Running Test of VVVF Inverter Type Railcar Using Lithium Ion Battery

Letter

Running Test of VVVF Inverter Type Railcar Using Lithium Ion Battery

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Lithium ion battery was applied to the running of VVVF inverter type railcar. 15kWh of Mn type lithium ion battery was used. The relation between running time and voltage, current and integrating watt was investigated. The running test was also carried out using VVVF inverter type railcar to investigate charge performance due to regenerative energy. Lithium ion battery module was quickly charged for three times at rate of 4.68C by regenerative braking system. It was estimated that the effect of energy saving was about 22% by the charge of lithium ion battery from regenerative energy.

Keywords : lithium ion battery, tramcar, contactwire-less, energy-saving, regeneration energy

1. Introduction

Recently, the rechargeable battery and fuel cell have been applied on the running of contact-wireless type of railcar[(1),(2)]. Lithium ion battery is expected as the driving source of it because of highest energy density and power density among the rechargeable. Some following advantages of contact-wireless type railcar with lthium ion batteries are expected. (1) the townscape is improved and the maintenance cost of overhead contact wire is reduced. (2) it is possible to utilize as an emergency power source in the overhead contact wire supply failure by disaster and accident. (3) the discharge of carbon dioxide, nitrogen oxides and sulfur oxides can be drastically reduced compared with dieselcar. (4) the energy-saving effect for running of railcar is improved by charging regenerative energy with rechargeable batteries.

We have been tried the running test of DC 600V type railcar by using large Mn type lithium ion battery in the business line of Echizen railway and Fukui railway[(3),(4)]. The running performance and energy-saving effect of railcar were discussed. It was found that the running performance of railcar with lithium ion battery was equal to that of contact-wire type railcar and the mileage was improved. Now, new VVVF (Variable Voltage Variable Frequency) inverter type railcars use the regenerative brake which the kinetic energy of railcar converts to electricity that is fed back into contact-wire. However, the regenerative braking loses its effectiveness when there are no other railcars running nearby that railcar immediately use the regenerated electricity.

(a) (b)

Fig. 1. 15kWh lithium ion battery module (a) and railcar uesd (b)

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VVVF inverter has been used in the new railcar to raise the energy saving in the running. However, it was well-known that the loss of regenerative energy often occurred because the regenerative energy was not charged to other railcar which ran nearby. To solve the problem, it is considered that the use of lithium ion battery is effective for the charge of regenerative energy.

In this work, the energy-saving effect for the running of railcar was investigated using by VVVF 600V type railcar in which the regenerative energy is charged by the lithium ion battery. In this paper, the energy-saving effect by charging regenerative energy with lithium ion battery was described. The performance of railcar run on a large lithium ion battery is also described.

2. Results and discussion

2.1 Lithium ion battery Homogeneous aluminum doped lithium manganate ($LiAl_{0.05}Mn_{1.95}O_4$) cathode materials were large produced by aerosol process[(5)] (The flame type spray pyrolysis equipment, ChugaiRo Co., Ltd.) using spray pyrolysis technique. The mixture of hard carbon and graphite (1:1) were used as an anode. Micro porous polypropylene sheet was used as a separator. 1 mol/dm^3 $LiPF_6$ in EC/DME was used as the electrolyte. Laminate sheet type lithium ion cell was assembled in a globe box under an argon atmosphere. The discharge capacity of lithium manganate cathode was 90mAh/g at 5C and 90% of its discharge capacity was kept after 1000th cycle at 5C. The energy and power density of laminate sheet type lithium ion cell were about 100Wh/kg and 2,000W/kg, respectively. Lithium ion battery submodule (200mm x 80mm x 700mm, 10kg) was consisted of 36 lithium ion cells, in which 4 cells connected in 9 series were connected in parallel. The aluminum case was used for the cooling

Table 1. Specification of lithium ion battery module

Average output voltage : 620V
Operation voltage range : 480-660V
Capacity : 32Ah
Weight : 180kg

of submodule during the charge and discharge.

2.2 Performance of railcar Figure 1 shows the photograph of the 15kWh lithium ion battery module (a) and railcar used (b). Lithium ion battery module had a weight of 180kg which was consisted of eighteen lithium ion battery submodules. Overcharge and overdisarge protection circuit were installed at all submodules in order to ensure the safety. Lithium ion battery module was mounted on railcar (Nippon syaryo moha 800, VVVF 600V). The weight of raicar was about 25t. The module was fixed in the wood rack in order to stand the vibration in the running. Table 1 shows the specification of the module. The output voltage range of the module was from 480 to 660V. Average output voltage was about 620V. The running performance was examined at Fukubu business line (1.5km) in Fukui railway. The change of voltage, current and temperature of modules during running was incorporated in personal computer through the data logger.

Figure 2 shows the relation between running time and voltage, current and temperature after the running of VVVF type railcar with lithium ion battery. VVVF type railcar ran for 1.5km, while the power running, coasting and stopping were repeated in three times. A current of 300A flowed to lithium ion battery and the voltage was dropped when the railcar was quickly accelerated. When the current decreased down to about 200A, the rapid speed down was tried by using regenerative brake from 50km/hr. The current of about -150A was obtained as regenerative energy. This suggested that 150A of regenerative energy was quickly charged to lithium ion battery by the regenerative brake. This means that lithium ion battery is charged at rate of 4.68C because 1C is equivalent to 32A. The temperature of module increased from 17 to 25°C. It was found that the safety of module could be maintained if the railcar was only uesd for the running of few km.

Figure 3 shows the change of speed and integrating watt after the running of VVVF type railcar by lithium ion battery and contact-wire. The maximum speed of 60km/hr was achieved in this work when VVVF type railcar was only derived by lithium ion battery. The integrating watt of lithium ion battery was 2.54kWh when VVVF type railcar ran for 1.5km while it repeatedly decelerated from 50km/hr by the regenerative brake. On the other hand, the electric power of 3.24kWh was consumed without lithium ion battery for the running of 1.5km. It was found that the energy-saving effect was about 22%.

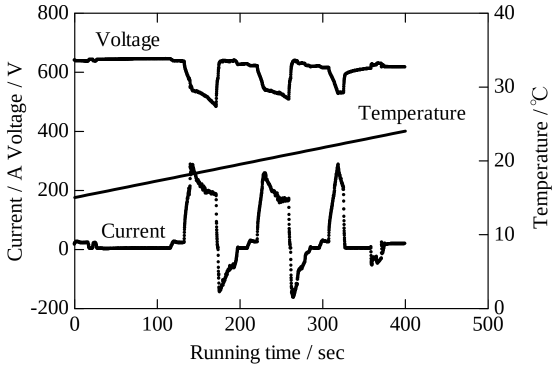

Fig. 2. Relation between running time and voltage, current, temperature

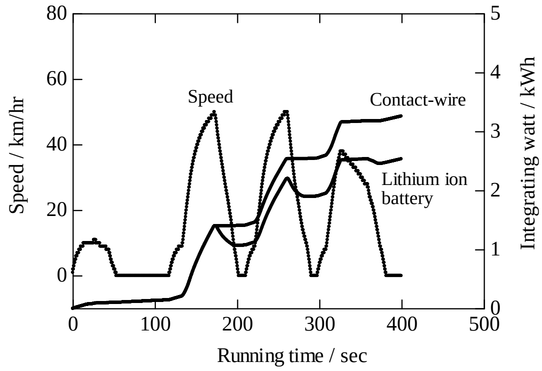

Fig. 3. Relation between running time and speed, integrating watt

3. Conclusion

The running test of VVVF type railcar was carried out by using Mn type lithium ion battery of 15kWh in the business line of Fukui railway. 150A of regenerative energy was charged to lithium ion battery by using regenerative brake. It was clear that 22% of mileage was improved when the regenerative energy was charged by lithium ion battery during the running. It was also found that the running performance of VVVF type railcar with lithium ion battery was equivalent to that of railcar which the electric power was supplied from contact-wire.

Acknowledgement

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