Method to tie feeding cables for energy conservation

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The railway transportation has more advantage than others at a point of view on energy expenditure. In the 21st century, consciousness for environment is increased steadily, so the railway transportation has an important role for modal shift more and more. With the progress of technology, energy conservation on the train has advanced particularly because of the regenerative brake system, in addition to improvement for modulus of machines and lightening the weight of the train. The regenerative brake system is that changes kinetic energy to electric energy on braking, and the distributed power system, which is composed on many trains in Japan, can produce electric energy on braking more than other systems. But no load use it, trains can’t stop only by the regenerative brake, then can’t help using the air brake. We need to stop trains only by the regenerative brake as possible, because of a point of view on energy expenditure and the maintenance for brake shoe, which the air brake system abrade. If the distance between the train on running and on braking is too long, the resistance of the feeding cable causes much waste of energy.

This paper describes the method to use electric energy occurred by the regenerative brake system effectively in West Japan Railway Company to tie feeding cables of up and down lines each other.

Keywords
1. Energy Conservation
2. The Regenerative Brake System
3. The DC Traction System
4. The upper and lower sides simultaneous feeding
5. The transmission loss
1. Introduction
The train in recent years often equips the regenerative brake system. It uses motors as generators and changes kinetic energy to electric energy on braking. Moreover the inverter controlled trains can return electric energy to feeding cables effectively. With the development of power electronics, it becomes a mainstream in the DC traction system.

However, the regenerative brake system sometimes can’t perform sufficiently because of the following two reasons.

(1) The transmission loss
When supplying electric energy to a train from substations, the transmission loss depends on the distance between them. It is not too long for maintaining the voltage on trains. But the regenerative power may be supplied though the distance between trains on running and braking is long.

(2) The loss by the control of the voltage at the train
It is possible that the voltage on feeding cables becomes overvoltage for equipment when the regenerative power is too much, because the regenerative power can’t return to the reception at the substation generally in the DC traction system. Therefore when the voltage on feeding cables becoming above the setting value, the train reduces the regenerative electric current and keeps not to be overvoltage on feeding cables. The case often occurs when not existing the train on running near on braking.

When the regenerative brake lacks for stopping a train, the air brake must be used for the shortage of it. The electric energy which a train may generate originally by the regenerative brake system is lost as the heat energy. In the case, the increase of the wear of the brake shoe and other wearing parts is caused. In other words, it is a demerit for the maintenance.

For the purpose of decreasing the transmission loss of the regenerative power or by the control of the voltage at the train, some methods are considered. One way is that we install equipment to consume the regenerative power. It is necessary that they are enough to consume the regenerative power. But it is difficult that they consume electric energy in DC 1500V. It is required to convert DC to AC by the inverter and use for equipment at stations and so on. In the case, the loss by the conversion is occurred. It is effective that the regenerative power is consumed by other trains. If there are not trains on braking near them, the transmission loss of the regenerative electric power becomes large. To tie feeding cables of up and down lines each other decreases it. Moreover it controls the voltage of feeding cables not to be overvoltage and the regenerative brake system to be used as much as possible.

2. Tying feeding cables of up and down lines each other
It is generally said that it is expected for energy conservation to tie feeding cables of up and down lines each other because of decreasing the transmission loss. As the introduction of the regenerative brake system, it becomes more effective to tie feeding cables of up and down lines because it utilizes the regenerative power
However it is introduced for the purpose of avoiding voltage to go down in some cases, and for energy conservation in few cases because it is difficult to estimate quantitatively its efficiency.

We show the result of the measurement of the effect for the reduction of electric conservation occurred by the regenerative brake system and tying feeding cables of up and down lines each other in the DC traction system.

3. The result of measurement
(1) The verification for the effect of the reduction of electric energy by the regenerative brake system

We set up two conditions. One was that all trains, which ran in a section, use the regenerative power and another was that didn’t use it. We measured and compared the electric energy of them. We measured electric energy at all substations, but particularly selected two of them because we needed to cut out influences such as inflow of the regenerative power from other sections. We also measured electric energy on the train.

(1) -1 Conditions
_ The period In September and October 1999
_ The time from 10:00 to 16:00
_ The sections GAKKEN-TOSHI line __See Figure 1 and 2__
_ In DC 1500V traction system, 44.8 km (27.8 km of double track sections), five substations
_ The trains 207 series
_ The headway 10 numbers of trains per one hour
Figure 1: The location of GAKKEN-TOSHI line

Figure 2: The location of substations and the section for tying feeding
(1) –2 Result
About 35% of electric energy used on running changes to feeding cables on trains for the regenerative power. But about only 20% of electric energy used on running can be confirmed as the effect of the reduction of electric energy at substations (Figure 3).

(1) –3 Consideration
The deference between two results of the effect of the reduction of electric energy by the regenerative brake system is considered to depend on the transmission loss. We could assume that the reduction of the transmission loss decreases the electric energy substantially.

(2) The verification for the effect of the reduction of electric energy by tying feeding cables of up and down lines each other
We could assume that the reduction of the transmission loss decreases the electric energy substantially from the result of (1). Then we measured the electric energy at substations on tying feeding cables of up and down lines each other, the upper and lower sides simultaneous feeding, for the purpose of decreasing the impedance of feeding cables.

(2) -1 Conditions
- The period In October 2000
- The time All day
The sections GAKKEN-TOSHI line

In DC 1500V traction system, 43.8 km (22.5 km of double track sections), five substations

The trains 207 series

The headway 8-10 numbers of trains per one hour

The section for tying See Figure 2

(2) -2 Result

We can confirm the effect of the reduction of electric energy not only on the substations in the sections where feeding cables of up and down lines were tied each other but on other substations in GAKKEN-TOSHI line, and moreover some substations in NARA line and YAMATOJI line. The effect of the reduction of electric energy on substations is about 5,500kwh per one day in total (Figure 4).

(2) -3 Consideration

By tying feeding cables of up and down lines each other, the effect of the reduction of electric energy can be confirmed at substations out of GAKKENTOSHI line because of the parallel feeding. The difference of the effect of the reduction of each substation depends on the voltage at them.

4. The line where the effect of the reduction of electric energy to be assumed

The reason why the effect of the reduction of electric energy can look forward to
by tying feeding cables of up and down lines each other is

- The transmission loss from substations to trains
- The transmission loss from trains on braking to on running
- The reduction of the regenerative electric current

The condition that it is easy for the effect of the reduction of electric energy to achieve by tying feeding cables of up and down lines each other is as follows.

- The distance between substations is long
  When the substation spacing is long, the transmission loss is large in comparison. In the case, the effect of the reduction of electric energy can be achieved by tying feeding cables of up and down lines each other. When supplying the regenerative power to trains on running through substations, the reduction of the regenerative electric current often occurs.

- The electric current is large
  The transmission loss is proportional to the square of the current. Therefore we can decrease electric energy by tying feeding cables of up and down lines each other where the current of trains is large.

- Many trains equip with the regenerative electric brake system
  The transmission loss and the reduction of regenerative electric current occur in the lines where many trains equip with the regenerative electric brake above all. Therefore the effect of the reduction of electric energy can be assumed there.

5. Conclusion
We measured and estimated the effect of the reduction of electric energy by the regenerative brake system and tying feeding cables of up and down lines each other quantitatively. We investigate for the construction of traction system for energy conservation on the basis of the results.