Control system of Heat & Cold Storage Optimization for Heating and Cooling Devices using Heat Pump Type

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Abstract Background/Objectives: ***Control system and method for optimization of heat or cold storage in heating and cooling devices using heat pump type were developed in this study. The heat pump will be activated by electric power with light duty in response to the fluctuation of electric charges only through building a simple and independent system.***

Methods/Statistical analysis: ***Development of control system and its method for optimization of heat and cold storage in heating and cooling devices using heat pump type can be provided not only to optimize the use of electric power but also to solve an existing problem of household that is not included smart grid system. The compositions of this system to achieve the goal are divided as follows; a sensor section that is able to measure temperature and rate of flow between inflow water and outflow water that is installed inlet and outlet water of heat/cool tank system, an input section to enter not only the load value according to seasonal and hourly charges but heat pump capacity and heat/cool tank capacity as a reference of activating heat pump and controlling heat/cool storage, a storage section that is to save temperature setting value for the load level of seasonal and hourly charges through input section as well as heat pump capacity and heat/cold controlling.***

Findings: ***Overall structure of system is composed of the section of sensor to measure temperature and flow value, input with one more key input tool, storage for temperature setting value, optimal control for heat/cool storage, driving relay to control heat pump, display in each temperature as well as pump capacity and communication. The optimal control section is also included an arithmetic operations part that of temperature variation, total heat used, heat pump uptime and capacity control of a total heat/cold storage. The communication section can be selected one of the following available options; a standard RS-232 link or RS485 serial communications, a wired or wireless internet communication interface, and a near-field communication interface like ETHERNET to communicate with an external equipment.***

Improvements/Applications

Use of electricity with lowest load level in response to the electric power rate fluctuations based seasonal and hourly charges makes it possible to activate heat pump or to control heat/cool storage. And then, electricity rate can be greatly reduced through optimized use of electric power based on the simple and independent system configuration of control system and method for optimization of heat/cold storage that had been researched in this study.

Keywords: Air-conditioning and heating equipment, Thermal storage, Cold Storage Tank, Heat pump, Refrigerant

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I. INTRODUCTION

Heat pump is a device for air conditioning and heating indoors. It is composed of a compressor, a condenser, and an expansion valve. A condenser condenses gaseous refrigerant under high temperature and pressure into liquid refrigerant by a compressor under medium temperature with high pressure. An expansion valve expands high vapor pressure liquid refrigerant under medium temperature into low vapor pressure liquid refrigerant under medium temperature by a condenser. An evaporator provides gas-evaporated refrigerants that was converted from low liquid pressure refrigerants under low temperature that passed through an expansion valve to a compressor [1,2]. Refrigerant in low pressure vapor is compressed by compressor to convey a condenser in high pressure vapor. Liquid state gas is condensed by releasing heat. Condensed refrigerant that expanded and decompressed through low liquid pressure refrigerants under low temperature that passed through an expansion valve passing expansion valve is supplied by evaporator. Refrigerant is reinstated by compressor after evaporating absorbed heat from outside[3,4]. The more power is relatively needed compared other electronic devices because heating and cooling devices with heat pump type have a compressor and a pump. Building a simple and independent system makes it possible to response rate fluctuation of electricity bill according to time and seasons under the variable power rate system. Power that has the lowest level of load value at light duty condition is used to operate heat pump or to control heat storage and cold storage for optimization of power usage. Therefore, optimizing control of heating and cooling device with heat pump type and its control method are researched in this study[5,6].

II. RELATED STUDY

Control method of heating and cooling device with heat pump type to control optimizing heat storage and cold storage has been implemented. Power that has the lowest level of load value at light duty condition is used to operate heat pump or to control heat storage and cold storage for optimization of power usage. Building a simple and independent system makes it possible to response rate fluctuation of electricity bill according to time and seasons under the variable power rate system[7,8].

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Control structure to save power charge in existing technology increases complexity and drives up costs of building system because load control server connected power monitoring system is not only conducting power supply for heat storage facilities in groups through wireless communication system but also controlling it regardless of specific time. There is also a downside for power management to save power charge if household does not include smart grid system due to not using power management network and smart meter in smart grid system. Therefore, it needs a system that is possible for power management to save power charges. A single formation of heating and cooling device using heat pump type that is installed independently makes possible for power management to save power charge without configuring the network within smart grid. Building a simple and independent system included its control method makes it possible to response fluctuation rate of electricity bill according to time and seasons under the variable power rate system[9,10].

III. DEVELOPMENT OF CONTROL SYSTEM

Control system is composed as follows; sensor, input, storage, optimized heat/cold storage control, relay driving, display and communication. Sensor section has one or more temperature sensor and flow sensor that is installed inlet and outlet water tank of heat/cold storage to measure inflow water temperature and outflow water temperature as well as flow rate. It can also consist of more temperature sensors that are installed inside heat/cold storage tank as well as heat pump to measure heat pump temperature and heat/cold storage tank.

Input section is equipped with key input tool for inputting seasonal and hourly load level value based on the electric power rate fluctuations with seasonal and hourly charges, heat pump capacity and heat/cold storage tank capacity, available thermal value, and temperature setting to control air-conditioning and heating. Key input tool can be selected among key pad, direction key, dome switch, touch pad, jog wheel, and jog switch. The seasonal and hourly value of load level(Rn) that is set by input section is considered as a variable rate system based on intelligence power grid. According to a variable rate system of electric power demand in Korea, seasonal and hourly power charges can be grouping in accordance with the load value of large, medium and small respectively.

It is desirable that a variable rate system that is varied by power charge per hour based on demand for power has three group with above three stage of level at least. R1 is low while R2 and R3 are medium, small respectively. Table 1 is shown that power charges varies according to not only load usage of large, medium and small but seasonal and hourly load. In case of different charges based on time zone such as minimum load time zone, medium load time zone and maximum time zone, manager or user is able to set and input load level value(Rn) that is shown in Table 2 according to each load rating.

Table 1. Power rate according to season and time zone based on power demand

Classification	Basic Rate	Energy Charge(₩/kw)			
		Time Zone	Summer (JUL~ AUG)	Spring/Autumn (MAR~ JUN, SEP~ OCT)	Winter (NOV~ DEC)
High Voltage B	8,050	Minimum load(₩) Time	53.8 23:00~ 09:00	53.8 23:00~ 09:00	60.0 23:00~ 09:00
		Medium load(₩) Time	106.0 09:00~ 11:00 12:00~ 13:00 17:00~ 23:00	77.1 09:00~ 11:00 12:00~ 13:00 17:00~ 23:00	105.1 09:00~ 10:00 12:00~ 17:00 20:00~ 22:00
		Maximum load(₩) Time	187.2 11:00~ 12:00 13:00~ 17:00	107.1 11:00~ 12:00 13:00~ 17:00	160.3 10:00~ 12:00 17:00~ 20:00 22:00~ 23:00

Table 2. Seasonal and hourly load level according to load rating

Season/Time		23:00~08:00	9	10	11	12	13	14	15	16	17	18	19	20	21	22
load level	Summer	R1	R2	R2	R3	R2	R3	R3	R3	R3	R2	R2	R2	R2	R2	R2
	Spring Autumn	R1	R2	R2	R3	R2	R3	R3	R3	R3	R2	R2	R2	R2	R2	R2
	Winter	R1	R2	R2	R3	R2	R2	R2	R2	R2	R3	R3	R3	R2	R2	R3

Storage section is to save the value of seasonal and hourly load level, heat pump capacity and heat/cold storage tank capacity, and the settings values for control air-conditioning and heating. Control section for optimization of heat/cold storage is to full control over each part of the system and is able to control air-conditioning and heating with heat pump based on input commend. It is also counting current time in real time owing to time counter for the purpose of output relay driving signal to heat pump activation and control heat/cold storage based on checking value of seasonal and hourly load level that was already saved storage section. Control section for optimization of heat/cold storage produces temperature of outflow and inflow that is measured sensor section, total used thermal value from measured flow value at this time. The over structure of control system for optimization of heat/cold storage with heat pump type is shown in Figure 1.

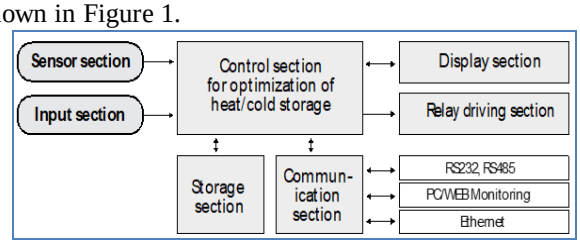

Figure 1. Block diagram in control system for optimization of heat/cold storage with heat pump type

Especially control section for optimization of heat/cold storage in configuration of control system for optimization of heat/cold storage can be composed of including arithmetic operation section of temperature variation, total used heat, heat pump uptime, and capacity control of a total heat/cold storage. Block diagram of detail component in control section for optimization of heat/cold storage is shown in Figure 2.

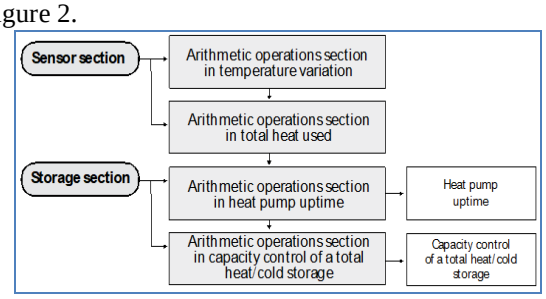

Figure 2. Block diagram of detail component in control section for optimization of heat/cold storage

Arithmetic operation section in temperature variation is to calculate temperature variation in heating water or cooling water within heat/cold storage tank through different measured value between outflow water temperature and inflow water temperature that was measured from sensor. Arithmetic operation section in total heat used is to calculate total used heat value from calculation between temperature variation multiply measured flow value form sensor. Arithmetic operation section in total heat pump uptime is to calculate heat pump running time based on total used heat value and heat pump capacity.

Arithmetic operation section in capacity control of a total heat/cold storage is to calculate total capacity value of heat/cold storage to control it from calculation between heat/cold tank capacity and available heat value. Relay driving section is to conduct heat pump activation and heat/cold control according to operation of relay driving signal for heat pump and heat/cold control from control section for optimization of heat/cold storage. Display section shows various temperature values and measured flow value through sensor section, heat pump capacity set by input section and heat/cold storage tank capacity, user temperature setting value, on/off condition of heat pump and control of heat and cold. Communication section is composed of means such as serial communication interface like RS232 or RS485, wired or wireless internet communication interface, and near-field communication interface like ETHERNET to control that is able to respond external commend or to transmit data for external monitoring devices according to system program's status or on-board application. Flowchart of an overall control process in the development of control system for optimization of heat/cold storage in air-conditioning and heat device with heat pump type is shown in Figure 3.

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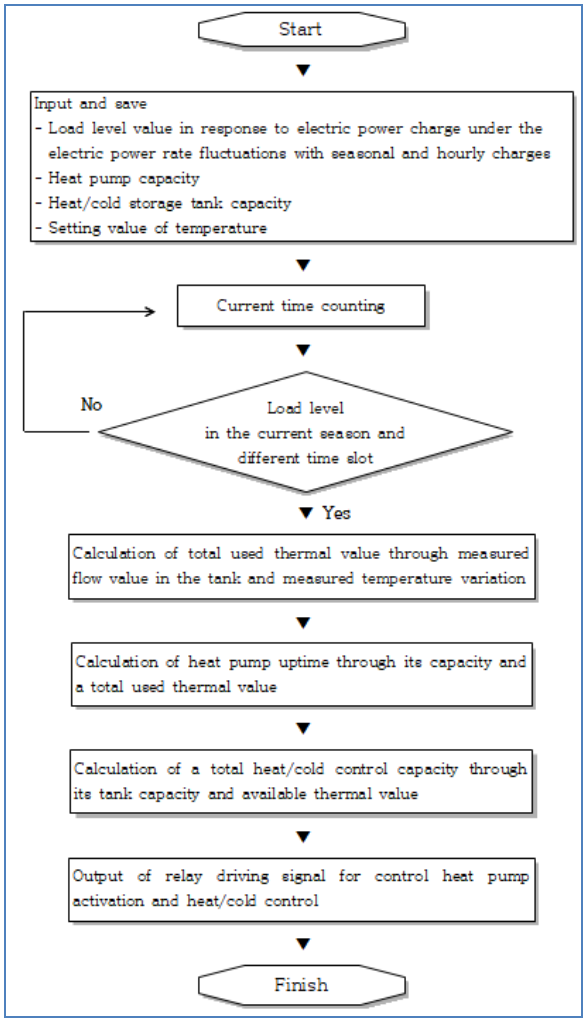

Figure 3. Flowchart of an overall control process of control system

IV. CONCLUSION

Power management to save power charges of household that does not include smart grid system enables efficient by a simple and independent system configuration. In this study, electric power energy cost can be saved to optimize power usage by controlling heat and cold storage or activating heat pump in case of using light duty power in response to fluctuation of electricity bill according to time and seasons under the variable power rate charges system. Building simple system that is researched control system and method included relay driving part for optimization of heat and cold storage in air-conditioning and heat device with heat pump type is able to not only save electric power charges but help to control power management to save electricity bill at home that is not included smart grid system. Use of electricity with lowest load level in response to the electric power rate fluctuations based seasonal and hourly charges makes it possible to activate heat pump or to control heat and cool storage. And then, electricity rate can be greatly reduced through optimized use of electric power based on the simple and independent system configuration of control system and method for optimization of heat and cold storage.

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