Chapter 7

Software/Application Programs

INTRODUCTION

Software packages designed for EMS consist of one or more money-saving programs that contribute to energy conservation through efficient energy management. These programs interact continuously to operate as an integrated system. Consequently, the net energy savings is the sum of their contributions, making it difficult to determine the savings from each program. The following programs perform most of the functions used to save money and energy in buildings.

PROGRAMS

Scheduled Start/Stop

The scheduled-start/stop program consists of starting and stopping equipment based on the time of day and day of week. Scheduled start/stop is the simplest of all EMS functions to implement. This program provides potential for energy conservation by turning off equipment or systems during unoccupied hours. In addition to sending a start/stop command, it is important to have a feedback signal indicating the status (on-off or open-closed) of the controlled equipment. The feedback signal verifies that the command has been carried out and provides the EMS operator with an alarm when the equipment fails or is locally started or stopped.

(**Application notes.**) The scheduled start/stop program operates in conjunction with optimum start/stop, day/night setback, ventilation/recirculation, and lighting control programs.

Optimum Start/Stop

The scheduled start/stop program described can be refined by automatically adjusting the equipment operating schedule in accordance with space temperature and outside air (OA) temperature and humidity. HVAC systems are normally restarted prior to occupancy to cool down or heat up the space on a fixed schedule independent of OA and space conditions. The optimum start/stop program automatically starts and stops the system on a sliding schedule. The program will automatically evaluate the thermal inertia of the structure, the capacity of the HVAC system to either increase or reduce space temperatures, and OA conditions. This accurately determines the minimum time of HVAC system operation needed to satisfy the space environmental requirements at the start of the occupied cycle, and determines the earliest time for stopping equipment at the day's end.

(**Application notes.**) The optimum start/stop program operates in conjunction with the scheduled start/stop program, day/night setback, and ventilation/recirculation programs.

Duty Cycling

Duty cycling is defined as the shutting down of equipment for predetermined short periods of time during normal operating hours. This function is normally only applicable to HVAC systems. Duty cycling operation is based on the presumption that HVAC systems seldom operate at peak design conditions. If the system is shut off for a short period of time, it has enough capacity to overcome the slight temperature drift which occurs during the shutdown period. Although the interruption does not reduce the energy required for space heating or cooling, it does reduce energy input to auxiliary loads such as fans and pumps. Duty cycling also reduces outside air heating and cooling loads since the outside air intake damper is closed (under local loop control) while an air handling unit is off.

(**Application notes.**) (1) The duty cycling program is used in conjunction with demand limiting, schedule start/stop, and optimum start/stop programs. (2) Duty cycling is not advisable for variable capacity loads such as variable volume fans, chillers, or variable capacity pumps.

Demand Limiting

Demand Limiting consists of shedding electrical loads to prevent exceeding an electrical demand peak value (target). This prevents an increase in electrical rates where demand oriented rate schedules apply. Peak demand contract values are established by the utility company using fixed demand intervals, sliding window intervals, and time of day schedules. Many complex schemes exist for reducing peak demand billings; however, all schemes continuously monitor power demand and calculate the rate of change of the demand value in order to predict future peak demand. When the predicted peak exceeds present limits, predetermined scheduled electrical loads are shut off on a prescheduled priority basis to reduce the connected load before the peak is exceeded.

(**Application notes.**) (1) The demand limiting program is used in conjunction with the duty cycling program to prevent any one load from being cycled on or off during the wrong time interval or an excessive number of times. (2) The demand limiting program is also used in conjunction with scheduled start/stop and optimum start/stop programs.

Day/Night Setback

The energy required for heating or cooling during unoccupied hours can be reduced by lowering the heating space temperature setpoint or raising the cooling space temperature setpoint. This applies only to facilities that do not operate 24 hours a day. Space temperature can be reduced from the normal 65°F winter inside design temperature to a 50°F or 55°F space temperature during the unoccupied hours. In space that require air conditioning during unoccupied hours, the normal temperature setting can be reset upwards to a temperature that is compatible with the space special requirements. OA dampers for the HVAC system are closed when the equipment operates during the unoccupied periods in order to avoid imposing additional OA thermal loads.

(**Application notes.**) (1) The day/night setback program operates in conjunction with the scheduled start/stop and optimum start/stop programs. (2) Space temperature sensors must be located to preclude freezing during the night setback period.

Economizer

The utilization of an all outside air dry bulb economizer cycle in air conditioning systems can be a cost effective conservation measure, depending on climatic conditions and the type of mechanical systems. The dry bulb economizer cycle utilizes outside air to reduce the building's cooling requirements when the outside air dry bulb temperature is less than the required mixed air temperature. The changeover temperature at which outside air is used for cooling is based on the outside air dry bulb temperature (enthalpy changeover point is determined by the total air heat content.) When the outside air dry bulb temperature is above the changeover temperature, the outside air dampers, return air dampers, and relief air dampers are positioned to provide minimum required outside air. When the outside air dry bulb temperature is below the changeover temperature, the outside air, return air and exhaust air dampers are positioned to maintain the required mixed air temperature. This program can also be used to compare the dry bulb temperatures of outside air with return air: whenever RA temperature is less than OA temperature, OA dampers close to a minimum position. Separate setpoints can be provided for each HVAC system. Refer to example in Table 7-1.

(**Application notes.**) This program cannot be used where humidity control is required, or when the enthalpy program is selected.

Enthalpy

The utilization of an outside air enthalpy program can be a cost effective energy conservation measure, depending on climatic conditions and the type of mechanical system. The enthalpy cycle utilizes outside air to meet the building's cooling requirements when the enthalpy (total heat content) of the outside air is less than that of the return air. When the outside air enthalpy is less than the return air enthalpy, the outside air and return air dampers are allowed to modulate to admit sufficient outside air to minimize cooling requirements. When the outside air enthalpy is greater than the return air enthalpy the outside air dampers, return air dampers, and relief air dampers are positioned to provide minimum required outside air.

(**Application notes.**) The enthalpy program cannot be used when the economizer program is selected.

Ventilation and Recirculation

The ventilation and recirculation program controls the operation of the outside air dampers when the introduction of outside air would impose an additional thermal load during warm-up or cool-down cycles prior to occupancy of the building. This program can also be used in those facilities which maintain environmental conditions for electronic

Table 7-1. OA-RA Economizer

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   OPERATOR <NAME>                         PGM DAY   5   THU   1 JUN <YEAR> 14:45

                                      * H V A C                 S Y S T E M
-------------------------------------------------------------------------------
<HVAC  2> *2    FRYKLUND HAL H4  FOUNDRY 111  SF  SUPPLY FAN        ON

-------------------------------------------------------------------------------
ACK [_]   CAN [_]  QUIT [_]  MODE [DIR]
   OA HUMID     48.2  % RH    DEMAND     2510.2  KW      OA TEMP      69.1  DEGF


HVAC -     FIELD DATA POINTS
 FOR: 1    HARVEY HALL    A1  ALL FLS WEST
   SF   SUPPLY FAN        ON    WS           DT   DISCH TEMP       67.6  DEGF
   DM   DAMPER MODE       LOC   12           RAT  RET AIR TEMP     70.6  DEGF
   EC   OA-RA DIFF       -2.1  DEGF          HUM  RET AIR HUM      40.3  %RH
 FOR: 1    HARVEY HALL    A2  AUDIT EAST
   SF   SUPPLY FAN        ON    WS           DT   DISCH TEMP       57.4  DEGF
   DM   DAMPER MODE       MIN   I2           RAT  RET AIR TEMP     64.7  DEGF
   EC   OA-RA DIFF        3.8  DEGF HI
 FOR: 1    HARVEY HALL    C   CHLR TRANE
   CH1  COMP1 STATUS      ON                 P1   CHL WTR PUMP      ON    WS
   CH2  COMP2 STATUS      OFF                LL   NORMAL LOAD       ON    WS
   OA   OUTDOOR AIR      69.1  DEGF          CWS  CW SUPP TEMP     40.1  DEGF



COMPUTATION SUMMARY                          PGM DAY 5  THU   1 JUN 1989  14:54
COMPUTATION SUMMARY
C04  GENERAL EQUATION
         C = D1*D2 + D3*D4 + ... + D25*D26       WHEN SP = CLOSED AND C <= D27
         C = D28                                 WHEN SP = OPEN   OR  C >  D27
  0 - 1     HARVEY HALL    A2    A2 ECON
                                         SYS    L1      L2      L3     DATA   UNITS
    C  : COMPUTATION OUTPUT               H     1       A2      EC       3.8   DEGF
    SP : STATUS POINT
    D1 : INPUT                            H    MIS      OA      TOA     68.5   DEGF
    D2 : INPUT                                                           1.0
    D3 : INPUT                            H     1       A2      RAT     64.7   DEGF
    D4 : INPUT                                                          -1.0
    D27: CHECK VALUE                                                   100.0
    D28: DEFAULT                                                         0.0
...END...
  0 - 1     HARVEY HALL    A1    A1 ECON
                                         SYS    L1      L2      L3     DATA   UNITS
    C  : COMPUTATION OUTPUT               H     1       A1      EC      -2.1   DEGF
    SP : STATUS POINT
    D1 : INPUT                            H    MIS      OA      TOA     68.5   DEGF
    D2 : INPUT                                                           1.0
    D3 : INPUT                            H     1       A1      RAT     70.6   DEGF
    D4 : INPUT                                                          -1.0
    D27: CHECK VALUE                                                   100.0
    D28: DEFAULT                                                         0.0
...END...
```

equipment or other humidity sensitive devices during building unoccupied periods. During unoccupied periods, the outside air dampers remain closed. During building occupied cycles, the outside air, return and relief dampers are under local loop control.

(**Application notes.**) This program operates in conjunction with scheduled start/stop and optimum start/stop programs prior to building occupancy.

Hot Deck/Cold Deck Temperature Reset

The hot deck/cold deck temperature reset program can be applied to dual duct systems and multizone HVAC systems. These systems utilize a parallel arrangement of heating and cooling surfaces, commonly referred to as hot and cold decks, for providing heating and cooling capabilities simultaneously. The hot and cold air streams are combined in mailing boxes or plenums to satisfy the individual space temperature requirements. In the absence of optimization controls, these systems mix the two air streams to produce the desired temperature. While the space temperature may be acceptable, a greater difference between the temperature of the hot and cold decks results in inefficient system operation. This program selects the areas with the greater heating and cooling requirements, and establishes the minimum hot and cold deck temperature differentials which will meet the requirements, thus maximizing system efficiency. Space temperature sensors and mixing box or plenum damper positions are used to determine the minimum and maximum deck temperatures necessary to satisfy the space temperature requirements during the building occupied period. Where humidity control is required, the program will prevent the cooling coil from further upward cooling coil control.

(**Application notes.**) This program operates in conjunction with the chilled water reset program.

Reheat Coil Reset

Terminal reheat systems operate with a constant cold deck discharge temperature. Air supplied at temperatures below the individual space temperature requirements is elevated in temperature by reheat coils in response to signals from an individual space thermostat. The reheat coil reset program selects the reheat coil with the lowest discharge temperature or the reheat coil valve nearest closed (the zone with the least amount of reheat required) and resets the cold deck discharge temperature upward until it equals the discharge temperature of the reheat coil with the lowest demand. Where humidity control is required, the program will prevent the cooling coil discharge temperature from being set upward. For air conditioning systems, where reheat coils are not used, the program will reset the cold deck discharge temperature upward until the space with the greatest cooling requirement is just satisfied.

(**Application notes.**) This program operates in conjunction with the chilled water reset program.

Steam Boiler Optimization

The steam boiler optimization program can be implemented in heating plants with multiple boilers. Optimization of boiler plants can be accomplished through the selection of the most efficient boiler to satisfy the heating load. Boiler operating data must be obtained from the manufacturer, or developed by monitoring fuel input as a function of the steam output. Determination of boiler efficiency also takes into account the heat content of the condensate return and make-up water. Based on the efficiency curves, fuel input vs. steam output, the boilers with the highest efficiency can be selected to satisfy the heating load. Boilers may be started manually by a boiler operator or automatically by EMS depending on site requirements. Burner operating efficiency can be monitored by measuring the O_2 or CO_2 in each boiler flue.

(**Application notes.**) The software inputs described may not be required in every case. The designer must study the existing or new system to determine which of the parameters are necessary. Care must be observed when providing automatic start/stop of boiler in lieu of operator supervised start-ups.

Hot Water Boiler Optimization

Hot water boiler optimization can be implemented in heating plants with multiple boilers. The techniques and considerations are the same as discussed in the previous section on steam boiler optimization.

(**Application notes.**) The software inputs described may not be required in every case. The designer must study the existing or new system to determine which of the parameters are necessary. Care must be observed when providing automatic start/stop of boiler in lieu of operator supervised startups.

Hot Water OA Reset

Hot water heating systems, whether the hot water is supplied by a boiler or a converter, are generally designed to supply hot water at a fixed temperature. Depending on the system design, the hot water supply temperature can be reduced, as the heating requirements for the facility decrease. A reduction in hot water supply temperature results in reduction of heat loss from equipment and piping. To implement this program, the temperature controller for the hot water supply is reset as a function of outside air temperature.

(**Application notes.**) A dedicated local loop controller may be implemented.

Chiller Optimization

The chiller optimization program can be implemented in chilled water plants with multiple chillers. Based on chiller operating data and the energy input requirements obtained from the manufacturer for each chiller, the program will select the chiller or chillers required to meet the load with the minimum energy consumption. The program must follow the manufacturer's start-up and shutdown sequence requirements. Interlocks between chilled water pumps, condenser water pumps, and chiller must be in accordance with the chiller manufacturer requirements.

(**Application notes.**) The software inputs described may not be required in every case. The designer must study the existing or new system to determine which of the parameters are necessary. Care must be observed when providing automatic start/stop of chillers in lieu of operator supervised startups.

Chiller Water Temperature Reset

The energy required to produce chilled water in a reciprocating or centrifugal refrigeration machine is a function of the chilled water leaving temperature. The refrigerant suction temperature is also a direct function of the leaving water temperature; the higher the suction temperature, the lower the energy input per ton of refrigeration. Chiller discharge water temperatures (leaving chiller) can be reset upward during non-peak design operating hours to the maximum which will still satisfy space cooling and dehumidification requirements. The program resets chilled water temperature upward until the required space temperature or humidity setpoints can no longer be maintained. This determination is made by monitoring positions of the chilled water valves on various cooling systems or by monitoring space temperatures.

(**Application notes.**) The chilled water temperature reset program will affect any system requiring chilled water.

Condenser Water Temperature Reset

The energy required to operate systems is directly related to the temperature of the condenser water temperature entering the machine. Conventionally, heat rejection systems are designed to produce a specified condenser water temperature such as 85°F at peak wet bulb temperatures. In many instances, automatic controls are provided to maintain a specified temperature at conditions other than peak wet bulb temperatures. In order to optimize the performance of refrigeration systems, condenser water temperature can be reset downward when OA wet bulb temperature will produce lower condenser water temperature. The program must incorporate manufacturer requirements governing acceptable condenser water temperature range.

(**Application notes.**) A dedicated local loop controller may be implemented.

Chiller Demand Limit

Centrifugal water chillers are normally factory equipped with an adjustable control system which limits the maximum available cooling capacity; thus, the power the machine can use. An interface between the EMS and the chiller controls allows the EMS to reduce the maximum available cooling capacity in several fixed steps in a demand limiting situation, thereby reducing the electric demand without completely shutting down the chiller. The method of accomplishing this function varies with the manufacturer of the chiller. The chiller percent capacity can be obtained by monitoring the chiller current input. When a chiller is selected for demand limiting, a single step signal is transmitted, reducing the chiller limit adjustment by a fixed amount. The chiller demand limit adjustment can be performed by shutting out taps of transformers in the control circuit or by resetting the control air pressure to the chiller compressor vane operator. As further need arises, additional stop signals can be transmitted until the demand limiting situation is corrected. Extreme caution must be exercised when applying this program, since incorrect control can cause the refrigeration machine to operate in a surge condition, potentially causing it considerable damage. The chiller manufacturer's recommended minimum cooling capacity limit must be incorporated into the program logic. In general, surges occur in chillers at loads less than 20% of the rated capacity.

(**Application notes.**) This program is used in conjunction with the demand limiting program and each chiller demand control step must be assigned an equipment priority level.

Lighting Control

Time scheduled operation of lighting consists of turning on and off lights, based on the time of day and the day of the week. Additional off commands may be generated at regular intervals to assure that lights are off (relay operated zoned lighting only). An alternative to this program is to initiate only the off function and require that the lights be turned on manually. Emergency lighting is not to be controlled by this program.

(**Application notes.**) The lighting control program is used in conjunction with the scheduled start/stop program.

Table 7-2 shows functional items as they relate to software terminology.

SPECIAL APPLICATIONS

Special software programs are most commonly left to the imagination of the EMS operator after he has a complete understanding of the operating system and necessary sensors are in place. Following are some "non-traditional" programs that have been used which are worthy of consideration.

Variable Speed Drives

Variable speed drives (VSD), as they relate to varying the speed of a fan or pump motor, entered the HVAC industry around 1980. VSDs operate on the principal of varying the frequency to a motor where the speed is directly proportional to the frequency at which it operates. See Figure 7-1.

Fan laws, by definition show that if a motor (and related fan) speed is reduced 50%, then the resulting power consumed is reduced 87%. Similarly, if you desire to save 50% of the consumed power of a motor, the speed only must be reduced 20%.

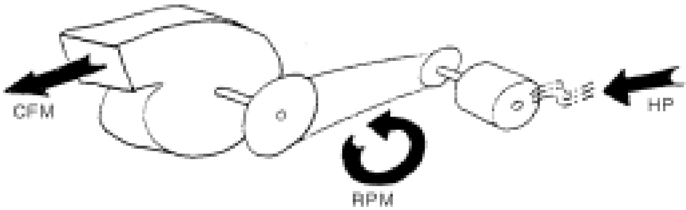
Fan Laws

1. The volume of air delivered by a fan (CFM) varies in direct proportion to the fan speed (RPM). CFM = RPM

Table 7-2. Functional Capabilities of Energy Management System

Function	*Terminology*
Turn off equipment when building is unoccupied according to a set schedule.	Start/Stop Control
Restart equipment at the latest possible time before reoccupancy.	Optimal Start/Stop
Change temperature set points of thermostats when building is unoccupied.	Temperature Setback/Setup
Use "free cooling" from outdoors when temperature is suitable.	Economizer Control
Provide more sophisticated economizer based temperature and humidity.	Enthalpy Control
Reduce excessive heating and cooling in HVAC systems.	Supply Temperature Reset
Balance chiller operation to required loads	Chiller Optimization
Balance boiler operation to loads and control combustion air.	Boiler Optimization
Reduce peak electrical demands.	Electrical Demand Control
Turn off equipment a percentage of the time according to an established schedule to reduce energy use.	Duty Cycling
Logging conditions, equipment run time, energy use, etc.	Monitoring/Alarm

Figure 7-1. VSD and Fan Laws



1. Volume of air delivered by a fan (CFM) varies in direct proportion to the fan speed (RPM).

CFM	=	RPM	
50%	=	50%	
80%	=	80%	(reduce 20%)

2. Power required (HP) varies as the cube of the fan speed (RPM).

$$\underline{HP} = \underline{(RPM)^3}$$

$$13\% = (50\%)^3$$

(of the power)

$$51\% = (80\%)^3 \qquad \text{(reduce 20\%)}$$

Speed Reduction	Speed (RPM)	Volume of Air (CFM)	Power Required (HP)	Power Reduction
0%	100%	100%	100%	0%
10%	90%	90%	73%	27%
20%	80%	80%	51%	49%
30%	70%	70%	34%	66%
40%	60%	60%	22%	78%
50%	50%	50%	13%	87%

2. The power required to drive a fan motor (HP) varies as the cube of the fan speed (RPM). $\underline{HP = (RPM)^3}$

VSDs, when applied to fan systems, can be utilized with the duty cycling or demand limiting software features by receiving a 20% or 50% speed signal from the EMS, thus reducing power consumption by 50% or 87% respectively. This avoids the need to cycle the fan OFF.

When fans are cycled OFF-ON, there is premature wear and tear on the mechanical equipment. Belts and pulleys wear out sooner; starter/contactors receive excessive wear; and automatic valves and dampers cycle excessively. There is also a complete disruption of air movement in occupied spaces which causes a distraction each time it occurs and may even violate code requirements for specified ventilation rates inside occupied areas.

Outside Air Dampers

Time-of-day/outside air (OA) dampers relates to the ventilation and recirculation software program. Many ventilation codes allow for OA dampers to remain closed until one hour after occupancy and can be closed one hour before unoccupancy. This can result in a savings of not cooling warm OA during the cooling season and not heating cold OA during the heating season for two hours per day throughout the year. Although the HVAC fan system(s) would be recirculating air during these time periods, there is no reason to needlessly condition OA. This time-of-day schedule could also be applied to areas of lower-than-normal occupancy rates which might occur during a lunch hour.

How Much Outside Air?

The percent of outside air has always been a question: "are we bringing in 15% or 50% OA?… the damper shaft and blade angle indicates the OA damper is open about 50% so that must be how much OA we are introducing to the HVAC system." We all know that, because of duct configurations, pressure drops through dampers, and other factors, damper position does not guarantee an equivalent % of air flow.

By use of an EMS however, with OA, return air, and mixed air sensors in place, a software program can be written to tell you exactly how much OA is being drawn into an HVAC system. The formula to enter into software is:

$$\%\ OA = \frac{RA \pm MA}{RA \pm OA} \quad \text{(or)} \quad \frac{MA \pm RA}{OA \pm RA}$$

If OA temp: = 60°F and RA temp. = 80°F and MA temp. = 63°F

then: $$\frac{80° \pm 63°}{80° \pm 60°} = 85\%\ \text{OA}$$

Location of the OA and RA sensors are rather standard and the temperature changes very slowly at these sensors. There should be no air stratification problems. Mixed air sensor, however, must have a 8 foot (minimum) averaging element mounted inside the mixed air chamber in a serpentine manner to cover as much of the chamber volume as possible. The mixed air sensor is the most critical of the three elements because of the constantly changing temperature and the problem of stratified air.

Unoccupied Night Purge

During the summer cooling season it is not unusual for the outdoor air temperature to drop considerably at night. Frequently, during the early morning hours prior to building occupancy time, the outdoor air temperature is below building space temperatures. This cool outdoor air can be utilized to cool the building, thereby eliminating the need for mechanical cooling during early morning occupancy hours. This free cooling will generate energy savings and also save wear on the mechanical cooling equipment.

At a preprogrammed time in the early morning hours, the program begins to monitor space and outdoor temperature and humidity. If space conditions indicate a need for cooling, and if outdoor air conditions are suitable, the night purge program is initiated. The program starts the HVAC supply fan and associated exhaust fan, and opens the outdoor air damper 100%. Warm air from the building continues to be purged until the space temperature and relative humidity indoors reach the same levels as the outdoor air conditions, or until the morning start-up program basis. The outdoor air temperature must be above a preselected minimum to ensure that the program is operable only during the cooling season.

The night purge program can be applied to most HVAC systems that are capable of using 100% outdoor air. Some package-type HVAC units and rooftop units are limited mechanically to admit 10 or 20% outdoor air, and therefore, do not qualify.