CHAPTER 1

INTRODUCTION AND MOTIVATION

GENERAL

Energy saving has become a subject of continual study to conserve natural resources. Energy saving for the Heating, Ventilating and Air-Conditioning (HVAC) systems have been studied and implemented extensively. The purpose of HVAC control systems is to keep people comfortable within an enclosed space, to maintain Indoor Air Quality (IAQ) and thermal comfort. Although comfort zone is through of an achieving a desired temperature in a building, it is also achieved by maintaining a desired level of humidity, pressure, radiant energy, air motion, and quality.

The Variable Refrigerant Volume (VRV) systems that vary refrigerant volume, are basically large-capacity versions of ductless multi-split air-conditioning systems. The revolutionary variable refrigerant volume systems first appeared in Japan in 1982 and are now used throughout the world. In contrast to the conventional HVAC systems, they circulate the refrigerant directly to multiple evaporator units, rather than using water (in a chiller) or air (in ducted DX systems) to achieve heat transfer to the conditioning space. Energy saving can be achieved with a VRV system and it can be attributed to the system’s high part-load efficiency. As a high-efficiency air-conditioning scheme, the VRV air-conditioning system is finding its way in office buildings. It is fast replacing the traditional chilled
water systems owing to its waterless operation, absolute flexibility and energy saving features. The VRV system modulates the refrigerant volume according to capacity requirements.

The Primary concern in designing an air-conditioned building encompasses proper thermal comfort, IAQ, Noise, Energy, Life Cycle Cost and Reliability. Of these, the most important are thermal comfort, IAQ and energy savings. The HVAC systems are major energy consumers in most industrial and commercial buildings. The HVAC system can cost up to 30% of the first cost of a building and 40% of the building’s operating energy expenses. A proper system design is one of the ways of reducing energy use and life cycle costs of a facility, as well as enhancing the performance of HVAC systems.

COMMON THERMAL COMFORT PROBLEMS

Comfort problems are common in many of the air-conditioned buildings. Explaining all the issues affecting comfort can be difficult, especially as it relates to the operation of a space heating and cooling system. The foremost of these are discussed.

The performance of a ventilation system is to provide satisfactory air quality conditions depending on its effectiveness in supplying adequate outdoor air to various locations in the occupied region and removing air contaminants generated within the room. Most of the designers use the ASHRAE standard 62-2001, that bases ventilation rate on a per person value. Even the average pollutant concentrations found indoors are more than the normal threshold limit. While pollutants commonly found in indoor air are responsible for many harmful effects, there is considerable uncertainty about what concentrations or periods of exposure are necessary to produce specific
health problems. People also react differently to exposure to indoor air pollutants. It is one of the imperative issues, which was often neglected by the HVAC designer.

The purpose of any ventilation system is to provide sufficient amount of outdoor air to remove contaminants and to maintain the interior environment at a comfortable temperature and relative humidity. But in practice, ventilation may have a lesser effect, due to a poor supply air distribution or a surplus. Proper distribution of conditioned air plays an important role in both the comfort of the occupants and the air quality of air-conditioned space. The effectiveness of ventilation systems is directly related to the manner in which supply air is circulated within the occupied zone. This pattern of air circulation, is in turn influenced by the location of air supply outlets, windows, room geometry, exhaust, and interior furnishings, as well as by the building’s heating and cooling systems.

According to the ASHRAE standard 113-1990, air velocity is an important factor in the calculation of the comfort zone. However, the standard also restricts the extent to which air velocity can be used to achieve comfort, by limiting it to a specific maximum of 0.15 m/s in winter and up to 0.25 m/s in summer. So the airflow velocity in the interior of the air-conditioned space is the most important factor of assessing thermal feeling during ventilation, because it relieves the ‘hot’ and ‘humid’ feeling even if air temperature remains constant.

Maintaining constant thermal conditions in air-conditioned space is important. Even minor deviations from comfort may be stressful in some places like offices, industries and research areas and it leads to impaired performance and safety. Conversely, workers already under stress are less tolerant of uncomfortable conditions. The person experiencing thermal discomfort will feel either too hot or too cold. While thermal discomfort may
not directly harm people, it does have many disadvantages. People may be less productive, feel tired or irritable, and make more mistakes that could result in injuries (Olesen 2002).

1.3 INDOOR AIR QUALITY PROBLEMS

Indoor Air Quality (IAQ) has become a pervasive problem plaguing the building industry worldwide. Poor IAQ in commercial and office buildings is primarily related to new building technology, new materials, new equipments and energy management operation systems. Occupants of buildings with air quality problems suffer from a common series of symptoms, including eye, nose, throat irritation, dry skin and mucous membranes, fatigue, headache, wheezing, nausea, and dizziness (WHO 1982). Although these symptoms are of significant concern and may in a limited number of cases lead to building-related illnesses, by far the biggest problem facing the engineering community is discomfort rather than serious health impairment. Discomfort leads to increased absenteeism and reduced performance and productivity. Pollution free environments are practically impossible. Optimum IAQ relies on an integrated approach to managing exposures by the removal and control of pollutants and ventilating the occupied space properly.

Increasing the inflow of outdoor air can reduce concentrations of indoor air pollutants. This too has to be done, taking care that the pollutants are removed from every part of the room, and the energy consumed during the process is being used efficiently. This is because, improper methods of pumping of the outside air can result in the formation of dead zones i.e., regions with no air circulation to have excess hazardous pollutant levels making it dangerous for the occupants.
Good IAQ may be defined as air that is free of pollutants that causes irritation, discomfort or ill health to occupants, of premature degradation of the building materials, paintings and furnishings or equipment. Thermal conditions and relative humidity also impact the perception of air quality in addition to their effects on thermal comfort. Focus on IAQ issues increased as reduced ventilation energy-saving strategies, and consequently increased pollution levels, were perceived. A poor indoor environment can manifest itself as a sick building in which some occupants experience mild illness symptoms during the period of occupancy. More serious pollutant problems may result in long-term or permanent ill-health effects. The IAQ of a building directly impacts the health and productivity of its occupants. There are several design strategies that can be used to deliver good IAQ. Controlled ventilation, proper design, occupant behavior, and the use of appropriate healthy building materials with a holistic design can provide good IAQ. Proper controller design, good construction, proper functioning, and well-maintained HVAC system will reduce the IAQ problem, if not eliminate, the majority of IAQ complaints by building occupants.

ASHRAE standards 62-1999 recommend the control of specific known contaminants. This is not feasible, as the pollutants in today's indoor rooms are innumerable. Natural ventilation is opted to improve the air quality indirectly. But, it was observed that naturally ventilated buildings in Canada have high levels of biologically active contaminants and higher air change rates making it more uncomfortable and uneconomical as determined by Lawton et al (1998). Hence other strategies are to be tried out. The three basic strategies to maintain IAQ are source control, air cleaners and ventilation improvements. Source controls are source specific and are aimed at removing the source. This is not always applicable when the source is an integral part of the zone. Air cleaners are designed only to remove suspended particulate matter. Hence, it cannot be expected to remove pollutant gases. For IAQ
maintenance, David and Daniel (1999) suggested that ventilation is the best solution as it is not a pollutant specific strategy. Inadequate ventilation can increase indoor pollutant levels by not bringing in enough outdoor air to dilute emissions from indoor sources and by not carrying indoor air pollutants out of the house as reported by the Environmental Protection Agency (EPA 1995).

1.4 CONTROLLER PERFORMANCE

Conventional control recognizes only the extremes. In refrigeration, for example, a conventional thermostat recognizes only whether temperature or suction pressure is above or below a set point. It then starts or stops compressors and fans accordingly. If the controller set points are too close together, the compressor and fans will short-cycle. Short cycling reduces equipment life, and it also wastes energy because startups require in-rush currents about 10 times as high as those for continuous operation. On the other hand, if the set points are too far apart, the product will experience wide temperature swings that may affect the life of the product.

In most of the commercial refrigeration systems, the fan and compressor speed are normally controlled using conventional controllers like the ON-OFF controller and the Proportional Integral and Derivative (PID) controller. In the PID, as the controller-settling time is more, single input - single output and mathematical models have to be designed. In the proposed system the conventional controllers are replaced by a fuzzy logic controller (FLC) in which there is fast response time and less peak overshoot and the system is fully knowledge-based in which multi inputs - multi outputs can be taken. Thus, by using the FLC for controlling the fan and compressor speed with respect to the load, conservation of thermal energy is possible.
1.5 HIGH ENERGY CONSUMPTION

The HVAC system components such as the fan, duct and cooling coil are designed for full load conditions. But, a full load will not prevail throughout the period of operation. In the conventional Constant Air Volume (CAV) system, the fan speed remains constant throughout its operation irrespective of the load, and hence the temperature in the zone decreases when there is a decrease in the load. This results in thermal energy wastage at part-load operation, thereby affecting thermal comfort. The CAV is replaced by the Variable Air Volume (VAV) system in which the fan speed is varied in accordance with the load. By varying the fan speed with respect to the duct static pressure and the damper opening in the VAV box according to the temperature to be maintained in the particular zone, the energy is conserved and thermal comfort is achieved within the zone.

The thermal comfort in the zone is maintained in the occupant zone by maintaining local air velocity, relative humidity, according to ASHRAE standards. In the VAV system, during part load operations, there is a problem of poor air distribution, which can be avoided by increasing the velocity of air at the inlet. By varying the velocities, the throw at the inlet is provided optimally and the problem of poor air distribution is minimized.

1.6 MOTIVATION OF THIS RESEARCH

The need for higher productivity to match the growing competition has forced employers to look for better indoor work environments. Better work environments are expected to prevail, when the guidelines framed by ASHRAE standards are implemented. Though the investigation on an already competing industry for this implementation, may be fruitful, it is practically troublesome. The design of a proper ventilation system has become a very urgent and long unsolved puzzle for a HVAC engineer. Most of the
ventilation systems are found to be insufficient in providing proper comfort conditions. The design for proper comfort conditions includes supply of conditioned air with appropriate design of a proper air distribution system. Maintaining a constant temperature throughout the room, and reducing the concentration of the contaminants inside the room are also to be considered. These factors play a vital role in the design, as they are interdependent. An attempt is made in the present work to analyze the air distribution pattern of the conditioned space with the following objectives.

The intention of selecting a Variable Refrigerant Volume (VRV) system for commercial air conditioning applications instead of conventional chilled water system is due to the following major reasons:

- Chilled Water (CHW) based air conditioning systems are less effective at part load conditions
- CHW has less energy efficiency than that of VRV systems
- The operational and maintenance costs of CHW systems are greater when compared to those of VRV systems
- Standby equipment is required and
- It occupies more space in the building

Although VRV systems are basically large-capacity versions of energy efficient multi-split air-conditioning systems, in most of them, the thermal comfort and IAQ are less pronounced. The VRV system employs a relatively larger amount of refrigerant, which may be either exposed or embedded in building structures where untreated leakages in the piping system may result in significant cost of refrigerant replacement. However, such risks are also found in other systems such as chilled water system (certainly water is less expensive), it is the matter of quality installation and testing procedures and adequate maintenance program to be implemented. In
the present work, it is aimed to develop a simulated model of the VRV-VAV system. Also the combined VRV-VAV A/C system that employs a variable speed rotary compressor integrated by an inverter technology, under two ventilation schemes for summer and winter design conditions will be investigated experimentally. The simulated model enabling the concept of fuzzy logic control analyzed under three ventilation techniques for the two weather conditions together, shall overcome the above mentioned troubleshooting and shall yield a positive result on the three broad areas such as thermal comfort inside the conditioned space, IAQ and energy conservation.

An attempt was made in the present research to analyze the controller design for thermal comfort, IAQ and energy saving in the VRV-VAV air conditioning system with the following objectives to

- Estimate the energy saving in the VRV-VAV Air conditioning system with the energy efficient controller.
- Implement the energy conservation techniques in order to improve the IAQ and energy saving.
- Carry out the detailed analytical investigations in air distribution patterns in a VAV air-conditioned room.
- Conduct experimental studies in a software laboratory for IAQ and thermal comfort assessment.
- Design the optimal controller for the VRV-VAV Air conditioning system using Genetic algorithms.
- Develop a scale model, take measurements and compare the results with the simulation results.
- Test the combined VRV-VAV A/C system experimentally under summer and winter conditions.