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Optimization and Simulation of Supermarket Refrigeration System using Pulse width Modulation Technique to Achieve high Cooling effect and Reduce Power Consumption

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ABSTRACT: The energy saving refrigeration system that is Refrigerated Condensing composed of a condensing unit and the refrigerated Unit display cases has been developed In this system, the compressor controls the evaporating temperature and expansion valves control superheat at the outlet of evaporators in the refrigerated display cases. Pipe The target value of the evaporating temperature is calculated from the temperature difference between the Cases refrigerated display cases and those cooling targets. The Data target value of superheat is set at degrees that is the best value for energy conservation of the Compressor refrigeration system. In this way, the electric power with DC motor consumption of the refrigeration system is reduced by in comparison with the conventional system.

Keywords: Energy saving, condensing unit, refrigerated Energy Refrigeration System expansion valve.

I. INTRODUCTION

In the supermarket, energy consumption of the refrigeration system for the food cooling accounts for 62% of total consumption of the supermarket The cooling load of the refrigerated display cases The refrigeration system is required to save energy varies widely by the outdoor air temperature and the to halt global warming and to save the running cost of the supermarket's opening/closing. To respond to the above problems, the compressor's capacity is controlled to match the cooling energy saving refrigeration system for the supermarket load of the refrigerated display cases .has been developed. In this system, the A compressor frequency control by the inverter targets compressor frequency control and the linear expansion the evaporating temperature of the refrigeration cycle .valve opening control reduce the energy consumption. In The cooling load of the refrigerated display cases, which this paper, the system configuration, the control technique is calculated from the temperature difference between and the examination results of the system are described. operating a refrigeration system for a container to pull down the temperature of cargo from ambient to a predetermined set-point temperature, the method comprising: operating a compressor of the refrigeration system at a first power to compress a refrigerant and direct the refrigerant through a condenser and an evaporator of the refrigeration system, wherein the compressor, condenser, and evaporator are connected in series initially operating an evaporator fan at a first speed to supply refrigerated supply air from the evaporator to the cargo within the container when the cargo is at ambient temperature; sensing the temperature of the supply air; comparing the temperature of the supply air with the predetermined set-point temperature; and increasing the speed of the evaporator fan to a second speed faster than the first speed when the temperature of the supply air is lower than the predetermined set-point temperature to maintain the temperature of the supply air at the predetermined set-point temperature.

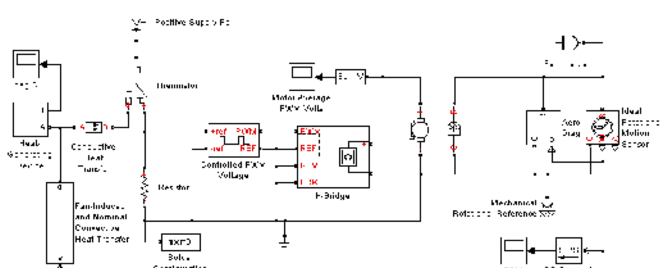

Fig. 1. Block diagram energy saving refrigeration system.

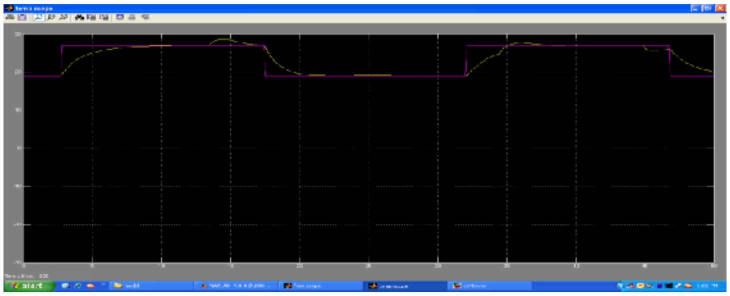

Fig. 2. Heat Temperature graph.

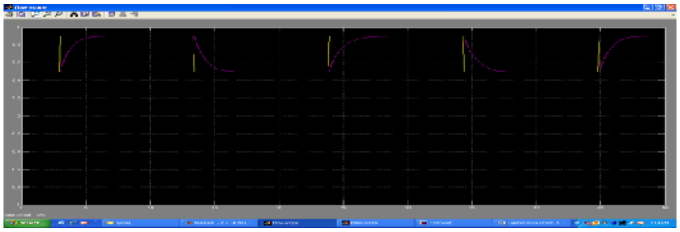

Fig. 3. Lequd Flow control graph.

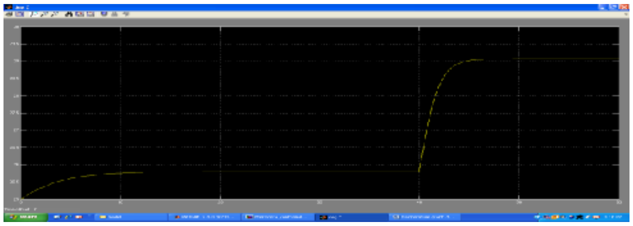

Fig. 4. Thermostat controlled Conductive heat and fan heat induced dec. graph.

The method of claim further comprising decreasing the speed of the evaporator fan from the second speed to a third speed slower than the second speed when the temperature of the supply air is higher than the predetermined set-point temperature to maintain the temperature of the supply air at the predetermined set point temperature. The method of claim further comprising operating the compressor at a constant power when the fan operates at the first and second speeds. The method of claim further comprising operating the compressor at a second power lower than the first power when the supply air equals the predetermined set-point and the evaporator fan is at the second speed. The method of claim wherein the first speed is a minimum speed and the second speed is a maximum speed. The method of claim wherein the first power is a maximum power. The method of claim further comprising driving the evaporator fan with a controllable evaporator fan motor. The method of claim further comprising controlling the evaporator fan motor by pulse width modulation (PWM) of the electric power supplied to the evaporator fan motor. The method of claim wherein driving the evaporator fan includes driving the evaporator fan with two-speed evaporator fan motor. The method of claim 1further comprising directing refrigerated supply air into the cargo container, circulating the air past the cargo, and returning the air as return air through the evaporator. A refrigeration system for a container to pull down the temperature of cargo from ambient to a predetermined set-point temperature, the system comprising: a compressor configured to operate at a first power to compress a refrigerant and direct the refrigerant through a condenser and an evaporator, wherein the compressor, condenser, and evaporator are connected in series; an evaporator fan configured to initially operate at a first speed to supply refrigerated supply air from the evaporator to the cargo within the container when the cargo is at ambient temperature's sensor configured to sense the temperature of the supply air; anda controller programmed to compare the temperature of the supply air with the predetermined set-point temperature, wherein the controller increases the speed of the evaporator fan to a second speed faster than the first speed when the temperature of the supply air is lower than the predetermined set-point temperature to maintain the temperature of the supply air at the predetermined set-point temperature.

The system of claim 11, wherein the controller is programmed to decrease the speed of the evaporator fan from the second speed to a third speed slower than the second speed when the temperature of the supply air is higher than the predetermined set-point temperature to maintain the temperature of the supply air at the predetermined set-point temperature.

The system of claim wherein the compressor is configured to operate at a constant power when the fan operates at the first and second speeds. The system of claim wherein the compressor is configured to operate at a second power lower than the first power when the supply air equals the predetermined set-point and the evaporator fan is at the second speed.

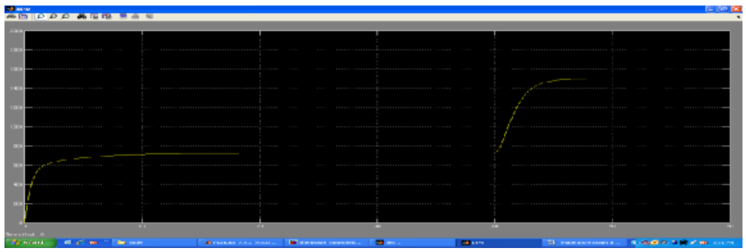

Fig. 5. Mechanical rotational RPM graph.

The system of claim, wherein the first speed of the evaporator fan is a minimum speed and the second speed is a maximum speed. The system of claim wherein the first power of the compressor is a maximum power. The system of claim wherein a controllable evaporator fan motor drives the evaporator fan. The system of claim wherein the controller controls the fan motor by supplying pulse-width-modulated electric power to the fan motor. The system of claim wherein the fan motor includes a two-speed evaporator fan motor. The system of claim wherein the evaporator fan is configured to direct refrigerated supply air into the cargo container, circulate the air past the cargo, and draw in the air as return air through the evaporator. A method for operating a refrigeration system for a container to pull down the temperature of cargo from ambient to a predetermined set-point temperature, the method comprising: operating a compressor of the refrigeration system at a first maximum power to compress a refrigerant and direct the refrigerant through a condenser and an evaporator of the refrigeration system, [12] wherein the compressor, condenser, and evaporator are connected in series; initially operating an evaporator fan at a first minimum speed to supply refrigerated supply air from the evaporator to the cargo within the container when the cargo is at ambient temperature; sensing the temperature of the supply air; comparing the temperature of the supply air with the predetermined set-point temperature; increasing the speed of the evaporator fan to a second maximum speed faster than the first speed when the temperature of the supply air is lower than the predetermined set-point temperature to maintain the temperature of the supply air at the predetermined set-point temperature; decreasing the speed of the evaporator fan from the second speed to a third speed slower than the second speed when the temperature of the supply air is higher than the predetermined set-point temperature to maintain the temperature of the supply air at the predetermined set-point temperature; operating the compressor at a constant power when the fan operates at the first and second speeds; operating the compressor at a second power lower than the first power when the supply air equals the predetermined set-point and the evaporator fan is at the second speed; and directing the refrigerated supply air into the cargo container, circulating the air past the cargo, and returning the air as return air through the evaporator.In a refrigeration process heat is absorbed in an evaporator by evaporating a flow of liquid refrigerant at low pressure and temperature. Controlling the evaporator inlet valve and the compressor in such a way that a high degree of liquid filling in the evaporator is obtained at all compressor capacities ensures a high energy efficiency. The level of liquid filling is indirectly measured by the superheat. Introduction of variable speed compressors and electronic expansion valves enables the use of more sophisticated control algorithms, giving a higher degree of performance and just as important are capable of adapting to variety of systems. This paper proposes a novel method for superheat and capacity control of refrigeration systems; namely by controlling the superheat by the compressor speed and capacity by the refrigerant flow. A new low order nonlinear model of the evaporator is developed and used in a back stepping design of a nonlinear adaptive controller. The stability of the proposed method is validated theoretically by Lyapunov analysis and experimental results show the performance of the system for a wide range of operating points.

The method is compared to a conventional method based on a thermostatic superheat controller. Refrigeration systems are widely used as well in applications for private consumers as for the industry. Despite differences in size and number of components, the main construction with an expansion valve, an evaporator, a compressor and a condenser, remains to a considerable extent the same. Large parts of the same technological challenges are therefore encountered in both markets. In this paper we focus on a small water chiller, however the generality of the results applies to a larger family of so-called 1:1 systems, i.e. system with 1 evaporator and 1 compressor. Refrigeration and air conditioning, accounts for a huge part of the total global energy consumption, hence improving energy efficiency in these system can potentially lead to a tremendous reductions in the energy consumption. Optimizing the set-points of these systems has been proved to enable a substantial reduction in the power consumption in [1]. In [2] a method for on-line optimization of the set-points to minimize power consumption is presented. In a refrigeration system one of the key variables to control, which greatly affects the efficiency of the system, is the superheat. The superheat is used as an indirect measure of the liquid fraction of refrigerant in the evaporator. Than the temperature in the hot reservoir (normally the surroundings *T a*), i.e. $Te < Tcr$ and $Tc > Ta$. The refrigerant has the property (along with other pure fluids and gases) that the saturation temperature (*T sat*) uniquely depends on the pressure. At low pressure the corresponding saturation temperature is low and vice versa at high pressure. This property is exploited in the refrigeration cycle to obtain a low temperature in the evaporator and a high temperature in the condenser simply by controlling respectively the evaporating pressure (*Pe*) and [11] the condensing pressure (*Pc*). Between the evaporator and the condenser is a compressor. The compressor compresses the low pressure refrigerant (*Pe*) from the outlet of the evaporator to a high pressure (*Pc*) at the inlet of the condenser, hereby circulating the refrigerant between the evaporator and the condenser. To uphold the pressure difference ($Pc > Pe$) an expansion valve is installed at the outlet of the condenser. The expansion valve is basically an adjustable nozzle that helps upholding a pressure difference. The test system is a simple refrigeration system with water circulating through the evaporator. The evaporator is a plate heat exchanger, i.e. an evaporator type with a low internal volume. The heat load on the system is maintained by an electrical water heater with an adjustable power supply for the heating element. The compressor, the evaporator fan and the condenser pump are equipped with variable speed drives so that the rotational speed can be adjusted continuously. The system is furthermore equipped with an electronic expansion valve that enables a continuous variable opening degree. The system has temperature and pressure sensors on each side of the components in the refrigeration cycle. Mass flow meters measure the mass flow rates of refrigerant in the refrigeration cycle and water on the secondary side of the evaporator. Temperature sensors measure the inlet and outlet temperature of the secondary media on respectively the evaporator and the condenser. The applied power to the condenser fan and the compressor is measured. Finally the entire test system is located in a climate controlled room, such that the ambient temperature can be regulated. For data acquisition and control the toolbox for SIMULINK is used.

II. SYSTEM CONFIGURATION

The system configuration is this flow rate of refrigerant was bigger than the needed system is composed of a condensing unit equipped with flow rate that matched the cooling load. So the an pwm compressor and the refrigerated display cases evaporating temperature was lower than the suitable equipped with linear expansion valves A high- temperature and the system efficiency was In efficiency DC brushless motor drives the compressor. This system, when the cooling load is low, a compressor is frequency pwm controls a compressor's capacity. A driven at low frequency and the evaporating temperature condensing unit communicates with the refrigerated The electric power consumption of the energy saving I the energy saving refrigeration system is reduced supermarket and the system price difference with the

Conventional system could be cancelled within one year. The demand for electricity is continuously increasing, growing at an average rate of 6.2% per year[1] well above the world average of 2.7%[2] . As a consequence, in order to maintain a 20% reserve capacity, additional power plants must be constructed to satisfy this demand. It was reported in ref.[3]that Kuwait must invest around over the to finance an expansion programmed for an electricity to cope with this predicted demand. Hot dry climate relies heavily upon AC systems for the cooling of buildings. AC systems have become a necessity for the modern life style to provide adequate comfort and a healthy indoor climate. AC systems of buildings consume many of the peak electrical power. Cool thermal storage has many benefits which are discussed and reported in [4] including the economics, energy saving, design consideration and impact on the environment.

The feasibility of incorporating cool thermal storage into conventional AC systems was studied in [5-6] where cool thermal storage was considered as one of the available energy saving technologies. Chilled water storage(CWS)[7] is one cool thermal storage technology that is widely used in many countries including the to shift the peak electrical power requirements from periods of high demand, to periods of lower demand. Many CWS systems have was installed for an Army installation to shift more than vapor compression heat pump systems have been used to reduce the temperature of a particular substance or process for over one hundred years. However, the refrigeration industry has historically paid very little attention to the energy needed to achieve the objectives of the refrigeration processes. As a result, industrial refrigeration system design and operation is more of an art form than a science. Even though a refrigeration system is producing the desired result, it may not be operating efficiently. Recent concerns about electrical usage and costs have prompted many in the refrigeration industry to reevaluate the cost-effectiveness of their system design and operating strategies. Heat pump system optimization can be defined as a process that produces the desired refrigeration effect for minimum cost (usually life-cycle cost). As energy and equipment become more expensive, the need for optimizing new and existing systems will continue to grow. The biggest challenge that most industrial refrigeration system designers and operators face is component diversity. All refrigeration systems consist of different components and often times each component will be produced by a different manufacturer. Compressor models for refrigeration system simulation include steady-state model and dynamic model. The most important advantage of the steady state model of compressor is its simplicity. Once the calculation method with the empirical parameters for isentropic exponent, effective clearance volume ratio and motor efficiency is determined, the calculation of the compressor performance becomes explicit and very fast. The steady-state compressor model is certainly suitable for a steady simulation of a refrigeration system. However, a dynamic model reflecting the dynamic characteristics of all parts of the compressor might be more accurate than a steady-state model but too complicated for simulation of refrigeration systems. Refrigerant mass flow rate through the compressor is a function of compression ratio, refrigerant density and reliance on AC system reduces the peak electrical power consumption of the chiller, compared to the conventional system at peak [9] cooling demand, by up to 100% depending on the selected operating strategy, and therefore on the peak electrical load of an air cooled AC system by up to 78%. However, the results have shown that chillers operating with load level and demand limiting partial storage strategies have slightly higher energy consumption The expansion device is one of the fundamental elements in a refrigeration system. The role of an expansion device in a refrigeration cycle is first to maintain the pressure differential between the low pressure side (evaporator) and the high pressure side (condenser) for a compressor driven refrigerating process, and the second purpose is to regulate the refrigerant flow to match the heat flux in the heat exchangers. [10] There are two types of expansion device: variable flow area devices and constant flow area devices. The process of a refrigerant flow through an expansion valve is a flashing process, when the pressure of a liquid suddenly drops below its saturation pressure and the liquid passes from a sub-cooled to a superheated state. An accurate knowledge of flashing phenomenon is essential in the prediction of critical flow rate.

III. SUPERMARKET REFRIGERATION SYSTEMS

The edible goods sold in supermarkets are usually located in open refrigerated display cases to avoid deterioration while allowing easy access for customers a simplified scheme of a typical supermarket refrigeration system.

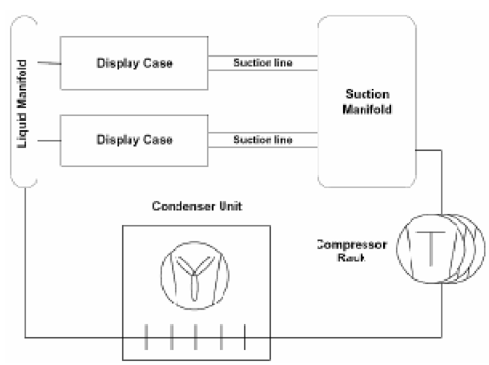

Fig. 6. Supermarket refrigeration system.

It consists of four main components: a number of display cases, a suction manifold, a compressor rack (consisting of a set of compressors connected in parallel), and a condenser unit. The main objective of this system is to supply the display cases with liquid refrigerant from the liquid manifold through expansion valves. The supermarket refrigeration system never reaches steady-state operation. Instead, the main process variables exhibit periodic behavior. This fact is exploited here to design a low-level controller that keeps the controlled variables within the admissible operating region. In this controller, the expansion valves of the display cases are used to regulate the air temperature of the case, and the compressors are switched to maintain the suction pressure a small portion of the air temperature trajectories [8]. The initially synchronized air temperatures are desynchronized within the first ten minutes of operation and remain desynchronized throughout the experiment reflects this fact - the frequency of compressor switching has been reduced compared to previously obtained on the system: In comparison to the simulation results under traditional control [12], our control scheme adheres much better to the constraints on the process variables and reduces the frequency of compressor switching by approximately 90 %. Although in our work a more complex model with slightly different parameters was used than in [3], [4], the can be compared under the justified assumption that the dynamics of both models is almost similar. The comparison from [3] shows that our control scheme adheres better to the constraints while reducing the frequency of compressor switching by about 60 %. The [4] show that the binary parameterization of the discrete input variables representing the compressors leads to considerably more compressor switching than our scheme.

IV. CONCLUSION

The energy saving refrigeration system for the compressor and the expansion valves, this system reduces by the electric power consumption in The expansion valve opening controls the comparison system. urban development, high subsidized energy cost and the reliance on AC system reduces the peak electrical power consumption of the chiller, compared to the conventional system at peak cooling demand, by up to 100% depending on the selected operating strategy, and therefore on the peak electrical load of an air cooled AC system by up to 78%. However, the results have shown that chillers operating with load level and demand limiting partial storage strategies have slightly higher energy consumption The expansion device is one of the fundamental elements in a refrigeration system. The role of an expansion device in a refrigeration cycle is first to maintain the pressure differential between the low pressure side (evaporator) and the high pressure side (condenser) for a compressor driven refrigerating process, and the second purpose is to regulate the refrigerant flow to match the heat flux in the heat exchangers. There are two types of expansion device: variable flow area devices and constant flow area devices. The process of a refrigerant flow through an expansion valve is a flashing process, when the pressure of a liquid suddenly drops below its saturation pressure and the liquid passes from a sub-cooled to a superheated state. An accurate knowledge of flashing phenomenon is essential in the prediction of critical flow rate. In fact, because of the very small volume of expansion devices, the expansion process can be considered as being adiabatic without any refrigerant mass variation inside it. The widely utilized expansion devices are the capillary tubes and the thermostatic expansion valves. system and its components is quite essential for different reasons: to assure that the installation will meet the demanded cooling load, predict the best configuration for a required application, test new refrigerants, assure compatibility between system components, and improve energy savings and installation efficiency. In this study, two approaches of component's modeling, using manufacturer's published design data and fundamental thermodynamic principles were investigated. It is evident from results obtained from both approaches that the heat pump cooling capacity, compressor power consumption and coefficient of performance will increase with the evaporating temperature and decrease with condensing temperature. The balance point temperature should be determined and compared continuously to the design evaporating temperature

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