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Integrating VRF Systems for Improved Efficiency and Comfort

Variable Refrigerant Flow (VRF) systems are both scalable and flexible, two factors that have contributed to the increase in VRF applications in recent years. Modular outdoor units using variable-speed compressors make it possible to design VRF systems or subsystems with capacities up to 30 tons, with the capability of connecting up to 40 indoor units or 40 separate zones each. Individual or ganged outdoor units can easily be paired with a variety of indoor unit sizes and styles. The flexibility of the VRF system makes it an excellent choice for a wide array of applications, from providing supplemental cooling to handling entire buildings. In all design applications, a DOAS (dedicated outdoor air system) unit is required to meet ventilation requirements. With the broad range of products offered by many manufacturers, it is now much easier to integrate a VRF system with many other heating, ventilation and air-conditioning (HVAC) systems. An integrated HVAC design, including equipment and controls, will further improve total building energy efficiency and occupant comfort. This article will look at applications in which integrating more than one HVAC technology into a unified building system provides benefits from each system and improves overall results.

Systems Integration Applications

Below are some applications that illustrate the benefits of integrating VRF technology with other HVAC systems.

New Buildings

A new building offers a designer the opportunity to find the one best system that meets the project requirements. Among the many current system types that may be considered, the added benefits of an integrated design can position the VRF system as a top competitor. An important benefit of a VRF system is how it handles diverse zoning sizes and needs.

VRF systems are optimally efficient when they are serving multiple zones with a diverse load profile, so the natural tendency is to lay out the entire building with a VRF system. But what if the building has several large open areas or large conference rooms? Serving these large open spaces from a VRF system will limit the load diversity seen by the outdoor unit and will generally require the use of larger ducted equipment in conjunction with the VRF system. What if, instead of serving these spaces with a larger VRF system, one or several high-efficiency rooftop units (RTU) were used instead? Those rooms would then be served by larger ducted equipment, but would still provide equivalent zone controls and excellent turndown and efficiency. The RTUs could provide a simpler method for integrating demand controlled ventilation (DCV) into the design, and provide more flexible static capabilities with greater fan/motor options.

The other very common integration solution seen today in the hospitality market is the combination of PTAC (packaged terminal air conditioner) units and VRF systems. In these solutions, the individual rooms are served by PTAC units while the common areas, lobby and small offices are handled by VRF systems.

VRF System Integration Examples

Mixed-Use Buildings

Design Challenges

Consider a mid to high-rise building that is mixed-use, multifamily residential on the upper floors and retail/ restaurant on the lower floors. The VRF system would be used to condition the residential portion of the building, providing individual zone control to each apartment or condo. For the retail and restaurant HVAC needs on the lower floors, the VRF system would likely require longer line lengths which lead to cooling capacity losses. Coupled with the typically high ventilation air requirement for restaurant and retail spaces, those spaces become challenging to design using VRF.

Integrated Solutions

Instead of VRF for the lower levels, an air-cooled chiller coupled with air handlers and zoning terminals could be considered. The constant water temperature maintained by an air-cooled chiller makes its use ideal for areas requiring higher amounts of ventilation air and the associated high latent loads. The water piping required by the chiller could be run from the roof with relatively little utility shaft space required. This approach maximizes the benefits from both systems and results in a more energy-efficient and comfortable building.

School Buildings

Design Challenges

Next, consider a typical K-12 school, with classrooms, a gym, a cafeteria/auditorium, and offices. The number of individual spaces is large, schedules are quite varied, and often there is partial use of the building during hot and humid summer months. Terminal systems are often given strong consideration, traditionally classroom unit ventilator and rooftop designs. Bigger schools often see central plant chilled water designs. Heat recovery is often provided using a water source heat pump system, and geothermal designs are selected to earn LEED points.

Integrated Solutions

The offices and meeting spaces may be better served by a VRF system providing independent zone control to each space, along with providing the summertime duty without bringing a central system on line. The gym and cafeteria/ auditorium are large open spaces with relatively high outdoor air ventilation requirements and varying schedules, making a perfect application for high-efficiency rooftop units, or a chilled water system with air-handling units (AHUs) and zoning terminals like VAV (variable air volume) or induction beams. Different systems in the building can be tied into one building automation system with programming to effectively bring on a given system based on demand and occupancy.

TRADITIONAL APPLICATIONS OF VRF SYSTEMS

Different buildings may require different indoor unit types depending on the design requirements or existing conditions of the building.

Historic Buildings

Older existing buildings may have limited available hidden space above ceilings or within walls for refrigerant piping and/or zone or ventilation ductwork, and may require ductless or smaller ducted systems to accomplish building conditioning. A VRF system is ideal for such projects because of the small refrigerant piping, separate ventilation systems using smaller ductwork or even natural ventilation, and the ability to unobtrusively fit indoor units into period construction methods and finishes.

Renovation Projects

Existing buildings undergoing a first major system upgrade or retrofit may have existing ductwork in place, making the choice of larger ducted systems more cost effective. When the full existing system is removed, including ductwork, piping and controls, the HVAC system design can be treated almost like a new building project. If everything is abandoned in place, VRF fits easily into the tight spaces between existing hard ceilings and new suspended ceiling.

Warehouses

Design Challenges

Generally, warehouses are single-story buildings with large open spaces that make rooftop units easy to design and cost effective to apply, but there are usually office spaces either within or attached to the warehouse that require separate zoning. Set points are usually different, and the warehouse may only be heated and ventilated. Schedules can be different as well, with multiple shifts occurring in the warehouse area, and even some extended hours in the shipping and receiving offices within the warehouse proper.

Integrated Solutions

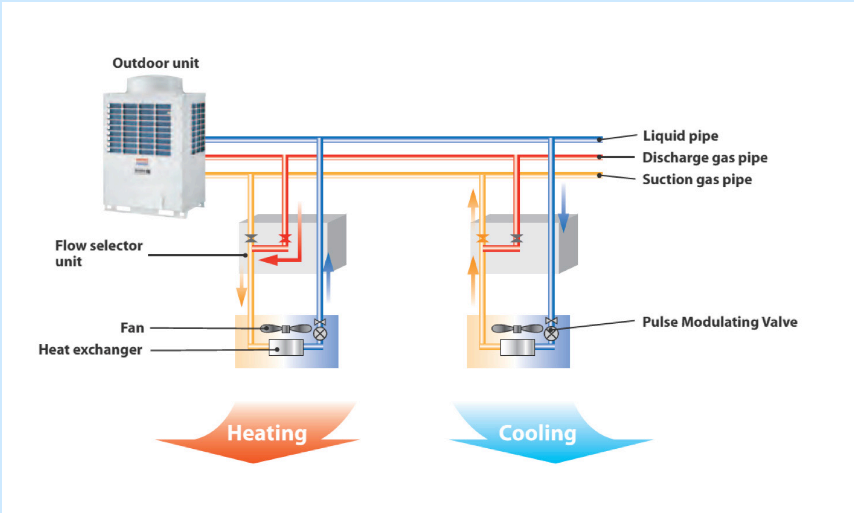
By applying VRF to the offices and rooftop units to the warehouse space, multiple system technologies can be used to meet the individual requirements of each space. The HVAC system integration design could be refined further by extending the VRF system into one or two of the warehouse "occupied zones" and choosing the heat recovery style VRF system. In those shoulder seasons when the offices are in cooling mode, the VRF system will send the rejected heat out into those warehouse zones.

VRF BASICS

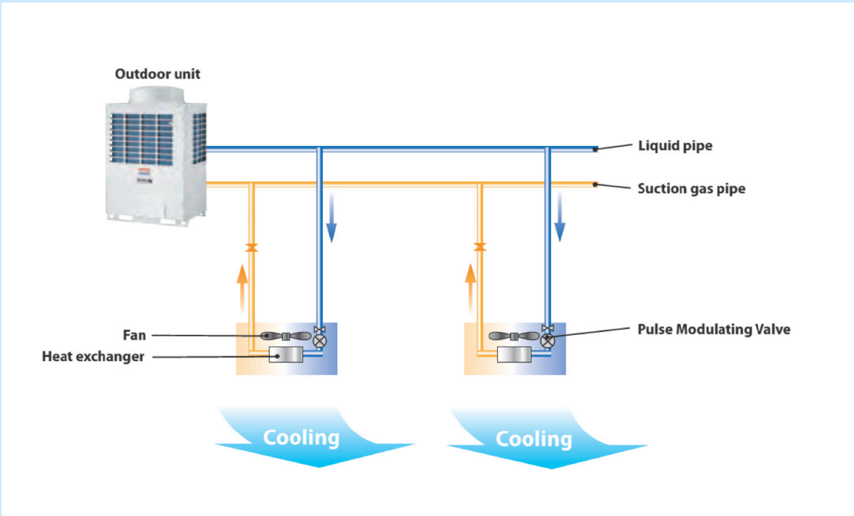
A VRF system moves heat between an outdoor unit and a network of indoor units. The outdoor unit has one or more inverter-driven compressors. The speed of the compressor can be varied by changing the frequency of the power supply to the compressor, thereby varying the amount of refrigerant delivered to the indoor units. The amount of refrigerant delivered to each unit is based on zone demand, so that the overall system load is met most efficiently. The ability of the VRF system to control the amount of refrigerant provided to the individual fan-coil units located throughout the building makes the VRF technology ideal for applications with varying load profiles or where a high degree of zoning and/or simultaneous heating and cooling is required.

VRF systems can be applied as cooling-only systems, as heat pump systems, or as heat recovery systems for those applications where simultaneous heating and cooling is desired. Multiple indoor fan-coil units may be connected to a single outdoor unit, distinguishing the VRF system from other direct expansion systems. Each indoor fan-coil unit has its own refrigerant metering device, or PMV (pulse modulating valve), which is controlled either by the indoor unit itself or by the outdoor unit. As each indoor unit control sends a demand signal to the outdoor unit, the outdoor unit responds to deliver the amount of refrigerant needed to meet the individual requirements of each indoor unit.

Heat Recovery System



Heat Pump System



VRF Design Considerations

When designing a building's HVAC system using VRF equipment, whether as the primary system or part of an integrated design strategy, there are several factors that should be considered to maximize energy efficiency and occupant comfort.

Zoning and the Use of Heat Recovery

The zone sizes are generally decided by the architect's space layout and the number of temperature control zones required by the occupants. If a system design requires a high degree of zoning and many zones have simultaneous heating and cooling requirements, a heat recovery style VRF system can provide simultaneous heating and cooling of the spaces at reduced energy usage.

A typical space layout is shown in Figure 1.

Block Load Sizing

All the zones or indoor fan-coil units connected to the same outdoor unit typically will not see a peak load at the same time. With this in mind, the outdoor unit can be sized by looking at the block load of the zones on the same system. This approach allows for smaller size outdoor units and will also provide a better advantage on the turndown capability of the VRF system.

Indoor Fan-Coil Units

Based on the zone layout, installation limitations, and capacity requirements, there are several options available, such as furred-in ducted/non-ducted, wall-mounted and cassette style fan-coil units.

One of the major advantages of a VRF system is the flexibility provided by the diversity of the product offering. Multiple types and sizes of indoor fan-coils are available to fit any application (Figure 2).

Figure 1 - Typical VRF System Space Layout

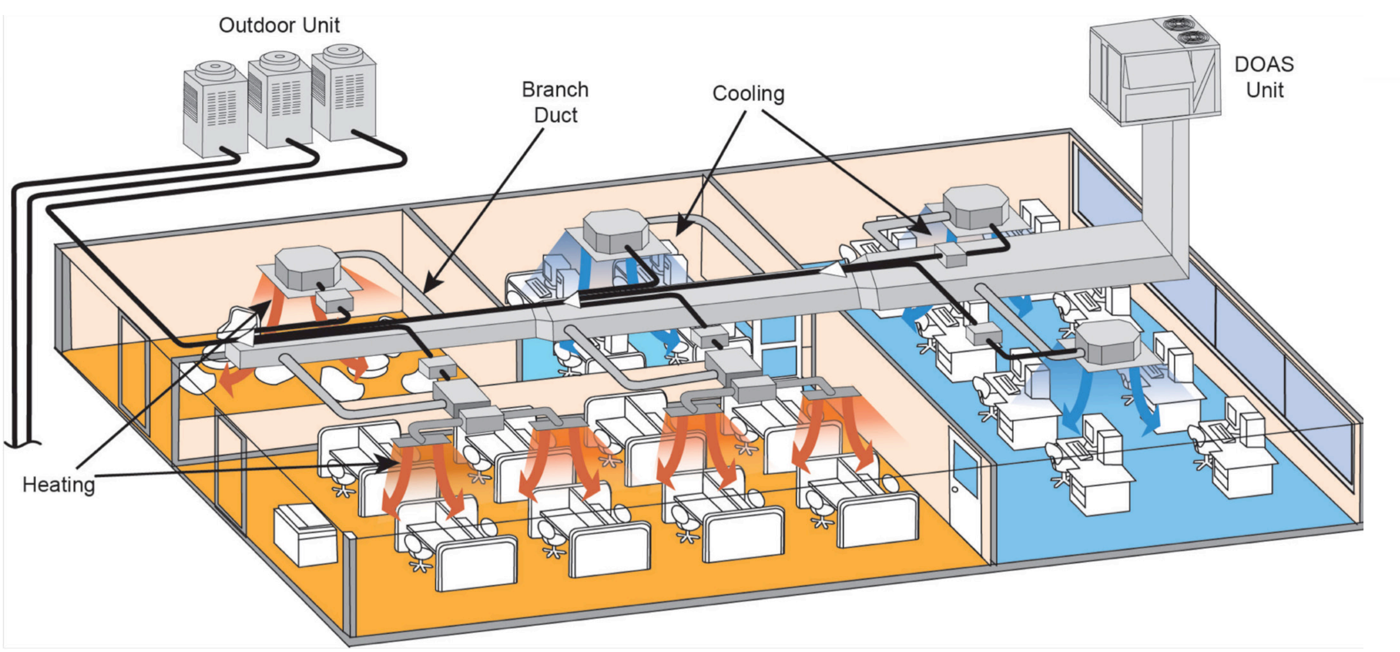


Figure 2 - VRF System Indoor Units

HVAC Loads Diversity

Indoor fan-coil units of different capacity, size and style can be connected to a single outdoor unit. Every fan-coil unit has its own metering device that provides the right amount of refrigerant to handle the space load. The turndown capability of VRF systems, paired with the wide capacity range of indoor units, allows for zoning to serve rooms with only fractional tonnage loads, while simultaneously serving rooms with higher loads.

Heating Capacity

When considering a VRF system, a key step is to assess the heating capacity at winter conditions. As the temperature outside decreases, all heat pumps will lose capacity. In addition, the defrost cycle takes the unit out of heating mode. To compensate for these factors, the VRF controls will speed up the compressor to try and maintain discharge air temperature set point, and in so doing, maintain required capacity. At some point, the compressor can no longer continue to speed up, resulting in a lower compressor discharge refrigerant temperature. The lower refrigerant temperatures lead to lower supply air temperatures and reduced capacity being delivered by the indoor unit(s). (Refer to manufacturer's design guide or selection software.)

When looking at the heating capacity loss at lower outside temperatures, there are several different ways to mitigate the loss to ensure room set point is maintained. One method is to utilize a discharge air temperature reset strategy on the DOAS unit. As the temperature outside decreases, the discharge supply air temperature can be increased, providing additional heat to the space. Typical strategies would bring the discharge from a room neutral 70 F gradually up to 95 F.

Another method for addressing this capacity shortfall could be to integrate supplemental heat into the VRF system by linking the VRF indoor unit with some form of auxiliary heat. This will allow the VRF system to act as the first stage of heat, and when the system can no longer maintain the room set point, the auxiliary heat will energize to raise the supply air temperature, increasing delivered capacity.

For example, if ducted units are installed in a space, an external electric heater can be installed in the supply duct downstream of the indoor unit. If the indoor unit cannot meet the space heating requirement, the electric heater will come on, the indoor unit fan will stay on, and the PMV on the indoor unit will close, preventing refrigerant flow through the coil. For non-ducted units, a fin-tube radiator can be installed to provide hot water or steam as supplemental heating.

Overcoming Piping Losses and Line Length Limits

The piping layout of any VRF system plays an important role in the functionality and efficiency of the system. While VRF systems have the capability to achieve impressive line lengths, there are limits that must be considered.

VRF systems have reduced cooling capacity when the system is designed with very long line lengths. The actual capacity of the indoor unit is calculated by multiplying the nominal capacity with the capacity correction factor based on piping length and lift. (Refer to manufacturer's design guide or selection software.) If the actual capacity turns out to be lower than the space load, the indoor unit will require upsizing. Once the capacity for each of the indoor units has been corrected, the total capacity must be compared with the corrected capacity of the selected outdoor unit. If the outdoor unit capacity is short of the combined indoor unit capacities, upsizing on the outdoor unit is also required. Although the corrected capacity for the units can be calculated manually using the manufacturer's design guide, the recommendation is to use the manufacturer's selection program for faster, accurate results.

Controls

When designing an integrated HVAC system with multiple technologies, including VRF, rooftop units, and/or chillers, it is important to integrate system controls as well. A solution that provides building management while allowing individual zone level control can enhance energy efficiency and provide maximum occupant comfort.

Control strategies may be implemented that allow the various HVAC systems to be sequenced together for optimized building operation based on the needs and requirements of its occupants. Applications of the strategies may include time-of-day scheduling per zone allowing for conditioning of only occupied spaces, ventilation control such as DOAS discharge temperature reset or demand control, and sequencing of VRF heating with supplemental heating systems based on outside conditions.

Additionally, a consolidated HVAC control user interface in a building management system transforms individual subsystem equipment and controls into a network that is easy to understand, monitor, regulate and change. The interface keeps facilities staff connected to their overall HVAC systems around the clock.

Facilities staff can access their system from locally-mounted displays or any web-enabled device. The user interface allows facilities staff to respond quickly and effectively to everything from alarm conditions to changing usage requirements, providing the best possible combination of efficiency and comfort for the individual zones.

DESIGN SOFTWARE

Whether designing a VRF system, a variable air volume (VAV) system, or a chilled water system with zoning terminals, it is always worthwhile to consider integrating different system technologies for optimum overall building occupant comfort and lowest owning and operating costs. Determining the right HVAC system for any building is possible by utilizing Carrier's eDesign software tools, such as the Hourly Analysis Program (HAP) and the Engineering Economic Analysis (EEA) program.

HAP is a detailed energy modeling tool that is capable of modeling complete building VRF primary systems as well as buildings using the hybrid system approach described in this article. HAP is able to model cooling-only, heat pump (non-heat recovery) and heat recovery VRF systems as well as a wide range of other HVAC system and equipment types. HAP also provides features for peak load estimating and system design. Engineering Economic Analysis is a tool for comparing the lifecycle economics of system alternatives, considering purchase, installation, maintenance and energy costs over the lifetime of a system or a building. For details, including instructions, on modeling VRF using Carrier's HAP, click here to access the Carrier EXchange newsletter that covers the topic in detail.

Controls on a VRF system can be standalone (non-communicating) which include mounted/remote or wireless controls. Centralized control allows the facility manager to monitor the system from a centralized location but is not part of the building automation system. Web-based controls allow the system to be tied into a building automation system using BACnet* or LonWorks† protocols.

Conclusion

Just as there is no single HVAC system that suits all applications, using just one type of HVAC system for an entire building may not result in the most energy-efficient design. Integrating different, independently-efficient HVAC systems for a total building solution not only provides better comfort but facilitates better control as well, managing building energy consumption for greater efficiency.

Carrier is proud to offer a full range of product and system solutions, energy assessment programs and analytical tools to help you address each building's performance, financial and environmental requirements.

Carrier provides a library of white papers with detailed information about a host of topics including VRF at commercial.carrier.com. The following link goes directly to the white paper noted: Variable Refrigerant Flow (VRF) Systems, Flexible Solutions for Comfort

* Sponsored by ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers).

† Registered trademark of Echelon Corporation.