System Design of Electric Assisted Bicycle using the EDLCs as Power Source

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Abstract:- The proposed system uses electric double layer capacitors (EDLCs), which is rapidly charged by using wireless power transmission. This paper compares the volume and power loss of the three kinds of DC-DC converters which are step-down type, boost-type and buck-boost type for the charging and discharging of EDLCs. The number and the output voltage range of the EDLCs is designed that the charge and discharge energy of EDLCs meet more than 53.0 kJ by literature [4]. The results showed that the total volume of the boost-type DC-DC converter is the small when the output power is less than 1.1 kW. On the other hand, the total volume of the step-down type is small when the output power is larger than 1.1 kW. Finally, the relationship between the total volume of proposed system and the output power is clarified.

Keywords : Electric assisted bicycle, Electric double layer capacitors, DC-DC converter, Wireless power transfer

1. Introduction

Recently, DC-DC converters for the control the output voltage of electric double layer capacitors (EDLCs) are actively researched [1]. However, there are only few literatures which consider the total volume of DC-DC converters and EDLCs from the viewpoint of the mounting them on a moving object such as electric vehicles and electric bicycles. Authors have been investigated the application of the EDLCs to the electric assisted bicycle so far. This paper evaluates the volume and power loss of step-down type, boost-type and buck-boost type of DC-DC converters which is used as charging/discharging operation for EDLCs.

2. Proposed system configuration

Fig. 1 shows the proposed system configuration. The proposed system uses a high frequency power source in front of the transmitting antenna for wireless power transmission [2]. Also, the proposed system is constituted by a rapid rechargeable AC-DC converter and EDLCs in the latter part of the receiving antenna. Also, during an assist of the energy for drivers, the DC-DC converter for assist performs the discharge control of the EDLCs when a brushless DC (BLDC) motor is driven. BLDC motor and DC-AC converter are commercial products [3].

3. Circuit configuration of the DC-DC converters

Fig. 2 shows the circuit configuration of three kinds of DC-DC converters. This paper considers step-down type, boost-type and buck-boost type as a circuit for the charging and discharging DC-DC converter using EDLCs as a power source. The number and the output voltage range of the EDLCs is designed that the charge and discharge energy of EDLCs meet more than 53.0 kJ based on the literature [4]. The DC-DC converters of three kinds are designed that the charge and discharge energy of EDLCs is almost equal (the energy of boost-type is 58.0 kJ, the energy of step-down type is 56.5 kJ, the energy of buck-boost type is 55.2 kJ). In addition, the specification of the input voltage of the DC-AC converter is 24 V (V_{outa}, V_{outb}, V_{outc}), and the output voltage of the DC-DC converter is controlled to 24 V the constant.

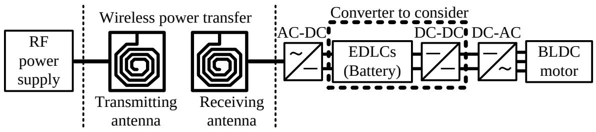


Fig. 1. Proposed system configuration.

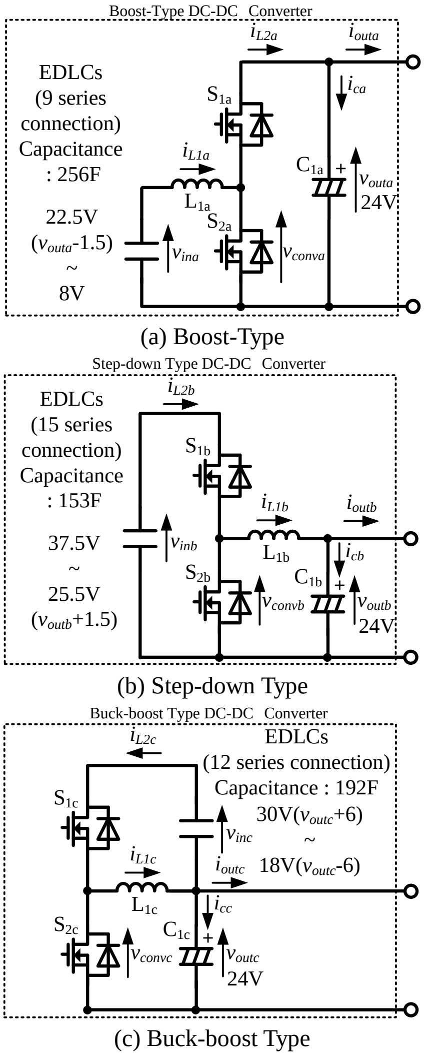


Fig. 2. Investigated circuit configuration.

4. Comparison of volume and power loss

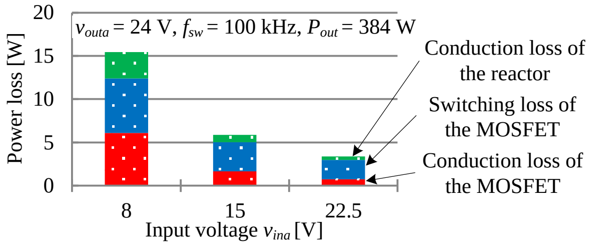
Fig. 3 shows the results of power loss analysis on the three kinds of DC-DC converters when the voltage of the EDLCs V_{in} in Figure 2 is changed. The power loss is analyzed under the conditions that the output power of the DC-DC converter is 384 W constant. In addition, it is noted that dead time is ignored. From Fig. 3, in the boost-type, it is confirmed that the switching loss and the conduction loss of the MOSFET is dominated. Also, in the step-down type and buck-boost type, it is confirmed that the switching loss of the MOSFET is dominated. The reason is that the input current of the boost-type is increased for the input voltage which is lower than the step-down type and buck-boost type.

Fig. 4 shows the relationship between the volume and the output power for the three kinds of DC-DC converters. It is noted that the power loss is maximum in case of the voltage of EDLCs in Fig. 4. In addition, the volume of the Fig. 4 is the sum of volume of EDLCs and DC-DC converter (smoothing capacitor, heat sink, reactor). The design approach refers to literature [5]. From Fig. 4 (b), around the output power of 100 W, the volume of the EDLCs is dominant in the converter of all types. The number of EDLCs for the boost-type is the fewest in all of other DC-DC converters. Therefore, the volume of boost-type is small. However, if the output power is 1.1 kW or more than 675 W, the volume of step-down type is small than the boost-type and the buck-boost type. In case of the boost-type and buck-boost type, the ripple current of the smoothing capacitor is increased when the output power is increased. Therefore, the ratio of the volume of the smoothing capacitor is increased. On the other hand, in case of the step-down type, the ripple current of the smoothing capacitor does not depend on the output power. Therefore, when the output power is increased, the volume of heat sink which is very small and reactor compared to the volume of the EDLCs is increased. However, the volume of the converter does not increase too much. Furthermore, if the output voltage of the DC-DC converter is set over 24V, the cross over point of the volume of three kinds of DC-DC converter is shifted toward high output power. The reason is that the volume of the capacitor is decreased depends on its ripple current according to the high output voltage of the DC-DC converter.

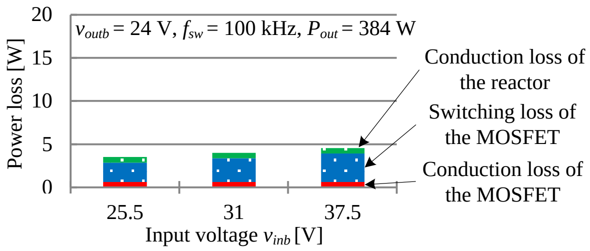
5. Conclusion

The results showed that the total volume of the boost-type DC-DC converter is the smallest up to the output power of 1.1 kW. On the other hand, the total volume of the step-down type is small when the output power is larger than 1.1 kW. Therefore, from the view point of the minimum volume of the system, the DC-DC converter of boost-type is the most suitable. Note that, the cross over point of the volume of three kinds of DC-DC converter is changed according to the output voltage of DC-DC converter.

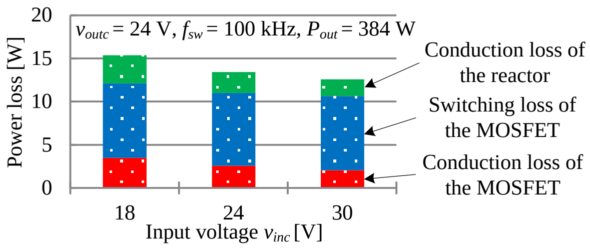
In the future work, the DC-DC converter of boost-type will be made as a prototype and it will be verified by experiments.



(a) Boost-Type

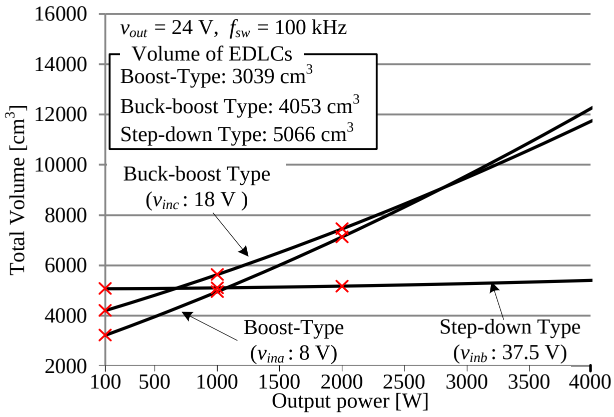


(b) Step-down Type

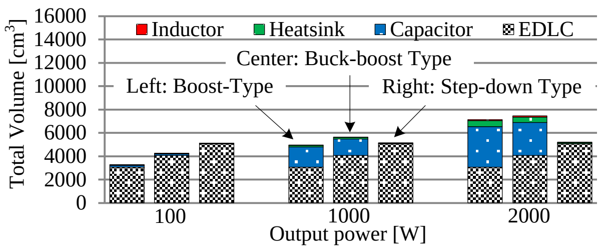


(c) Buck-boost Type

Fig. 3. Results of power loss analysis of the three kinds of DC-DC converters



(a) The total volume



(b) Ratio of the volume

Fig. 4. Relationship between the volume and the output power for the three kinds of DC-DC converters.

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