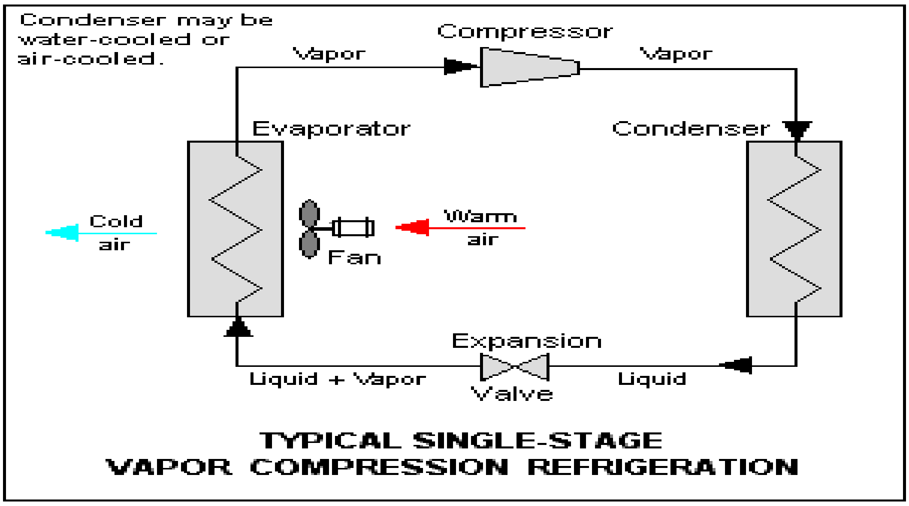
Stable Head Pressure Control in Refrigeration Systems

Refrigeration Cycle

The vapour compression refrigeration cycle is well documented and this bulletin is aimed at those with a basic knowledge and understanding of the concepts of such systems. The cycle in brief is where a refrigerant is circulated in a loop around a circuit. This circuit contains a compression device, a means of expanding the liquid refrigerant to a vapour, an evaporating unit to absorb energy from the cooled medium, and condensing unit to return the compressed vapour back to a liquid state.



Evaporator Control

Heat energy absorbed by the evaporator can be controlled by modulating the amount of compressors running, and / or the loading of the running compressor to maintain a required temperature within the evaporator.

Condenser Control

There are generally three methods of controlling the condenser pressure.

1. **Liquid Cooled –** where the condensing heat exchanger has a cooling medium such as river water on the primary side, and the refrigerant is passed through the secondary to cool and condense.
2. **Evaporative –** where a device similar to a cooling tower uses fans and a water spray system to exploit the increased performance of evaporative cooling on the external tube surfaces.
3. **Air-Cooled –** where the refrigerant is passed through a finned heat exchanger and fans are cycled on and off.

Depending upon the application and resources physically available, each of the three methods have various advantages and benefits. For this document we concentrate on the air-cooled, (3 above) device which empirically is prone to unstable head pressure control due to the traditional control methods applied.

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Air-Cooled Condenser Control

Consider a refrigeration circuit with an eight fan air cooled condenser. A step controller is used to schedule in the fans from one to eight, depending on the airflow required to maintain a set pressure. The fans required will be directly proportional to the cooling power available from the ambient air at any given time. The control loop has at its disposal one to eight stepped individual loads to combat the natural rise in pressure from the compressed refrigerant. This refrigerant is loaded with energy absorbed in the evaporator, and hence gives the relationships between the energy absorbed by the evaporator and the energy rejected by the condenser.

Each stage has a step effect on the pressure within the condenser, thus condensing pressure is modulated to values only available for each step up to full condenser required with all fans running, and down to minimum condenser required with no fans running. These steps may span the required set pressure and therefore oscillation of a fan stage will occur in an attempt to settle on the set pressure. This system ''hunt'' can be as much as 3 Bar or more in badly setup control loops.

What are the adverse effects?

The condensing side of the refrigerant circuit is often termed as the ''high side'' meaning pressure changes are relatively large when viewed in comparison to the ''low side'' (evaporating part of the system). This in real terms means that a change in pressure in the ''high side'' can have dramatic effects in the ''low side'', which after all is part of the same dynamic refrigeration loop. A system that is modulating its compressors on the ''low side'' pressure will be directly influenced by ''high side'' pressure fluctuation. These pressure fluctuations cause the compressor(s) control loop to unnecessarily make changes to compressor(s) loading due to unstable ''high side'' pressure control.

Compressors are generally the biggest electrical loads within a system and rapid switching of these large loads is widely considered undesirable. Measures are often taken within the compressor control loops to combat this, e.g. intelligent controllers and anti-recycle timer devices. These measures, if not correctly configured, can compound the problem as loads can be held on or off artificially during a control cycle.

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Scenario

Consider an air cooled system with three compressors and eight condenser fans attempting to maintain a ''high side'' (head pressure) of 13 Bar, and a ''low side'' (suction pressure) of 3 Bar. The prevailing ambient conditions mean that there are four fans running to achieve 14 Bar and five fans running to achieve 12 Bar. This would mean that the ''high side'' (condenser) control is constantly switching between four and five fans in a control loop attempting to achieve 13 Bar. This loop gives a 2 Bar hunt in ''high side'' (head pressure). As the dynamics of the system are linked, this hunt in ''high side'' pressure is transposed into the ''low side'' (suction), causing the system to modulate between two and three compressors. The compressors have anti-recycle timers set at ten minutes, therefore a single hunt cycle in the ''high side'' (condenser) could cause a compressor to be unavailable for up to ten minutes, and this in-turn allows the ''low side'' (suction pressure) to rise as the cooling duty required is not met. The compressor, when available, then has a larger load to address when it starts, and therefore runs for longer periods at higher capacity. The cycle resets and once again the increase in the ''high side'' (condenser pressure) manifests itself in compounding the original hunting issue. Thus the system would be operating inefficiently and causing unnecessary component wear and tear.

If ambient conditions and system parameters achieve certain values it is a possibility for the whole system to hunt (even on a ''balanced'' system). Empirically the scenario above occurs more often than recognised and manifests itself in different ways, e.g. repeated component failure and inefficient system performance.

Solution

Control the system's ''high side'' (head pressure) to the required setting without hunt in the loop? We can achieve this by the simple introduction of an analogue control method removing the step changes caused by digital fan switching. Our analogue method can be introduced by retrofitting a variable speed drive (VSD) to which all fans are connected in parallel. The net effect is that all fans are used simultaneously, but are modulated depending on the condensing power required. Incorporating this type of VSD necessitates the use of our advanced proportional integral derivative (PID) controller to accurately maintain the required ''high side'' (head pressure), and so remove the hunt from the ''high side'' control.

Benefits

Retrofitting a VSD can remove unnecessary loading and unloading of plant and therefore reduces wear and extends component life.

The system provision that all fans are running, means that all the surface area of the condenser is being exploited at all times, not just the area directly attributed to the running fan(s). The result of optimising the surface area of the condenser results in the reduction of mechanical power required for airflow, and thus saves absorbed power by the condenser fans.

As the airflow across the condenser is now even, other system anomalies such as condenser cold spots due to an area of the condenser receiving more cooling than others, can be addressed. These condenser cold spots are often the cause of restrictions in refrigerant flow from the condenser.

Optimising the operation of the condenser fans will result in the fans running at reduced speed to that of the staged fixed speed system. This means that the squared law of reducing the motor power by reducing motor speed can also be achieved.

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Efficiency

Depending on the system configuration and original set-up, our studies of systems retrofitted with VSD for condenser control have shown an overall efficiency performance of plants ranging from **4 – 15%.**

By providing stable condensing conditions, our use of VSD head pressure control also enhances technologies involved in floating head pressure efficiency, e.g. liquid pressure amplification (LPA).

Implementation

We would be pleased to supply and install a preparatory control device specifically designed to provide a VSD stabilised head pressure control system.

For further information or advice, please feel free to contact us.

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