Better Controls To Improve Air-Conditioning System Efficiency

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ABSTRACT

This paper highlights the importance of controls technology in improving the performance o f air-conditioning systems. The compressor is the highest power-consuming component in the air-conditioning system and the new Copeland Digital Scroll™ compressor provides superior energy efficiency performance. Apart from the compressor, there are other system components like electronic expansion valves, condenser fans, bypass solenoid valves etc that affects the system performance. Optimization of such controls can help to increase the system performance. An example of a Samsung 10HP DVM™ air-conditioning system is taken to illustrate how the compressor and system control can provide a superior performance.

KEY WORDS

Samsung DVM™ System, Copeland Digital Scroll™ , capacity modulation, tandem, hot gas bypass valve, liquid bypass valve, oil separator, oil return, electronic expansion valve, S- Net, zone control.

INTRODUCTION

The average summer temperatures experienced by most countries are increasing every year and consequently the energy needs to provide air-conditioning is

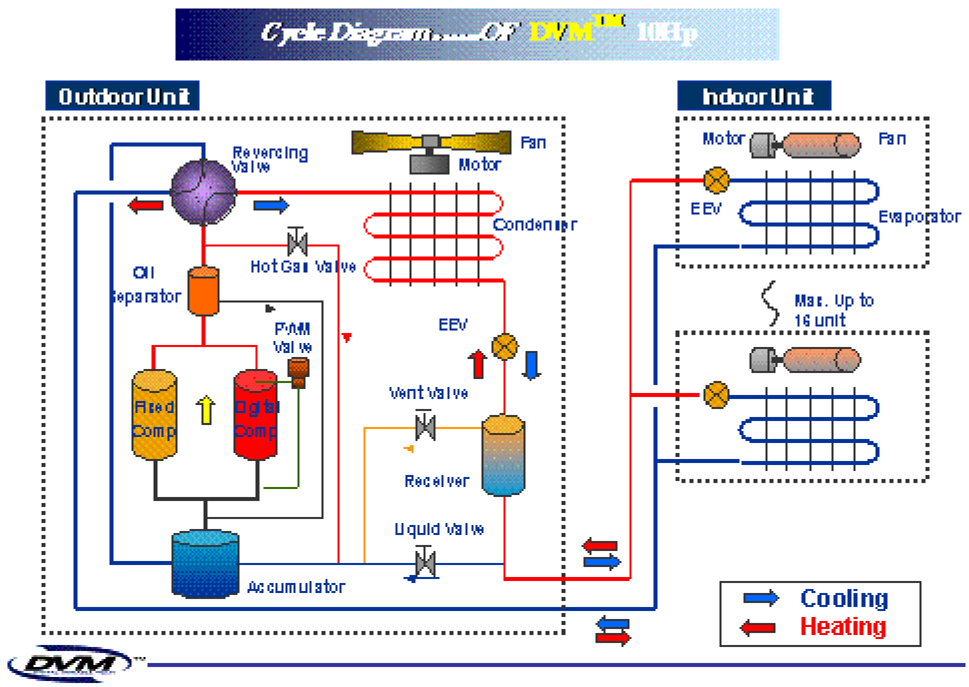
also increasing annually. The HVAC industry has a challenging task of providing energy efficient technologies to satisfy this growing demand with a minimum impact on global warming and ozone depletion. The air-conditioning system efficiency is very important as it determines the amount of energy that is being consumed for heating and/or cooling. Many countries are creating minimum efficiency grades, to ensure that

the HVAC industry continually strives towards the development of more efficient systems, thereby reducing the demands of energy.

The increasing buying power of consumers globally is also generating a large demand for the development of air-conditioning systems that provide a higher level of comfort than that provided by the standard fixed capacity systems. These trend, economic and environment related, is placing a growing demand for the development of variable capacity systems. A variable capacity system offers unique benefits - it has higher seasonal energy efficiency and is able to control the room temperature to a much tighter band, thus ensuring higher customer comfort.

In this paper, we are going to talk about all the elements in an air-conditioning system that determines the system efficiency. We will discuss the Digital Scroll compressor characteristics and also the controls technology that can be used to improve the overall system efficiency.

SYSTEM DESCRIPTION



The above schematic depicts the system configuration for a direct expansion Samsung 10HP DVM™ heat pump system. It shows a condensing unit that consists of a 10HP Digital Scroll tandem compressor, oil separator, reversing valve, condenser fan motors, electronic expansion valve, receiver, accumulator, hot gas bypass valve, liquid bypass valve and vent bypass valve. This condensing unit can be combined with a number of indoor evaporator units - upto 16 evaporators for a 10HP system.

Digital Scroll Compressor

Figure 1 shows the 2 operating state of the Digital Scroll compressor. During the loaded state, the fixed and orbiting scrolls are always engaged and the compressor delivers 100% capacity. During the unloaded state, the top scroll moves up axially by 1.0 mm. Since there is no scroll sealing now, the compressor delivers 0% capacity.

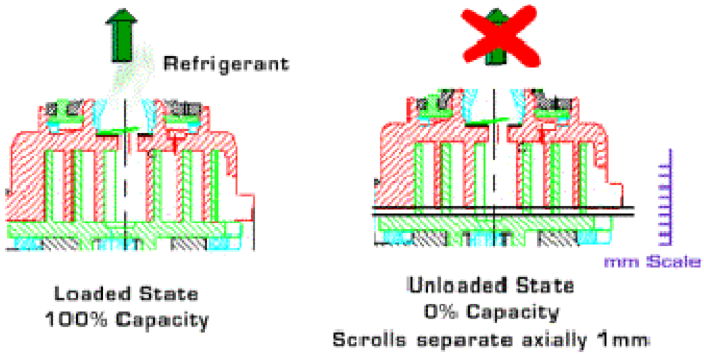


Figure 1. Operating States

Figure 2 shows how time signals can be used to modulate the compressor from 10% to 100%. The wide operating range of this compressor ensures that there are fewer start stops and so it enhances the system performance.

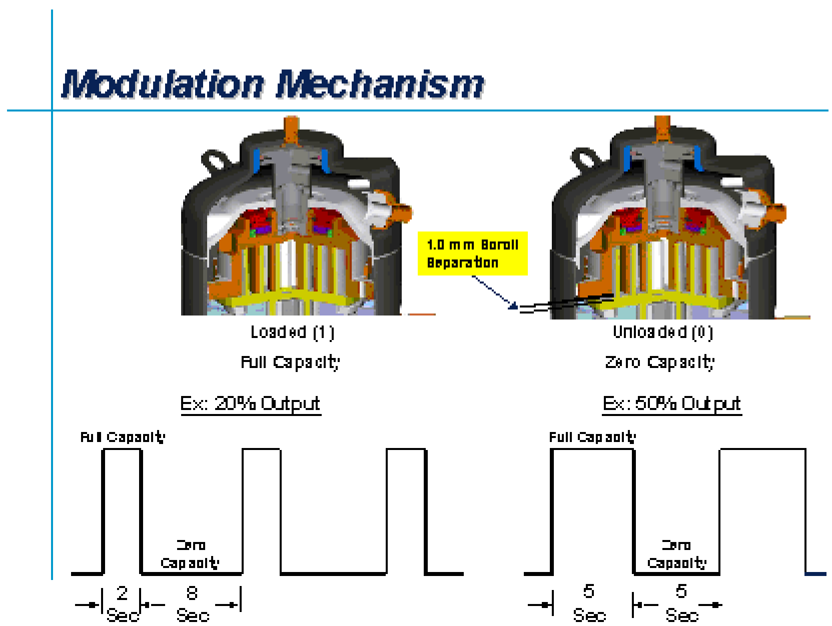


Figure 2. Modulation Mechanism

Figure 3 shows the power input of this compressor. During the unloaded state, the power consumption is about 10% of full load power and so the total average power consumption is low at low capacities.

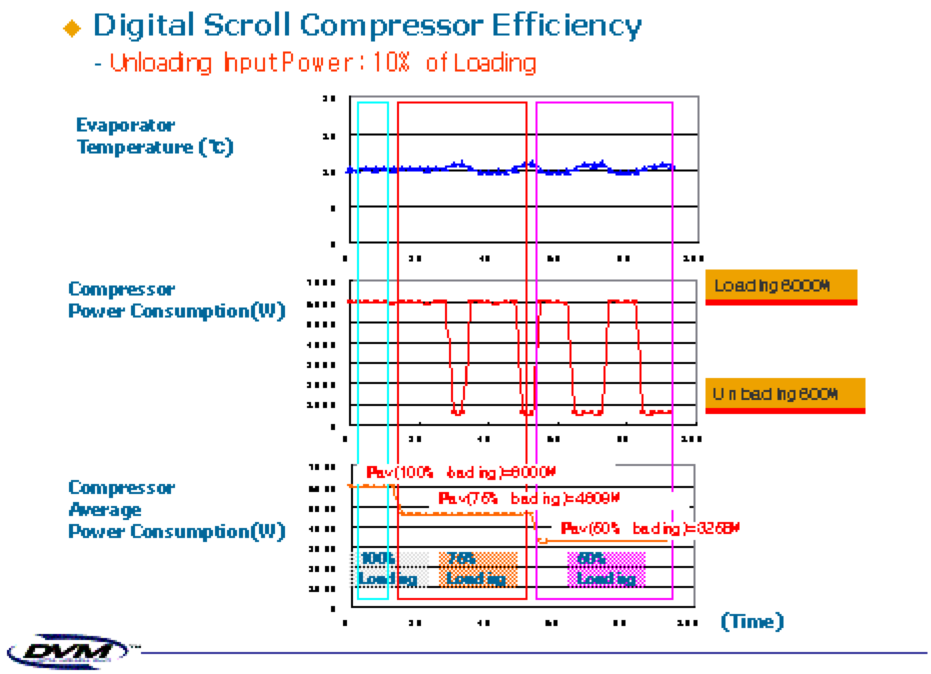


Figure 3. Average Power Consumption

The Digital Scroll delivers excellent seasonal energy efficiency (SEER). The SEER advantage becomes even greater for a tandem configuration. When both compressors are operating, the system has a high EER of 11.3 and at 50% capacity, when only one compressor is operating at full load, the compressor operates at a high EER of 11.3 too. The operating range for a single Digital Scroll is from 10% to 100% and in a tandem configuration is from 5% to 100%. Wide operating range ensures fewer start-stops on the compressor. Fewer start-stops ensure higher system performance.

Oil Separator

The Samsung DVM system uses a centrifugal type oil separator that has >80% oil separation efficiency. Oil separation is important to ensure that there is adequate

lubrication for the compressor, especially during part load operation. The separation of oil is also important to improve the heat exchange coefficient in the condenser and evaporators.

Electronic Expansion Valve (EXV)

For variable capacity systems, an EXV provides superior performance as compared to a thermostatic expansion valve (TXV). Figure 4 shows the performance improvement of using an EXV as compared to a TXV.

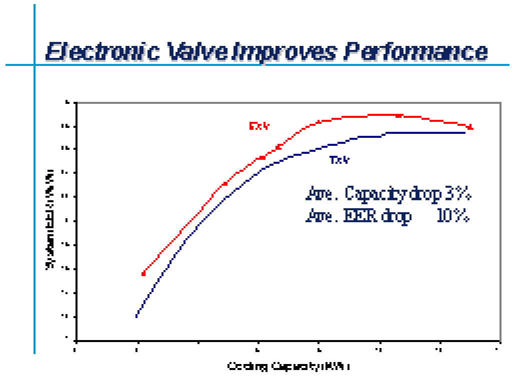


Figure 4. EXV vs TXV Performance

During the cooling cycle, the outdoor EXV has no function. However, during the heating cycle, the outdoor EXV is used for controlling the superheat of the outdoor coil. The temperature and pressure sensors on the liquid line helps to calculate the suction superheat on the outdoor unit (the refrigeration table is programmed in the microprocessor). Depending on the operating condition, the system has an optimum value of superheat. The opening/closing of the EXV is controlled to reach this optimum target superheat.

Outdoor Fan Motor Control

Solid State Relay (SSR) is used in the DVM outdoor fan motor control. There is an option to operate this in 21 steps, from 0 step (Stop) to 20 steps (Full Speed). Multi stage fan speed operation provides 2 benefits. The first is input power saving of motor itself, because lower step has lower power consumption as compared to higher steps. The second is optimum condenser pressure control to achieve the desired D p that can ensure the optimum mass flow through the system. Cycle stabilization provides optimum efficiency as compared to oscillating fan controls.

Accumulator

Traditionally the accumulator is used as a safety device to prevent liquid floodback to the compressor. However, in the DVM system, a Liquid Line Suction Line Heat Exchanger (LLSLHX) is embedded in the accumulator. LLSLHX increases subcooling and prevents performance drop caused by pressure drops in long pipe length systems.

Receiver

Although receiver has a very simple structure, its role is very important in multi heat pump system. Receiver maintains adequate subcooling on the liquid line and modulates the amount of refrigerant circulation. It compensate the difference of required refrigerant amount between cooling and heating, all indoor unit running and one indoor unit running.

For the DVM system, the receiver is particularly important as it helps to improve system performance. Figure 5 shows the fluctuation in the compressor discharge pressure. A test was conducted at 50% capacity with 6 secs compressor loaded and 6 secs unloaded. Using a 3 Kg receiver, the fluctuation in receiver outlet pressure was 0.25 Mpa.

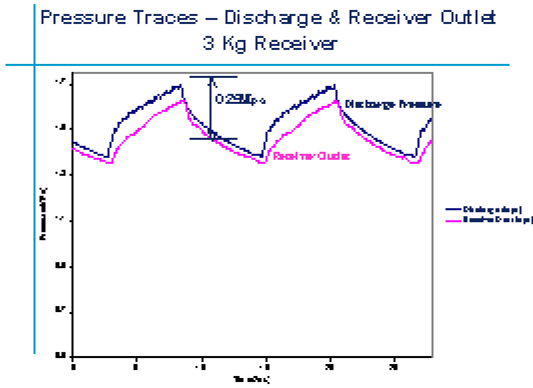


Figure 5. Effect of Small Reciever

If the size of the liquid receiver is increased, the amount of pressure fluctuation decreases. Decreased pressure fluctuation ensures a steady stream of refrigerant to the indoor electronic expansion valve. This helps to increase the system capacity. Figure 6 helps to show how the larger receiver size provides lower D p (0.07 Mpa) & additional cooling capacity.

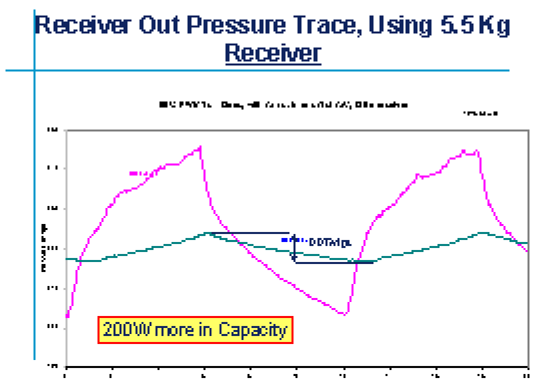


Figure 6. Effect of Large Reciever

Hot Gas Bypass Valve

Hot gas bypass valve vents a regulated amount of gas from the discharge side to the suction side. It is used to prevent sudden drops in suction pressure. This valve is not for performance enhancement but more for safety reasons to prevent the compressor from being stopped on low-pressure cutout.

Liquid Bypass Valve

To maintain an optimum discharge temperature, sometimes a controlled amount of liquid is injected to the suction gas. It helps to keep the discharge temperature within an optimum limit.

Indoor Electronic Expansion Valve

Depending on the total room cooling/heating demand, the Digital compressor modulates to deliver the appropriate capacity. In a multiple evaporator system, the function of the EXV is to distribute the appropriate amount of refrigerant to each evaporator to satisfy the room demand optimally. Thus the role of the EXV is 2 fold - maintain the pressure differential and also to distribute the right amount of refrigerant to each indoor unit.

There are 2 temperature sensors on each evaporator - one is on the liquid inlet and one on the gas outlet. The temperature differential gives an indication of the superheat on the evaporator. In the microprocessor, there is a table of target superheat versus room demand. When the room demand is high, the evaporators need a lot of refrigerant and in such conditions the target superheat is kept low. Since the target superheat is low, the expansion valves try to open more to feed additional refrigerant to the evaporator. When the demand is satisfied, the target superheat becomes higher and the EXV closes to reduce the refrigerant flow to the evaporator.

Thus the control algorithm is continuously providing signals to the EXV to open or close by small amounts to vary the amount of refrigerant being delivered to the evaporator. Such a fine control on the refrigerant flow not only provides a superior level of room temperature control but also helps to ensure that there is no wastage of energy.

Pressure Control

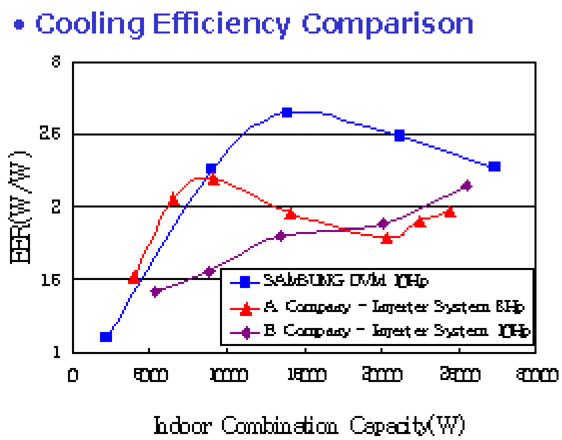
During the "cooling mode" operation, the Digital Scroll compressor modulation is determined from the system suction pressure while during "heating mode" it is determined from the system discharge pressure. This pressure control enables the compressor modulation to adjust to the thermal load automatically.

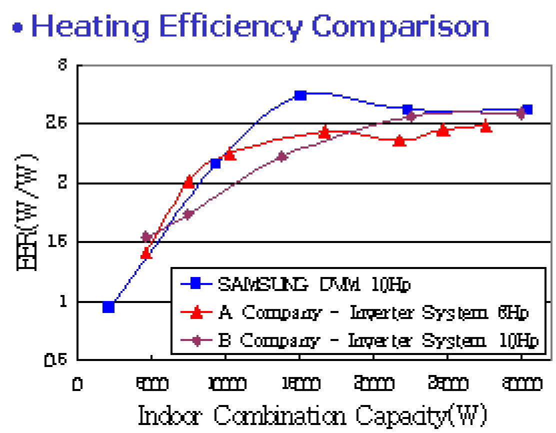
For example, in the "cooling mode" when the indoor thermal load goes up - the suction pressure increases. The compressor capacity is modulated automatically (in this case, the modulation is increased) to achieve the target low pressure. Lower thermal load reduces the system suction pressure and the compressor is modulated down to increase the suction pressure to the target set point. This pressure control method gives " quick cooling/heating", "energy savings" and "comfortable air-conditioning". The target low-pressure value can be adjusted depending on the length of the refrigerant piping as well as users choice.

Pressure control method is more relevant for the heating mode. Variation of outdoor air temperature is wider in heating than in cooling. During warm weather, the capacity output from the fixed speed compressor is too high while in cold ambient, it is too little. Variable compressor and pressure control algorithm can solve this problem. During low ambient, the system operates at low suction and discharge pressures. Compressor modulation is increased by the microcontroller and the heating capacity is also increased as per the thermal load. During warm ambient, the modulation is low and this leads to energy savings. Discharge pressure control in heating mode provides " constant heating capacity" regardless of ambient temperature and also provides energy savings.

System Performance

The DVM system, using a high efficiency Digital Scroll compressor and sophisticated controls technology (electronic expansion valve control, pressure sensor etc), provides a superior system performance. The following graphs shows the energy efficiency ratio (EER) of the DVM system benchmarked against the leading inverter technologies.





The above efficiency graphs show that the optimized DVM system has a better efficiency in most of the operating area, specially the 40% - 80% operating region, where the efficiency need is most important.

Monitoring Control Technology

Other than the controls that are optimized to enhance the system performance, system monitoring is an effective tool to visually monitor the system functioning.

S - Net System

S- Net is the Samsung proprietary "system monitoring" program. The software can be used to monitor the functioning as well as the health of the system - pressures and temperatures at all key points in the air-conditioning system. Each indoor unit can now be controlled remotely through this software. S - Net is available in both RS232 protocol and also TCP/IP. It is now easy to monitor the health of an air-conditioning system through the Internet, from a remote monitoring site. Figure 7 shows the S- Net cycle monitoring screen. Figure 8 shows the S- Net remote controlling screen.

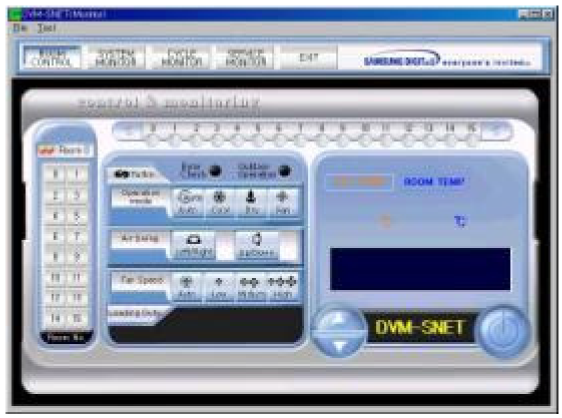


Figure 7. S-Net Cycle Monitoring Screen

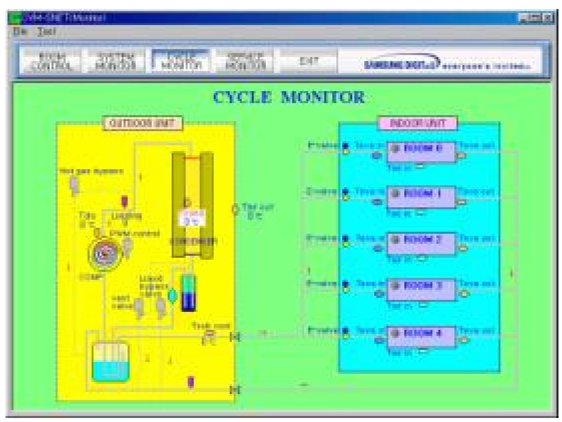


Figure 8. S-Net Remote Controlling Screen

Integrating Power Distribution System

In case several indoor unit users share the same condensing unit, they must share the electricity bill as per the usage hours. Integrating Power Distribution program is able to calculate the exact electricity bill for each indoor unit, depending on the usage.

Centralized Group Controller

Through a centralized group controller, a maximum of 256 indoor units can be controlled. This controller can group some areas into "zones" and can do "zone air-conditioning". The S- Net also has this feature of zone air-conditioning. All these controls help to enhance the system performance and reduce the operating costs for large commercial buildings.

Future Of Control Technology

Up until now, the focus of control technology has been to devise "more energy efficient" and "more comfortable air-conditioning" controls. One of the future technologies that Samsung has invested resources is the "failure expectation" control. This technology will usher in a new era of superior control technology, especially for large commercial buildings. It will open up the world of "never fail never stop air-conditioning" and "pre-service" will substitute "after service".

Summary

As can be seen from this paper, the mechanical hardware in an air-conditioning system has not changed much over the past few years. However, the electronic control technology has advanced tremendously - not only to help improve the system performance but also to increase the reliability of the system. Sophisticated monitoring technology is enabling OEMs to monitor and control the health of important installations.