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Development of a Multiple SMPS System Controlling Variable Load Based on Wireless Network

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Abstract –This paper proposes a multiple switch mode power supply (SMPS) system based on the wireless network which controls variable load. The system enables power supply of up to 600W using 200W SMPS as a unit module and provides a controlling function of output power based on variable load and a monitoring function based on wireless network. The controlling function for output power measures the variation of output power and facilitates efficient power supply by controlling output power based on the measured variation value. The monitoring function guarantees a stable power supply by observing the multiple SMPS system in real time via wireless network. The performance of the proposed system was examined by various experiments. In addition, it was verified through standardized test of Korea Testing Certification. The results were given and discussed.

Keywords: SMPS, Power supply, Load control, Remote control, Wireless network

1. Introduction

Recent electronic devices use various methods of power supply to serve diverse functions according to the state or mode of operation [1-3]. As the method of power supply diversifies, the demand for the AC-DC converter to activate the devices is also growing. The AC-DC converter is a switch mode power supply which switches received AC power supply into regular amount of DC power supply to drive electronic devices using DC power supply.

The existing analogue-controlled SMPS bears the distinctive limitations of additional cost and time for development due to its complicated design and limited scope of application [4, 5]. Especially, its filter circuit to secure loop bandwidth serves as the major cause of limiting the scope of application [6, 7]. To address these issues, the methods for digitally-controlled SMPS are being considered as an alternative.

The digitally-controlled SMPS has an advantage of being robust to the noise in power supply and easy to activate when compared to the analogue-controlled ones with their excellent performances in the normal and dynamic state. However, the digital-controlled SMPS still retains digital compensator which serves as filter circuit to secure analogue-controlled loop bandwidths, resulting in the complexity in design and increase of chip area [8-10]. Such problems call for introduction of design and production technology for power supply circuits which can provide a high rate of power conversion while leaving the form of electronic devices unaffected.

The hybrid control method of SMPS [11] enables stable and efficient power supply by real-time monitoring and digital-controlling of SMPS via wireless networks in order to optimize the power conversion and transmission in analogue way and counter the volatility of external factors. However, designed and manufactured for fixed load, the system suffers from major drawbacks of lowering the efficiency and power factor of output power under variable load conditions. Technology to monitor the variation of load in real time and make power supply safe and stable is required to overcome these limitations.

This paper presents wireless network-based multiple SMPS system which controls variable load. The system is an expanded version of the existing hybrid SMPS system [11] which was designed by authors to allow controlling and monitoring output power based on the wireless network. It uses the 200W SMPS [12] as a unit module, allowing power supply up to 600W. The functions of the system include controlling variable load-based output power and monitoring based on wireless network: while the controlling function measures variation value of output power and enables stable power supply by controlling output power based on measured variation value, monitoring function stabilizes power supply by observing multiple SMPS real-time via wireless network. Three tests (the efficiency measurement and output power measurement tests by load variation and the one by the national certification institution) are conducted to examine the performance of the proposed system.

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2. Multiple SMPS System Controlling Variable Load Based on Wireless Network

Fig. 1 shows the structure of the proposed multiple

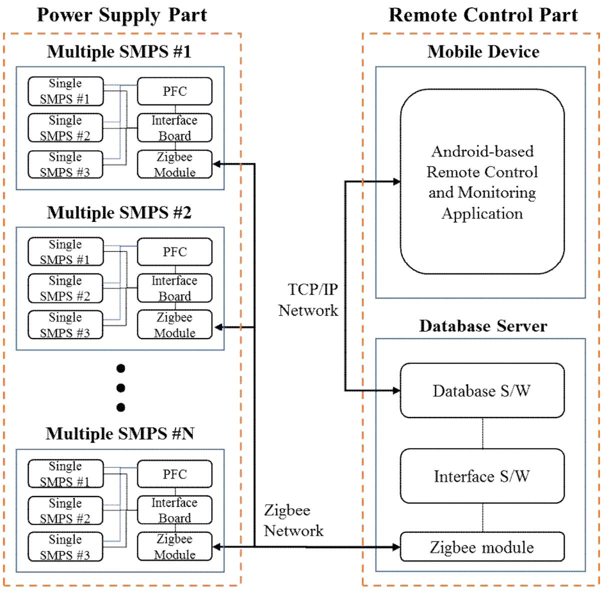


Fig. 1. Structure of the proposed multiple SMPS system

SMPS system, and the detailed explanations are given in the following sections.

2.1 Power supply part

The power supply part is integrated with a number of multiple SMPSs. Each multiple SMPS is designed to control an output power based on variable load, and composed of three single SMPSs (single SMPS means a unit module with 200W), power factor correction (PFC), interface board, and Zigbee module as shown in Fig. 2. Zigbee module transmits SMPS monitoring data (voltage, current, temperature) received from the interface board to remote control part and transmits SMPS control data received from the remote control part to the interface board. The interface board controls PFC and the three single SMPSs modules according to the transmitted control data. Also, the board passes on the monitoring data to remote control part via Zigbee module by ADC of the monitoring signals. PFC controls the three ones and supplies power by converting DC power to AC power.

Fig. 3 illustrates the operational flowchart of the proposed multiple SMPS. As shown in the figure, PFC is initialized in the initial operation, measuring output voltage and current. Once the output voltage and current are measured, the multiple SMPS calculates output power using the measured and operates the first SMPS (illustrated as single SMPS #1 in Fig. 2). While being operated, it activates the second one (single SMPS #2) when the output power gets greater than 200W (the maximum power capacity which can be provided by single SMPS). In sequence, it turns on the third one (single SMPS #3) when the output power gets greater than 400W. Such way of operation minimizes the standby power by supplying the power matching actual power volume. It also contributes to

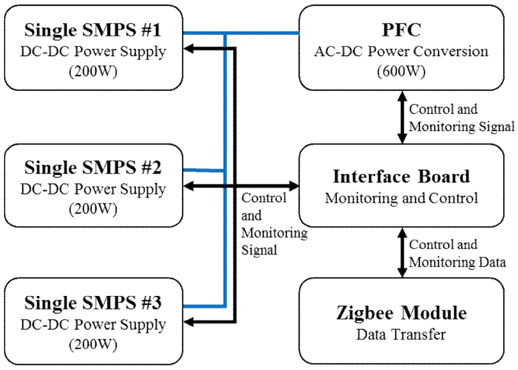


Fig. 2. Structure of the individual multiple SMPS proposed for controlling output power based on variable load

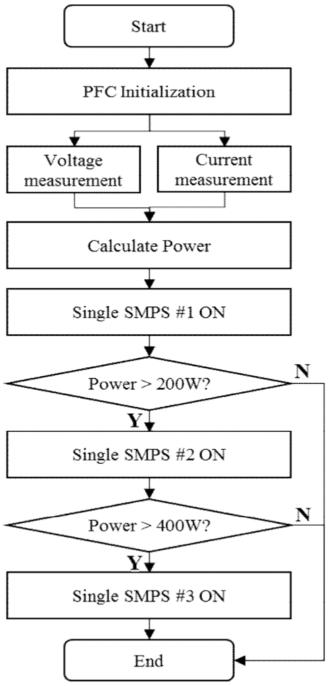


Fig. 3. Operational flowchart of the proposed multiple SMPS

enhancing efficiency and power factor of power supply and maximizing the product longevity of power supplier by reducing the current and voltage stress in power devices.

2.2 Remote control part

The remote control part has a role in controlling and monitoring the power supply part, and is comprised of mobile device (Android-based tablet and smart phone) and database (DB) server. Connected with each other via TCP/IP network, the mobile device for remote control and the database server transmit monitoring data and receive controlling data for multiple SMPS of the power supply part at a 1s interval. Linked together via Zigbee, the remote control part and the power supply part exchange both the controlling and monitoring data of the multiple SMPS, being synchronized at every 0.05ms interval.

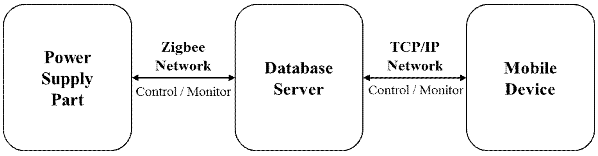
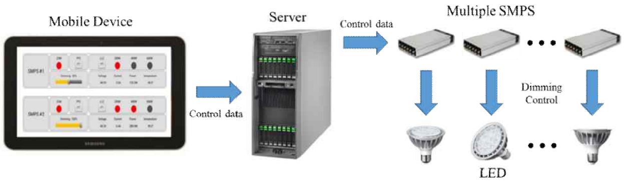
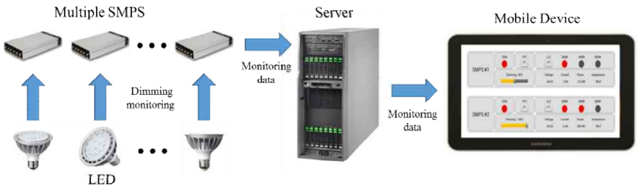


Fig. 4. Structure of the remote control part



(a) Data flow process for the multiple SMPS control



(b) Data flow process for the multiple SMPS monitoring

Fig. 5. Data flow process of the proposed multiple SMPS

Control data frame								
Header	ID	Time	PFC	Single SMPS#1	Single SMPS#2	Single SMPS#3	Dimming	Checksum
2byte	1byte	3byte	1byte	1byte	1byte	1byte	1byte	2byte

Monitoring data frame							
Header	ID	time	Voltage	Current	Power	Temperature	Checksum
2byte	1byte	3byte	1byte	1byte	1byte	1byte	2byte

Fig. 6. Structure of data frame

The multiple SMPS control data is used to control multiple SMPS and LED dimming transmitted in the order of mobile device, server, and multiple SMPS as shown in Fig. 5(a). The multiple SMPS monitoring data fulfills the function of providing the operator with multiple SMPS and LED dimming monitoring after being transmitted in the order of multiple SMPS, server, and mobile device as illustrated in Fig. 5(b).

The communication data frame complies with the form used for the single SMPS system [11] and was expanded for the multiple SMPS control as displayed in Fig. 6. The common header frames in controlling and monitoring data frame are used to identify the multiple SMPS system data. ID frame is used for identifying server and each SMPS and checksum frame for detecting errors of the communication data. The control data frame includes PFC, threes single SMPSs, and LED dimming control data; monitoring data frame comprises data for voltage, current, and power to control output according to the load and temperature data to protect SMPS.

Android-based application GUI for remote control and monitoring is illustrated in Fig. 7. The major function of

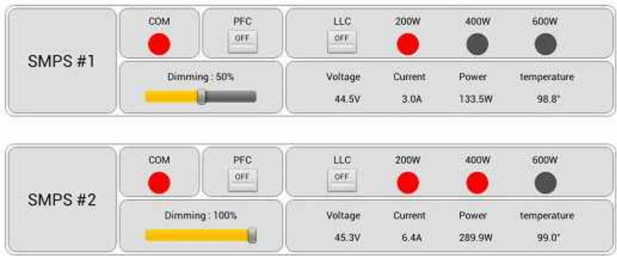


Fig. 7. Android-based application GUI for remote control and monitoring

the application divides into the multiple SMPS monitoring and SMPS control. In order to simulate such functions, authors established wireless network environment composed of 2 SMPS, through which voltage, current, and temperature, and control status of the multiple SMPS were monitored.

3. Experiment and Discussion

This section deals with the performance evaluation of the proposed system by efficiency measurement test for both single SMPS as a unit module and multiple SMPS as a system, and the standardized test of Korea Testing Certification.

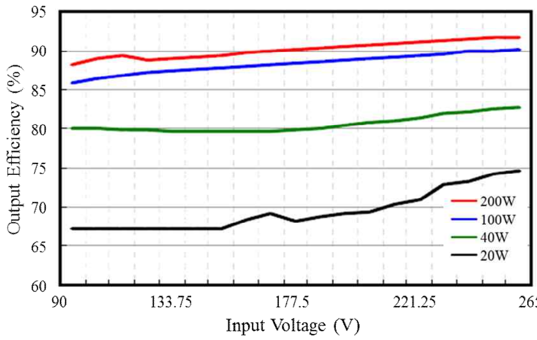
3.1 Experiment 1: Measurement test for the unit module efficiency

The efficiency measurement test for the variation of input voltage and output load of single SMPS was conducted by applying an actual power load (Fig. 8(b)) to

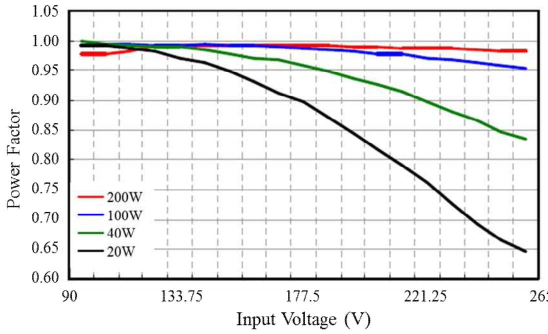
(a) Wireless communication module

(b) Single SMPS integrated with wireless communication module

Fig. 8. Test environment used for a unit module efficiency measurement



(a) Output efficiency with respect to the variation of input voltage on different output loads



(b) Power factor with respect to the variation of input voltage on different output loads

Fig. 9. Efficiency measurement test results on the unit module

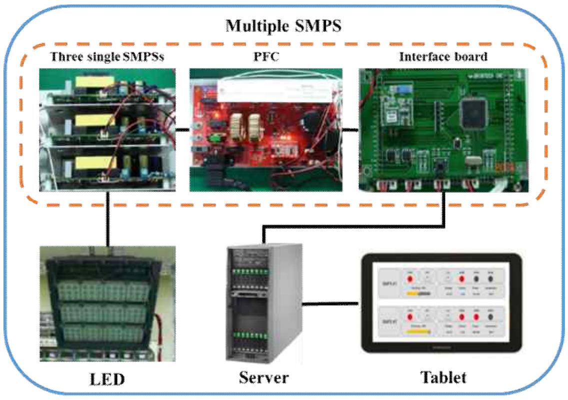


Fig. 10. Environmental setup used for the multiple SMPS efficiency measurement

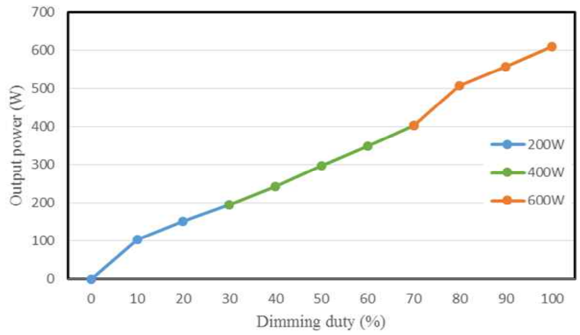


Fig. 11. Efficiency measurement test results obtained using the Proposed multiple SMPS system

a wireless communication module (Fig. 8(a)) to review the performance of a unit module in the system.

The performance test result is shown in Fig. 9: Fig. 9(a) illustrates the output efficiency with respect to the variation of input voltages on various output loads, and Fig. 9(b) represents the power factor with respect to the variation of input voltage on various output loads. The red line maps the results of 100% output load (200W), the blue line of 50% (100W), the green line of 20%(40W), and the black line of 10%(20W) output load, respectively.

The test results (mean efficiency (90%) and mean power factor (0.98) of the unit module in case of full (100%) output load) confirmed that the efficiency was good only in 100%, and that it was greatly affected by the variation of input voltage and output load. Those results reassure the importance of the system's function to control output power according to the variable load.

3.2 Experiment 2: Measurement test for the multiple smps efficiency

Output measurement test for multiple SMPS was conducted to review the output power control function of the proposed system. The remote control part of the proposed system is combined with a number of multiple SMPSs. But, the experiment was performed using a set of multiple SMPS for simplicity: the experiment was conducted in the test environment where LED for load, three single SMPSs, PFC for power regulation, interface board for control and communication, server for communication and data saving, and tablet (Android platform) for remote control were set up as shown in Fig. 10.

The efficiency measurement test result obtained using the proposed multiple SMPS system is shown in Fig. 11. Fig. 11 represents output power according to load, the blue line standing for 200W power (one single SMPS is used), the green line of 400W power (two single SMPSs are used), and the orange one of 600W power (three single SMPSs are used), respectively. The experimental result confirmed that output power could be efficiently controlled by providing the power (200W, 400W, 600W) which is proper to the variable load conditions (variation of LED's dimming duty).

3.3 Experiment 3: the standardized test of korea testing certification

The standardized test was conducted under the supervision of Korea Testing Certification for objective verification. The experiment was conducted under the conditions of 600.52W of loaded output power, 21-25℃ Ta (ambient temperature) and 20-40% RH (relative humidity). Each category was measured after preheating each module with electric power loader for ten minutes

Table 1. Measurement test results for the proposed multiple SMPS system under 100% load

Input voltage(V)	Input current(A)	Input power (W)	Output power (W)	Efficiency (%)	Power factor (%)
219.18	3.034	665.0	600.5	90.3	99.76

under full load condition. The certified results are given in Table 1.

The test result (90.3% efficiency and 99.76% power factor under full load) obtained from the standardized test objectively and officially certified the performance of the proposed system, and also confirmed that output power matching the load could be supplied in an efficient way using the proposed multiple SMPS system.

4. Conclusion

In this paper, a wireless network-based multiple SMPS system to control variable load was presented. The proposed system allowed an efficient power supply up to 600W by integrating 200W unit-module-type SMPS (called single SMPS), our previous work, and stable power supply by providing output power control based on variable load and wireless network-based monitoring. The efficiency with respect to various output loads was examined and the performance was also reviewed by the measurement test for output power, and finally received the official certification by Korea Testing Certification. The test results obtained from both the input voltage and output load variation verified that the performance of the single SMPS under 100% output load was excellent (mean efficiency was 90%, and mean power factor was 0.98). The level of performance (efficiency and power factor) of the single SMPS was low under the load less than 100% (50%, 20%, 10%), which highlighted the importance of the system's output power control based on variable load. From the measurement test results for output power under the load (variation of dimming duty in LED), it was confirmed that the proposed system could enable controlling the output power proportional to the variable load, which efficiency was objectively assessed by the national standardized test.

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