Chiller Vs VRF Comparison

At the time of designing a HVAC project, it is required to understand the project requirements, type of application, duty conditions and compliance to relevant standards. In order to decide which air conditioning system to be used for any particular project, it becomes essential to evaluate different HVAC technologies & systems that will best suit for that project. In today’s world, the designer has many choices for designing the HVAC system and it could be very confusing to identify a correct system for a given application. In order to understand which particular system is best suited for any application, the designer has to consider various aspects such as life cycle cost analysis, system architecture, space availability, etc. In today’s world, a common confusion is whether to design a system for central plant with chilled water system or to use the Variable Refrigerant Volume System (VRF System). In order to understand the merits and demerits for each system, let us compare Chiller Plant System Vs VRF on different aspects that are generally considered during HVAC designing.

• Technology – Merits & Demerits
• System Life Cycle Cost analysis
• System Architecture
• Reliability

Technology

Variable Refrigerant Flow (VRF)

VRF in refrigeration terminology is termed as Multi Evaporator AC system, a ‘central’ air conditioning system having capacity modulation. VRF system comprises of one or more number of ODUs (out door units), many IDUs (in door units), which are connected with each other through refrigerant piping network. The ODUs are installed either on the rooftop or in the shaft space or anywhere at the convenient place. Refrigerant is circulated through the pipes, to the evaporator units. Inside spaces are cooled with the help of refrigerant that is circulated through evaporator units. Generally an Electronic Expansion Valve is used as an expansion device. Capacity modulation happens through two fundamental techniques – 1) electrical modulation – inverter based & 2) mechanical modulation.

Merits –
1. Different IDU options can be used like Hi-wall unit, cassette unit, concealed unit, ducted type units and so on. This can help in blending the air conditioning system with the appropriate interior design of the space.
2. With the current available options, one can reach up to LEED-Gold rating
3. Operation is very simple, probably as simple as operating a split air conditioning system and hence no separate manpower is required for operating the system.

4. Good option for providing air conditioning to apartments / villas, small installations where in the complexity of the system (a major demerit of this system) can be kept to a minimum.

Demerits –
1. Complex system architecture, large amount of refrigerant piping running around in conditioned space.
2. If decided to use for larger capacities, more space required to install many number of ODUs. Access to ODUs is necessity as all the maintenance work required will be mostly on the ODUs.
3. Will not be of much benefit where the cooling load has limited diversity, such as in IT / ITES offices, malls, multiplexes, etc. where in the diversity is limited to some conference rooms and / or cafeterias, etc.
4. Can be hazardous for the occupants, being refrigerant circulated through pipes, susceptible to leakages, with the refrigerant possibility of entering the conditioned space.
5. Highly skilled labour required for installation and commissioning and maintenance, especially to identify and correct leakages.
6. Different evaluation standards are referred for performance evaluation
7. Limitation on CFM delivered inside the space, up to 350CFM / TR, can be a serious limitation from indoor air quality as air circulated can be insufficient.

Technology

Water Cooled Screw Chillers

Merits –
1. The most matured technology with the history of over 6 decades
2. International standard is referred for performance evaluation – AHRI 550/590
3. Highly energy efficient, enables comfortably complying to LEED – Platinum requirements
4. With proper system design and installing multiple chillers, even in case of high diversity, chillers become a good option due to their good efficiency even at part load conditions.
5. Project size is not the constraint at all
6. Non-hazardous for the occupants, as water is circulated throughout the refrigeration circuit, no chance of hazardous material entering the conditioned space.
7. Advantage on efficiency can be multiplied by using Thermal storage; and usage of differential tariff.
Demerits –
1. Availability of water is a must
2. Requires additional space for plant room for chillers, AHU rooms and space for mounting the cooling towers.
3. Trained manpower is required for operating the central chiller plant.

Life Cycle Cost Analysis

\[
\text{Life Cycle Cost} = \text{Initial CapEx} + \text{Operational Cost} + \text{Maintenance Cost}
\]

Case study for 1000TR capacity system

<table>
<thead>
<tr>
<th>No</th>
<th>Parameter</th>
<th>Unit</th>
<th>VRF</th>
<th>W/C Screw Chiller</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Initial CapEx, average cost</td>
<td>Rs / TR</td>
<td>50,000 ~ 65,000</td>
<td>50,000 ~ 55,000</td>
</tr>
<tr>
<td>1a</td>
<td>Total CapEx</td>
<td>Rs</td>
<td>57,500,000</td>
<td>52,500,000</td>
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<tr>
<td>2</td>
<td>Operational Cost</td>
<td>ikW / TR</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Equipment (Weighted Avg. Power – IPLV)</td>
<td>ikW / TR</td>
<td>0.90</td>
<td>0.50</td>
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<tr>
<td></td>
<td>Condenser Water Pumps</td>
<td>ikW / TR</td>
<td>NA</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Chilled Water Pumps</td>
<td>ikW / TR</td>
<td>NA</td>
<td>0.06</td>
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<tr>
<td></td>
<td>AHUs</td>
<td>ikW / TR</td>
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<td>0.10</td>
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<td></td>
<td>Cooling Tower</td>
<td>ikW / TR</td>
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<td>0.02</td>
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<tr>
<td></td>
<td>Total ikW/TR</td>
<td>ikW / TR</td>
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<td>0.73</td>
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<tr>
<td>2a</td>
<td>Total operational cost @Rs. 8.75/kW</td>
<td>Rs / Yr</td>
<td>35,437,500</td>
<td>28,743,750</td>
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<tr>
<td>3</td>
<td>Cost of make up water @Rs. 20/m³</td>
<td>Rs / Yr</td>
<td>NIL</td>
<td>557,000</td>
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<td>4</td>
<td>Maintenance Cost (CAMC)</td>
<td>Rs / TR / Yr</td>
<td>1800 ~ 2000</td>
<td>1200 ~ 1500</td>
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<td>5</td>
<td>Operational maintenance Man-hours</td>
<td>Rs / Yr</td>
<td>NIL</td>
<td>300,000</td>
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<td>5a</td>
<td>Total maintenance cost</td>
<td>Rs / Yr</td>
<td>1,800,000</td>
<td>1,500,000</td>
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<tr>
<td>6</td>
<td>Total O &amp; M Cost / Yr (2a+3+5a)</td>
<td>Rs / Yr</td>
<td>37,237,500</td>
<td>30,800,750</td>
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<td>7</td>
<td>O &amp; M Cost for 15 Years</td>
<td>Rs</td>
<td>558,562,500</td>
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<td>8</td>
<td>Life Cycle Cost (1a+7)</td>
<td>Rs</td>
<td>616,062,500</td>
<td>514,511,250</td>
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</tbody>
</table>

Calculation References:
1. Total CapEx: Average cost/TR
2. Total operating cost: Lowest figure for ikW/TR; Running hours 15 Hrs/day x 300 Days
3. Total maintenance cost: Lowest cost/TR/Yr
**System Architecture**

In order to achieve capacity modulation, VRF system essentially requires lot of electrical & electronic controls. Most of the controls are fitted in the ODUs panel board. Apart from electrical-electronic controls, each outdoor unit consists of refrigeration components like compressor, condenser, fan, refrigeration components & controls, and quite a lot copper piping. Fig-1 & Fig-2 speak all about the complexities.

The system also needs communication cable to run all the way through from outdoor boxes till each & every indoor unit to exchange electronic signals between ODUs and each IDU. Having copper piping, electrical cabling, communication cables, makes the refrigeration network bit complex.

On the other hand, water cooled screw chiller system architecture & its functioning is quite simple. It does not require complex electrical – electronic controls, refrigeration network for the system to operate and for the capacity modulation too. Further, circulation of water to the AHUs is also a very simple system and all the designer needs to adhere to is simple piping rules.

We all know simpler the system architecture, better reliable it will be & better from the serviceability standpoint too.
Reliability

Oil Management

VRF – In VRF, refrigerant is circulated throughout the refrigeration circuit. Oil along with the refrigerant leaves the compressor through every compressor discharge, which then is circulated throughout the refrigeration circuits. It is very essential that whatever oil that has left out of compressor, should be returned to a compressor, to facilitate lubrication.

At low part load conditions, velocity of the refrigerant & oil is not adequate enough to bring both (oil & refrigerant) back to the compressor. In order to bring the oil back to the compressors, it becomes most essential to run the entire system at high load, for few minutes, after every certain hours.

Many times because of the application requirements, the liquid line distances are quite long, to the tune of 400 ~ 450+ feet. The longer liquid lines further create more challenges on account of oil recovery. Also, longer the refrigerant lines, less efficient the system would be.

Chillers – All chillers have an in-built oil management system, thereby eliminating any issues of oil recovery.

Refrigerant flood back

VRF – Since there is a large quantity of refrigerant available in the system, during part load conditions when only few compressors (matching to % part load) are in operation, the entire refrigerant mass is handled by those few compressors. In such duty conditions, many a times, system may run into issues if due care is not taken. In that case the compressors see flooding of liquid refrigerant that eventually leads to compressor motor burn out, mechanical breakage of the compressors, etc.

Chillers – Liquid flooding is not an issue at all, as the system is properly designed and only the amount of refrigerant required is circulated, rest stays in the condenser.
Conclusion

For smaller systems, up to 100 ~ 200 TR, with limited ODU and IDU, VRF system can be a
good solution, as for smaller central plant system, space availability for chillers, AHUs may not
be available. Also, for such small systems, the VRF system can remain simple with limited
refrigerant piping and without much complexities.

However, when the installation size starts increasing, VRF systems, as seen above, start
becoming complex and in such cases, planning the installation for a central plant is always
beneficial. The life cycle cost of such a system is not only lower than the VRF system, but it
also avoids safety related issues such as leakage of refrigerant in conditioned space, better air
circulation, better indoor air quality, etc.