

Performance Enhancement of PV Cooling System – Using VRF Technology

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Abstract:

From the various techniques that enhances the solar fraction of solar Photovoltaic cooling system VRF technology is most important. Use of VRF technology enhances the solar fraction along with the reduction in the energy consumption and payback period. The solar fraction reaches up to 0.89 for hot and dry climate (Ahmedabad), 0.95 for moderate climate (Bangalore), 0.84 for warm and humid climate (Chennai) and 0.88 for composite climate (Delhi). It is lowest for the warm and humid climate due to highest annual cooling demand and it is highest for the moderate climate because of the lowest annual cooling demand and higher cost of VRF than PTAC.

1. Introduction:

A Variable Refrigerant Flow (VRF) system is a refrigerant system that varies the refrigerant flow rate with the help of a variable speed compressor and electronic expansion valves (EEVs) located in each indoor unit to match the space cooling or heating load in order to maintain the zone air temperature at the indoor set temperature. In cooling mode, the outdoor unit heat exchanger acts as condenser through the four-way valve, while the indoor unit heat exchanger acts as evaporator. The discharged refrigerant from the compressor flows into the outdoor unit, releases heat, and becomes high-pressure low temperature refrigerant. It is then throttled to low pressure by the EEV, absorbing heat from the indoor air through the indoor unit and superheating. Finally, the superheated refrigerant returns back to the compressors. In heating mode, the four-way valve reverses the refrigerant path and turns the outdoor unit into evaporator and the indoor unit into condenser. Thus the indoor unit rejects heat to the indoor air and heats it up [Hong T 2014].

The main advantages of a VRF system over the conventional multi-split system are wide-range capacity modulation, individual room set point control, and—for the heat recovery type VRF systems—the simultaneous cooling and heating capability [Goetzler W 2007], which collectively lead to better energy performance and indoor comfort. The VRF systems are residential systems that operate either in cooling mode or heating mode but not simultaneous cooling and heating. Small VRF systems have one compressor, while large systems typically include two to three compressors with fitted for variable speed capability, thus enabling wide capacity modulation. The inverter yields high part-load efficiency because HVAC systems often operate in the range 40% to 80% of its maximum capacity, while the single speed units have to cycle on and off causing efficiency losses. Heat recovery is readily accomplished when simultaneous heating and cooling occurs, which leads to energy savings. The inverter technology used in the VRF system can maintain precise room temperature control, generally within $\pm 0.55^{\circ}\text{C}$ ($\pm 1^{\circ}\text{F}$) [Hong T 2014].

EnergyPlus version 8.1 can model the heat pump type and heat recovery type VRF systems. The object AirConditioner: VariableRefrigerantFlow describes the outdoor unit which connects to the zone terminal units (indoor units). Zone terminal units operate to meet the zone sensible cooling or heating requirements as determined by the zone thermostat schedule. The actual operation mode is determined based on the master thermostat priority control type. There are five algorithms available: LoadPriority, ZonePriority, ThermostatOffsetPriority, MasterThermostatPriority, and Scheduled. LoadPriority uses the total zone load to choose the operation mode as either cooling or heating. ZonePriority uses the number of zones requiring cooling or heating to determine the operation mode. ThermostatOffsetPriority uses the zone farthest from the room set point to determine the operation mode. The MasterThermostatPriority operates the system according to the zone load where the master thermostat is located. Scheduled operates the VRF system either in cooling or heating based on schedule. When the system is running in cooling mode, the cooling coils will be enabled only in the terminal units where cooling is required. In heating mode, the heating coils only response to the zones with heating load. The indoor unit supply fan can be modeled in two operation modes: cycling fan cycling coil (AUTO fan mode) or continuous fan cycling coil (Fan ON mode). To model the AUTO fan mode, only the Fan: OnOff object can be used. For the Fan ON mode, both Fan: OnOff and Fan: ConstantVolume objects can be used [Hong T 2014].

Model validation

The whole building modeling was done in the energy plus software with the same building parameter and HVAC

systems. Fig1 shows the variation of cooling load for a day time calculated by the two software TRNSYS and Energy plus. It is clear from the graph that the cooling load is nearly same.

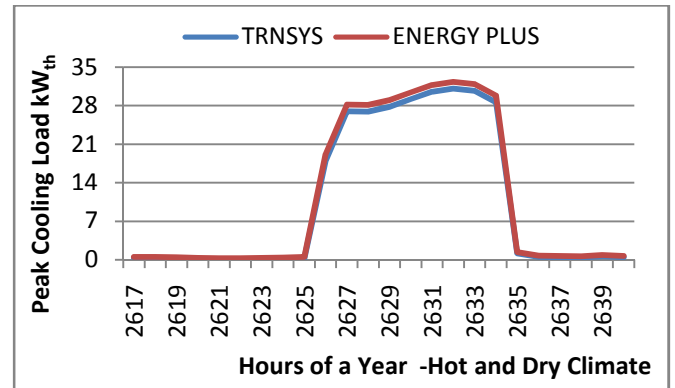


Fig: 1 Comparison of Cooling Load [Hot and dry climate -Ahemedabad]

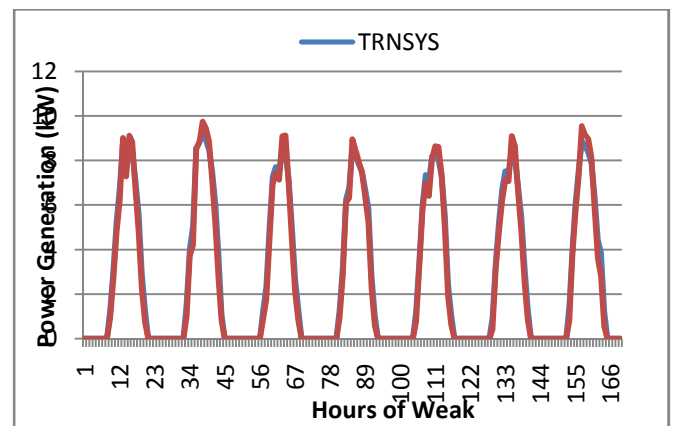


Fig.2 Comparison of Power Generation [70 m² PV Area Mono crystalline]

Fig.2 shows the comparison of power generation by the two software's TRNSYS and ENERGY PLUS. It has been observed from the graph that the power generation is approximately same in ENERGY PLUS as in TRNSYS.

2. Performance analysis of PV cooling system with VRF

In this section performance analysis of PV cooling system using variable refrigerant flow presented and discussed.

Solar Fraction

The Power consumption of the VRF cooling system decreases in comparison to the PTAC system while the power generation from the photovoltaic remains the same. So in the day time there is good matching between the PV generation and the energy consumption of the VRF system that enhances the solar fraction.

Fig 3 (a) shows the variation of solar fraction with PV area. It has been observed that the highest solar fraction is achieved for the moderate climate Bangalore because of low cooling demand resulting in low electrical energy consumption of the VRF system. In the moderate climate power generation from the photovoltaic system is good and energy consumption by air conditioner is low so there is a good matching of power generation and consumption in the day time that enhances the solar fraction. The lowest solar fraction is for warm and humid climate (Chennai) because of the highest annual cooling demand. Using VRF technology the solar fraction reaches upto 0.89 for hot and dry climate (Ahmedabad), 0.95 for moderate climate (Bangalore), 0.84 for warm and humid climate (Chennai) and 0.88 for composite climate (Delhi). Fig.7.3 (b) shows the comparison of solar fraction for the PTAC and VRF system. The solar fraction is higher for VRF technology.

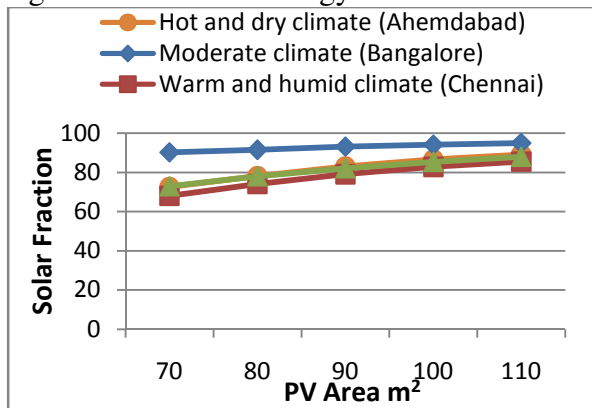


Fig: 3(a) Variation of Solar Fraction with PV area

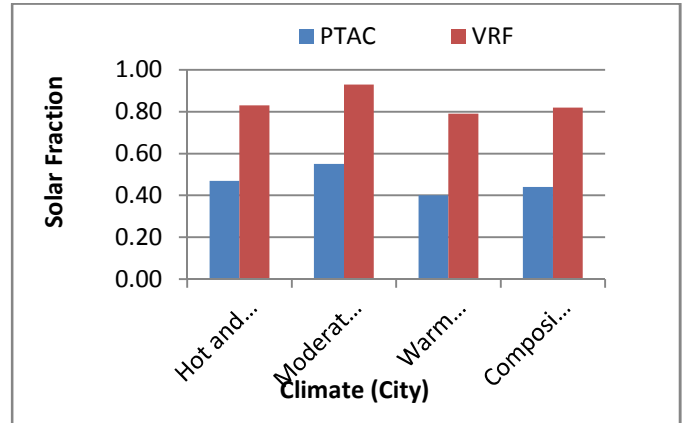


Fig: 3 (b) Comparison Solar Fraction (PV area-90m²)

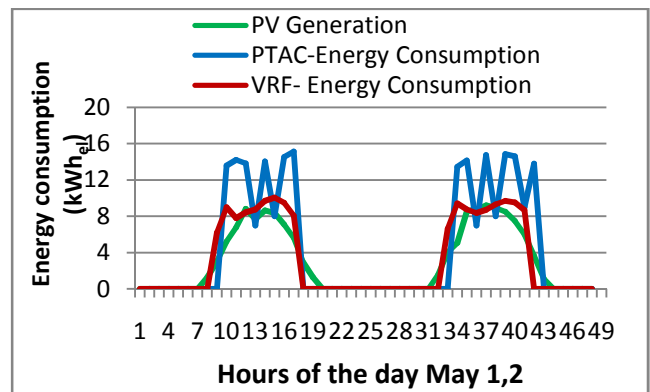


Fig: 4 Comparison of PV generation and consumption [Hot and dry climate (Ahmedabad) PV area 90 m²]

Fig.4 shows the comparison of energy consumption and PV generation for hot and dry climate (Ahmedabad). It has been observed from the graph that the PTAC consumption is very high in comparison to the PV generation. The difference between the two is taken by grid supply that is the reason why the solar fraction is lower in the PTAC system. The consumption of the VRF system follows the same trends as the generation of PV power so only a small amount of grid supply is required resulting in the high solar fraction. In the PTAC system there is condition in the day time when the thermostat OFF the compressor in that case the PV generates power but consumption is zero and solar fraction is not calculated.

Although using VRF system the solar fraction achieved is very high in comparison to the conventional system but the total energy consumption is reduced 11-28%. Fig.5 shows the comparison of annual electrical energy consumption for the four different climates with the VRF and conventional PTAC system.

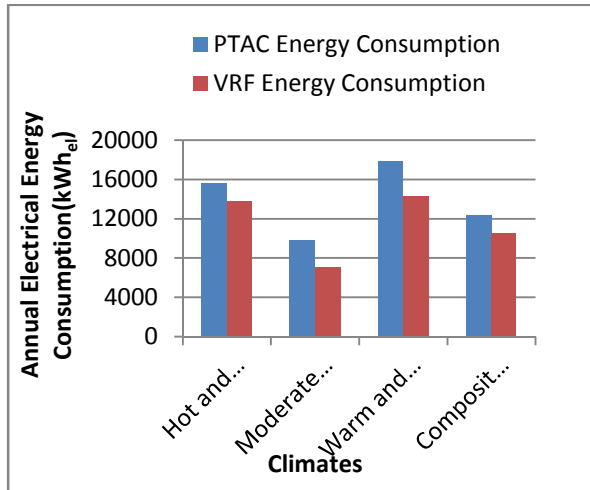


Fig: 5 Comparison of annual electrical energy consumption

It has been observed from the graph that the saving in the annual electrical energy consumption is very high 28% for moderate climates because the cooling demand of moderate climates is low in comparison to the other one. The low cooling demand decreases the size and electrical energy consumption of the cooling system. In the hot and dry climate (Ahmedabad) and composite climates (Delhi) the peak cooling load are highest during summer season so the both systems (PTAC and VRF) consume the electrical energy at almost same level. In the warm and humid climate the cooling load remains same throughout the year so in this condition the VRF system can save the electrical energy consumptions.

Conclusion

Use of VRF technology enhances the solar fraction along with the reduction in the energy consumption and payback period. The solar fraction reaches up to 0.89 for hot and dry climate (Ahmedabad), 0.95 for moderate climate (Bangalore), 0.84 for warm and humid climate (Chennai) and 0.88 for composite climate (Delhi). The payback time come down to 13, 18, 11, and 17 years for hot and dry climate, moderate climate, warm and humid climate and composite climate respectively. It is lowest for the warm and humid climate due to highest annual cooling demand and it is highest for the moderate climate because of the lowest annual cooling demand and higher cost of VRF than PTAC.

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