equipment that does not have a TDR (most of the equipment in the field) and ADRES performs more than the simple TDR function. In air conditioning, the ADRES monitors the temperature of the supply air and keeps the indoor fan operating until the BTU output has dropped to 25% of its normal output. This is done by monitoring the temperature drop across the indoor coil (return air temperature-supply air temperature). At the 25% level, the BTU output from the system is about equal to the power required to operate the indoor fan to recover the BTU's.

7.2 Intelligent Indoor Fan Operation

Many commercial users operate their indoor fan continuously without regard to the energy being consumed by the fan or the effect on cooling or heating call time. A fan that is operating continuously can actually be heating the indoor environment when the thermostat is in the cooling mode. This may be caused by high return air temperatures, economizers stuck in the open position, poorly insulated return air ducts or make-up air vents that are improperly set.

The ADRES can reduce this wasted energy by operating the indoor fan in five different modes; continuously on, automatic, pulsed, timed continuous on / off controlled. The user can select one or more modes of operation that do not conflict. The different operating modes are described below.

- **Continuous Operation**

This mode is the normal ON position used in most thermostats. It operates the fan continuously independent of the cooling system.

- **Automatic Operation**

  In this mode, the fan will only operate during a call for cooling or heating. At the end of a cooling call, the ADRES will keep the fan operating to salvage the remaining cold energy in the compressor, coil and mechanical system.

- **Temperature Control**

  In this mode the fan will run continuously in cooling as long as the supply air is colder that the room temperature. If the supply air temperature rises to where it could heat the occupied space, the fan is automatically turned off.

- **Timed On / Off Control**

  The indoor fan can be programmed to operate in the continuous mode during certain hours of the day. The ADRES can be programmed for a single timed on then off operating period for each day. This eliminates the possibility of the indoor fan being left operating when a facility is not occupied.

- **Duty Cycled Operation**

  A facility may require some additional operation of the indoor fan to circulate air, but not require the fan to be operated continuously. The ADRES can operate the indoor fan on a duty cycle or pulsed mode where it will operate from 5 to 59 minutes out of each 60-minute interval. The user can program the desired interval for each HVAC system.

7.3 Energy Conservation by Measured Efficiency

The ADRES allows the consumer to measure both operating times and efficiency. This is done by monitoring the amount of time the system operates in cooling or heating and monitoring the cooling-degree or heating-degree days for the period. This provides the consumer with a relative measure of system efficiency. The ADRES tracks the efficiency over a two-month period.

7.4 Energy Conservation by Monitoring Efficiency and Predictive Maintenance

In most applications, a consumer does not repair or maintain an HVAC system until it has failed or its performance approaches failure resulting in a severe negative impact on overall efficiency. The ADRES continuously monitors the HVAC system performance and will generate and report an alarm condition if minimum performance parameters are not maintained. The ADRES allows routine maintenance and repairs to be tracked over a twelve month period. After each service of the HVAC system, the repairs and service performed can be entered into the ADRES and displayed at any time. Preventive maintenance is the best way to prevent degradation of system efficiency.

8.0 Remote Programming and Reporting

The ADRES has a USB port that provides remote access to all of the ADRES functions and stored data by employing a PC Computer with a USB port or a modem. The PC Computer must use the Windows XX operating systems and the EnergyPro software. This allows the user to monitor, control, program, configure and receive alarms from the HVAC systems controlled by each ADRES Master Control Unit located at remote facilities.