Welcome

to

Presentation

on

Automation and Controls for Energy Conservation

in

HVAC Systems

Automation and Controls for Energy Conservation in HVAC systems

- Concept of Energy conservation started after the energy crisis of 70s.
- HVAC systems consume 30-40% of energy in a commercial building.
- Need was felt to make HVAC systems energy efficient.

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- An HVAC system has many components like Chillers, Cooling Towers, AHUs, Pumps, Fans, etc.
- Each component could have multiple units in an HVAC system.
- Two ways to achieve energy efficiency.
  - Improve the operating efficiency of each component.
  - Improve collective efficiency of the whole system.

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- An HVAC system could be considered as a team with its components as players.
- A team manager is generally required to get the best out of the team.
- It has to plan in advance the role of each player.
- Controls play the role of team manager.

- Till 80s the controls in use were Pneumatic, Electric and Analog Electronic.
- Then, Control logics had to be hard wired, and were
  - Difficult to build, and
  - Expensive.
- Therefore, more effort was directed towards improving equipment efficiencies.

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- Later, Digital technology made microprocessors available.
- It lead to development of computers and software logics.
- Centralized Building Management Systems were introduced.
- All the controls were connected to a centralized computer.

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- Now, complex control logics could easily be created in software.
- Humans rule this planet because of their communication skills.
- Communication improves collective performance substantially.
- Microprocessors could communicate with each other.

- And thus, it became possible to create a team in the real sense.
- With all the team players reporting to the team manager, the Central Computer.
- However, too much centralization was also not good.
- Extensive Input/Output wiring created reliability issues.

- Further development in microprocessors lead to development of Direct Digital Controls (DDC).
- Now, each DDC could carry out most control functions, independently, without any support from central computer.
- But at the same time it could communicate with the Central Computer as well as other controllers.

- Thus came Building Management Systems with distributed intelligence.
- Much more efficient and reliable.
- And controls were now ready to play a major role in energy conservation.

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- I made a presentation on similar topic in 1987 in a seminar organized by ISHRAE at hotel Ashok in New Delhi.
- Many of the control strategies for energy conservation discussed at that seminar remain the same.
- Few more are now possible with the improvements in available technologies.
- But, the mindset of people has not changed, at all.

- Even today most HVAC managers/designers think money on controls is not well spent.
- Controls cost a few percent of total HVAC system cost.
- But HVAC managers are always looking to cut cost of controls.
- That reminds me of a book by Sharu Ragnekar - "In the Wonderland of Indian Managers"

- A must read book.
- It talks about "what ought not be done, but is done"
- It describes an incident where a management decides to cut down on stationery costs to save money.
- Stationery costs a fraction of a percent of total expenses, how much can be saved.
- A minuscule amount, not worth the effort.

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- HVAC equipment manufacturers, over the past few decades, have increased the operating efficiency considerably.
- The industry is fast approaching the theoretical limit of efficiency improvement of individual equipment.
- It is becoming difficult to improve equipment efficiency further, economically.
- The law of diminishing return has set in.
- Whereas, the energy saving potential of controls has only been exploited marginally.
- Much better energy saving returns are possible with little monetary input.

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- HVAC designers spend a lot of time, energy and money in selecting the most efficient equipment.
- Each equipment is designed to perform best under certain predefined operating conditions.
- Car manufacturers' often state mileage under test conditions.
- Road conditions differ & so does the mileage.
- Actual mileage achieved also depends on driver's skill

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- Same is true of HVAC equipment.
- Operating conditions differ from test conditions.
- HVAC system loads vary substantially depending on
  - Solar load
  - Ambient conditions
  - Occupancy
  - Lighting
  - Equipment/Process load

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- HVAC systems rarely ever operate at full load.
- Most of the time operation is at part-load.
- Each component may be selected for most energy efficient operation, but actual efficiency achieved depends on the actual operating conditions.
- Controls are needed to achieve
  - The best efficiency of each equipment.
  - The best efficiency of the whole system.

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- Most energy efficient equipment has controls to ensure best individual performance.
- More controls are needed to ensure best system performance under varying load conditions.
- Two chillers each operating at 50% capacity would most probably consume more energy than one chiller running at 100%, controls are required to take such decisions.
- Controls decide when to operate, which equipment, under what conditions.

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- System performance takes precedence over individual performance.
- Therefore, the need of the hour is to put control strategies in place to improve system efficiency rather than concentrating on improving the individual efficiencies of the system components.
- It has potential to deliver energy savings previously unthinkable.

- Another area that needs attention is the cooperation between HVAC engineer and controls engineer.
- Mechanical engineer understands HVAC process, Control engineer understands how to control a Process.
- Both have to cooperate to be able to develop control strategies.

- Microprocessor based controllers (DDC) have made the life of control engineer easy.
- Now, programs can be written in software and can easily be changed also.
- Achieving control logics in hard wired system was always difficult, and changing even more so.

- DDC controls are inherently dumb.
- Intelligence is built in to them by programs.
- Programs tell them what to do, when.
- For that programmers are needed.

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- Here, once again, HVAC managers fail to realise their importance.
- Many a times they buy the best controls, but are unwilling to pay software development cost.
- They fail to differentiate the difference between the software that comes as part of hardware and the software that has to be developed to suit the site.
- Each project is different and has to be programmed differently.
- Common solutions do not work.

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- In developed countries the software could almost cost as much as the hardware.
- Skilled engineers with sufficient knowledge of HVAC and control technology are required to write good control strategies, and have to be paid well.
- Its time to recognize soft skills and non-tangibles.
- Many control strategies have been known for decades but are still not being implemented, mainly due to lack of skilled engineers.

Automation and Controls for Energy Conservation in HVAC systems

- Some of the control strategies for energy conservation that can easily be implemented are:
  - Optimum Start/Stop Control
  - Enthalpy Optimization
  - Night Purge Cycle
  - Cooling Tower Management
  - Variable Flow Water System
  - Chiller Staging
  - Managing Low ΔT Syndrome

Optimum Start/Stop Control

- Buildings have large mass and it stores heat.
- Stored heat resists change in temperature.
- This effect is known as Thermal Inertia.
- Larger the building, more the Thermal Inertia.
- This effect can be used to save energy as well as improve comfort in intermittently occupied buildings.

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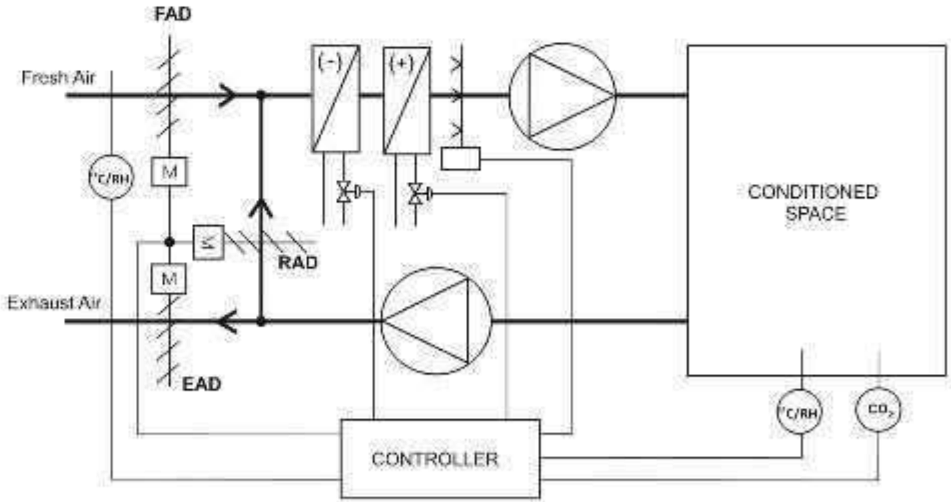
- HVAC plant could be started early so as to achieve comfortable conditions by the time occupancy starts.
- Similarly, the plant could be shut off early and let the thermal inertia provide the necessary heating/cooling till the end of occupancy.
- How early a plant should be started or stopped depends on ambient conditions, load and heat stored in the building.

Enthalpy Optimization

- Energy savings may be realised by choosing air source, either return air or outside air, whichever contains least/most heat depending on cooling /heating season.
- Temperature comparison suffices for systems maintaining temperature only, enthalpy to be compared for systems controlling both temperature and relative humidity.
- Enthalpy is derived from temperature and relative humidity measurements.

Automation and Controls for Energy Conservation in HVAC systems

- During times when the outside air conditions are favorable, more of outside air and less of return air is used.
- For better results such air handling unit should have,
  - Two fans, one for supply air and the other for return air,
  - Three sets of dampers, one set each for outside air, return air and exhaust air.
- Strategy is to utilize the maximum of free heating/ cooling potential of outside air before using mechanical cooling/heating.

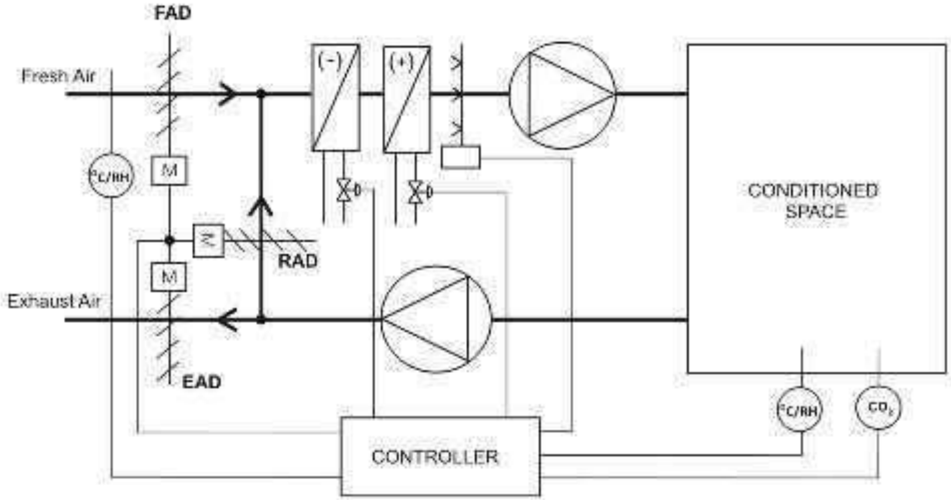


Enthalpy Optimization

Night Purge

- It is somewhat similar to enthalpy optimization.
- It is carried out during night time when the building is unoccupied.
- Temperature/enthalpy of the inside air is compared with outside air and if outside conditions are favorable the same is circulated.

- This reduces the mechanical heating/cooling requirement next morning.
- Again, for better results such air handling unit should have,
  - Two fans, one for supply air and the other for return air,
  - Three sets of dampers, one set each for outside air, return air and exhaust air.

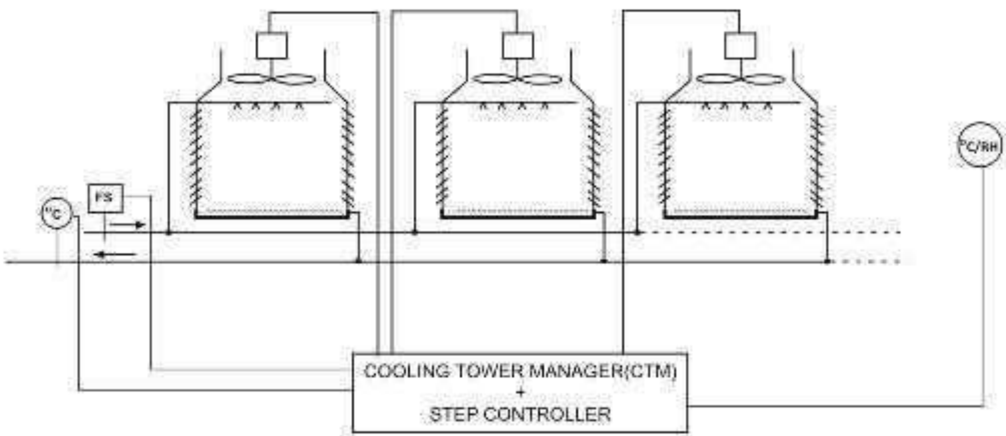


Enthalpy Optimization

Cooling Tower Management

- Cooling Tower design is based on,
  - Ambient wet bulb temperature
  - Approach – difference between ambient wet bulb and leaving water temperature
  - Mechanical construction
  - Air flow.

- Lower leaving water temperature ensures better chiller efficiency due to reduced condensing pressure.
- Substantially lower leaving water temperature may not equally reduce chiller power consumption.
- Under such conditions, when wet bulb temperature is low, energy can be saved by either
  - Reducing the number of operative cooling towers, or
  - Reducing the air flow by reducing fan speed.



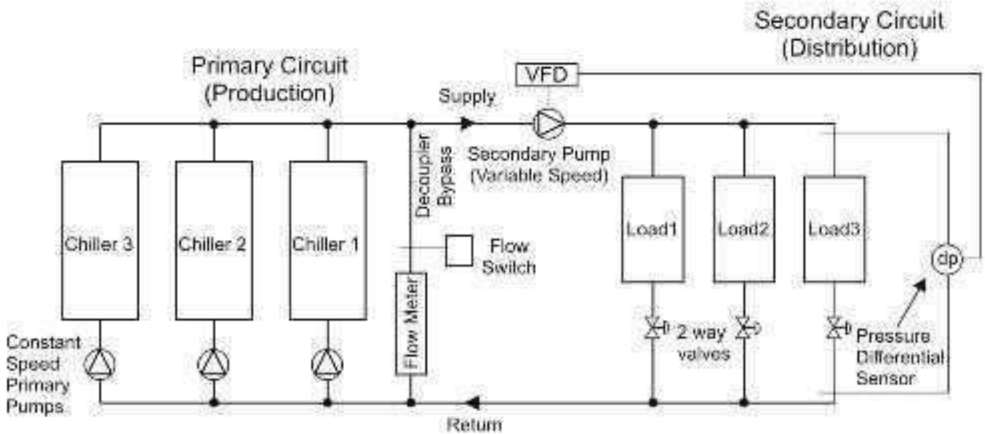
Cooling Tower Management

Variable Flow Water System

- I installed a variable flow water system at Muscat Airport in Oman in 1984.
- The controls used then were primitive from today's standard, but the concept has remained the same.
- Here, two water flow circuits are used, primary and secondary.
- The flow rate in the primary circuit remains constant for a given chiller capacity whereas the same in secondary circuit varies as per instant load.

- The flow rate in the secondary circuit is varied by changing the pump speed.
- A lot of power can thus be saved, as HVAC systems operate at part load most of the time.
- The first most important thing to understand in such a system is the function of Decoupler Bypass.
- Its function is to hydraulically isolate the primary and secondary flow circuits.
- It bypasses the excess water in any of the two circuits.

- The second most important thing to understand is how to control the pump speed.
- Generally, a differential pressure transmitter is installed at the farthest hydraulic circuit to ensure sufficient water supply at all times.
- However, to save more power, in systems with BMS the control valve position of each hydraulic circuit can be monitored and pump speed can be adjusted so as to keep at least one control valve fully open.



Variable Flow Water System

Chiller Staging

- Primary objective of chiller staging is to service the instant load with minimum number of operative chillers and associated equipment.
- Chillers have limited range of capacity control.
- Therefore, multiple chillers and pumps are used to service fluctuating HVAC load.
- Chiller's individual capacity control is followed with switching chillers and associated equipment ON/OFF.

- Staging of chillers can easily be automated by installing a flow switch and a flow meter in the decoupler bypass.
- Flow through decoupler bypass indicates capacity mismatch between the instantaneous load and operative chiller capacity.
- Forward flow, from supply header to return header, in the decoupler bypass indicates surplus whereas reverse flow, from return header to supply header, indicates deficient operative chiller capacity.

- Flow switch is installed in the bypass to detect reverse flow and in such case a chiller is switched ON.

- Flow transmitter measures the forward flow in the bypass and a chiller is switched OFF whenever the forward flow in the bypass header increases beyond 110% of the flow rate of a single chiller.

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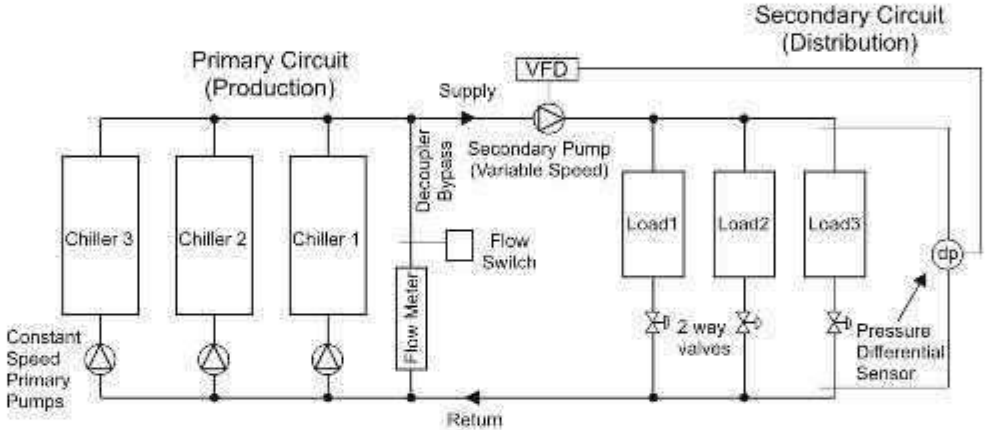

Variable Flow Water System

Managing Low ΔT Syndrome

- The problem is so widespread that it is called a syndrome.
- Low return water temperature results in low ΔT across the chillers as the chiller leaving water temperature is generally fixed.
- A system with lower ΔT has higher water flow rate for the same capacity.

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- Increase in water flow rate consumes more pumping power.
- It reduces chiller capacity and increases power consumption per unit of heat output.
- Higher flow requirement in secondary circuit sometimes may also necessitate running additional chiller, further increasing energy consumption.

- Low ΔT across chillers could be for any or combination of following reasons:
  - Forward flow in decoupler bypass
  - Excess water flow through AHU coil
  - Inefficient heat transfer in AHU coil
- In Primary constant Secondary variable flow systems forward flow is always maintained so as to keep chiller capacity above the load requirement.

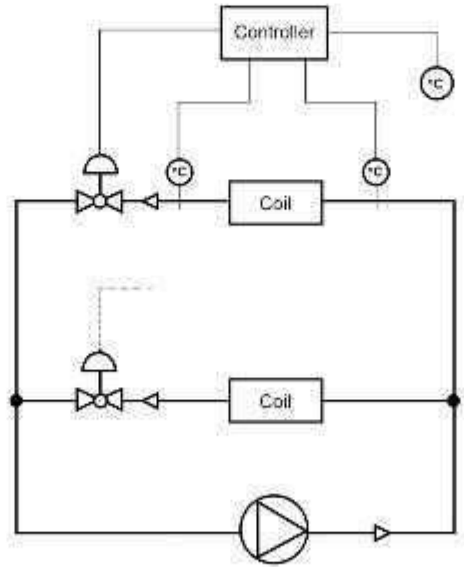
- The solution to above problem is to go for Primary variable flow system, but it has its own other problems.
- The other two reason can easily be over come by controlling ΔT across AHU coils.
- In both these cases heat transfer capacity of water flowing through coil is more than the heat transferred by AHU coil to air.
- Heat transfer capacity of coil is worked out based on ΔT, water flow rate and air flow rate.

- Its actual capacity could get affected by
  - Change in air flow rate due choking of filters
  - Fouling on air and/or water side
  - Dry or wet operation
  - Air entering temperature
- Keeping ΔT constant across the coil ensures that the heat transfer capacity of water flowing through it matches the heat transferred by coil to air.
- Generally, flow through a coil is controlled by a control valve operating under the dictates of a space sensor.

- Low ΔT across coil means that the control valve is permitting more water to flow through it than required.
- Two water temperature sensors, one at inlet and other at outlet of coil, can be added to the control loop.
- Controller can be programmed to override the dictates of space sensor whenever ΔT drops below the set point.

- The point to be noted is that whereas the space sensor operates the control valve to allow water flow to satisfy the instant load requirement, the ΔT sensors allow only as much water as the instant heat transfer capacity of the coil.

Automation and Controls for Energy Conservation in HVAC systems



Low ΔT Control

Conclusion

- Think of control systems as the brains that operate HVAC equipment.
- Controls play an important role to ensure peak performance of an HVAC system.
- A well-designed and installed control system improves the operating efficiency of a building, while enhancing comfort and reducing costs.

Thank you.