Power Consumption Pattern Analysis of Home Appliances for DC-based Green Smart Home

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Abstract

Research on modification and replacement of conventional AC distribution system to DC distribution system has been widely conducted. When DC system is applied, it is possible to improve energy transferring efficiency because most of the home appliances are electric loads which require DC input voltage. Furthermore, compatibility with renewable energy sources and secondary batteries should be improved as they are DC based power sources. To design energy efficient DC system, it is important to understand the load characteristics of the electric devices. In this paper, the electric appliances are classified to 3 types: motor, heating, and electric loads and their typical power consumptions are shown. Load patterns of load which can be used in analyzing the designed system are modeled according the statistics. Feasibility of the developed load patterns are verified by applying it in distribution system design tool.

1. Introduction

Recently global warming is one of main issues in the world as it is accelerated by increasing carbon emission of industrial development of human being. To overcome the situation in many countries a lot of research on sustainable development has been conducted. In the same manner, study on replacement of AC conventional system with DC system has been widely done to improve power transferring efficiency and reduce energy delivery stages.

While state of the art electric devices that give convenience in human life are widely spread, analog devices have been quickly changed to digital which is operated by DC power source. In this trend, the percentage DC-operated loads account will be dramatically increased and the conventional AC distribution system should face the limitations in energy efficiency improvement. As a result, DC distribution system which delivers electric energy directly to the load is highlighted as a solution.[1]-[2]

To implement the DC distribution system, power electronics technology is indispensable and optimal design should be preceded. To optimize power components, load patterns of electric devices should be observed and it can be used in system design.

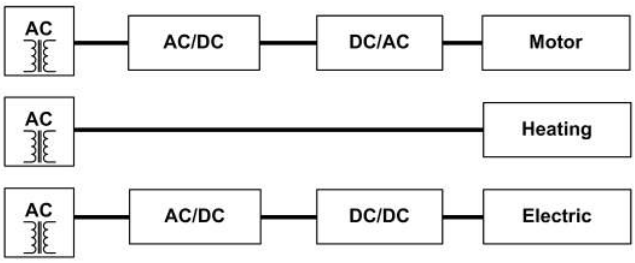

Fig. 1. Power Transferring Structure of loads in AC Distribution

Table 1 Classification of home-used devices with rated power

Quantity	Rated Power	Quantity	Rated Power
Refrigerator(M)	39.3kWh	LCD TV(E)	150W
Iron(H)	2.1kW	CRT TV(E)	130W
Washing(M)	520W	PDP TV(E)	280W
Cooker(H)	1.5kW	Electric Fan(M)	50W
Microwave(H)	1.1kW	Air con.(M)	1.8kW
Vacuum(M)	510W	Fluorescent(E)	20W
Computer(E)	350W	Electric pad(H)	280W

In this paper, home appliances used in household are classified to 3 types: motor, heating, and electric loads. Load profile is modeled using statistics given by Korea Power Exchange (KPX). The feasibility of the model is shown by providing system simulation results.

2. Classification of Home Appliances

Home appliances are classified to motor, heating and electric loads and the structures of their power supply are shown in fig. 1. Motor loads are operated by AC power such as refrigerator, washing machine, vacuum cleaner, electric fan, and air conditioner. Heating loads are considered as a resistive load and they can be operated by both AC and DC voltage such as iron microwave, and electric pad. Computer, television, florescent lamp, and DVD player are considered to be electric loads as they consume DC power.

Widely used electric home appliances are classified in table 1 with their load type and rated power. Typical energy consumption for a month is shown in case of refrigerator as it is usually in operation to keep temperature of foods. As shown in fig.2, it is clear that DC distribution can be more efficient because the smaller the number of power conversion stages, the larger the system efficiency is.

However, there are negative sides in DC system such as larger line drop caused when relatively low voltage is applied. So system modeling is required to predict the system performance and optimize system structure and load profile applicable in design stage is also required to improve designed system reliability.

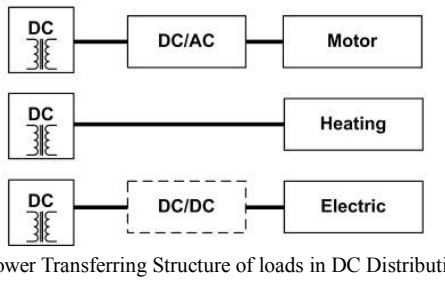

Fig. 2. Power Transferring Structure of loads in DC Distribution

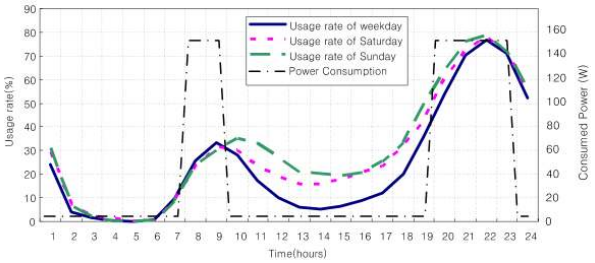

Fig. 3. Average Load Pattern and Power Consumption of Television

3. Model of Home Appliances including Load Power Consumption Pattern based on Statistics

In this section, load pattern model is discussed for system design based on statistics. Because the load pattern is seriously related to the life style of individuals, this paper utilizes the statistics published by KPX 2009.[3]

According to the data, such as penetration rate of appliances and usage rate by time, day, and season, a scenario can be written for system design. This paper develops scenario #1 as an example to show the usability of this method.

In scenario #1, 5 people family whose energy consumption is about 450kW per month is assumed. The scenario consists of lad patterns of several home appliances which have high penetration rate. TV, washing machine, refrigerator, electric fan, air conditioner, computer, electric cooker, microwave, and vacuum cleaner are included in the scenario. Fig. 3 also shows day of the week the average television usage and TV load pattern can be developed. Standby mode operation is also applied to the load power consumption pattern according the life style based on the measured data.

4. Simulation Results

In this section, the feasibility of the study is shown applying the developed scenario #1 to design tool. Fig. 4 shows the total load pattern of scenario #1 that shows power consumption of a house for one week.

In this paper, MATLAB SIMULINK is used as a design tool. To predict the effect of replacement of AC conventional system to DC, a system structure is assumed. It is assumed that the alternative system offers not only 400V but also 24V DC line in this simulation. 24V is used by the devices that prefer low voltage DC source such as TV, and computer shown in fig. 5. 400V is used in high power device such as air conditioner where high conduction loss of wire is the main concern. In the DC distribution system integrated AC/DC and DC/DC converter shows high performance and efficiency throughout wide operating range by rack type parallel operation.[4]

Fig 6 shows the energy consumption of a house for a week with AC and DC distribution and energy saving of 41.2kWh for a month is predicted with DC system applied which shows superiority with about 15,000 KRW saving each month.

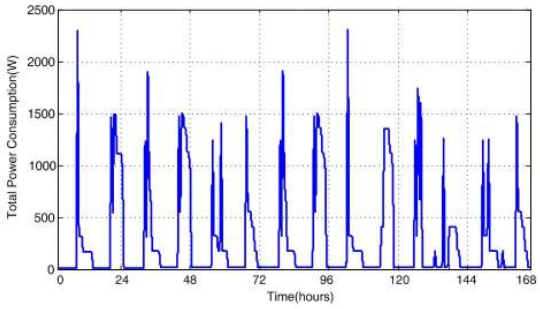

Fig. 4. Total Load Pattern for a week in Scenario #1

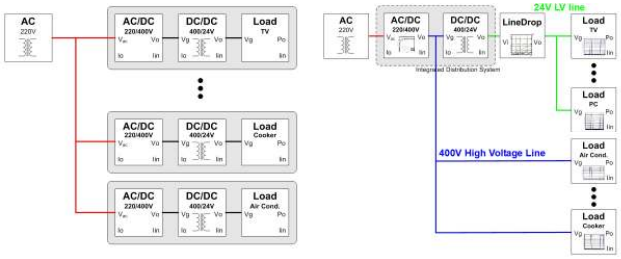

Fig. 5 Simulation of Scenario #1 in AC and DC System Design

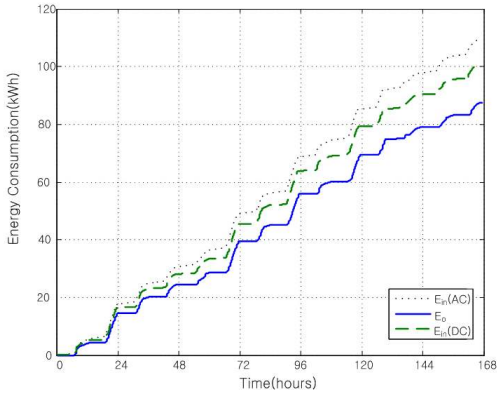

Fig. 6. Comparison of Energy Consumption of DC system to AC system with Scenario #1 applied

In the simulation, the results depend on the standard voltage level of the distribution system, wiring in the building, and other system components including load pattern. Modification can be made for optimal design analyzing the simulation results.

5. Conclusion

In this paper, home appliances are classified to 3 types according to their power consumption characteristic. Electric devices having high penetration rate are listed with their type and typical consumption power. According to the statistics of KPX, a scenario is developed and simulated using system design tool. The result verifies the applicability of load pattern model of this paper in DC distribution system design.

Acknowledgment

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