Natural Air Cooling for Traction Transformer

Authors: *Shiki Hayamizu*, Toshihiro Noda** and *Koki Shinjo**

1. Introduction [1] [2]

The main type of traction transformers installed on recent AC electric trains on narrow-gauge lines is the natural air cooling type, which uses natural wind during traveling and eliminates the need for blowers. Its characteristics are different from those of the conventional forced air cooling type and so its design requires careful consideration.

This paper describes natural air cooling type transformers that have been contributing to reducing energy requirements, maintenance, and noise, and their expansion and application in both Japan and overseas.

2. Natural Air Cooling Type

2.1 Cooling of traction transformers

Traction transformers are important equipment that supplies electricity drawn from the overhead lines to all devices on the train. They supply electric power to the main circuits that drive the train and to the auxiliary circuits to operate the air conditioning systems and other devices.

On general traction transformers, blowers are used to forcibly send wind to the coolers for cooling. Meanwhile, on natural air cooling type transformers, wind caused by the traveling train is drawn into the coolers and used to cool the traction transformers and thus no blowers are required.

Figure 1 illustrates a natural air cooling type transformer and Fig. 2 shows its appearance.

2.2 Characteristics of natural air cooling type transformers

Natural air cooling type transformers that do not require blowers have the following characteristics.

(1) Energy-saving (no electric power for operating blowers is required)
(2) Reduced maintenance (maintenance of blowers and cleaning of coolers are unnecessary)
(3) Low noise (no operation noise of blowers)

2.3 Notes on cooling designing

When designing the cooling of natural air cooling type transformers, the following points are considered.

2.3.1 Relationship between travel speed and cooling wind velocity

One characteristic of cooling of the natural air cooling type is that the velocity of wind caused by the traveling train depends on the travel speed and so the cooling capacity changes all the time.

The cooling is designed based on the relationship between travel speed and cooling wind velocity determined from past tests.

2.3.2 Calculation of cooling capacity and capacity of traction transformers

Considering that the cooling capacity varies as a function of travel speed, temperature simulations are performed on designated lines and for designated travel patterns to determine the rated capacity.

2.3.3 Arrangement of traction transformers

The cooler of a natural air cooling type transformer needs to be installed on the side of a train if possible as shown in Fig. 1, and appropriate spaces need to be secured between the cooler and devices installed in front and to the rear of the cooler such that wind caused by the traveling train is easily drawn into it.

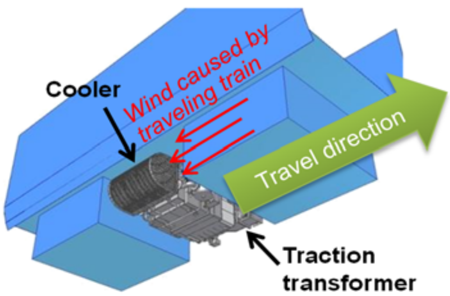

Fig. 1 Image of natural air cooling type transformer

Fig. 2 Natural air cooling type transformer for type E657 train (JR-East)

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For trains for which the bottoms of the floors are completely covered, in order to draw in wind caused by the traveling train, the coolers need to be located outside of the side covers in the configuration. We have adopted an air intake structure. In this structure, inclined covers are used in front and to the rear of a cooler to draw more wind caused by the traveling train into the cooler. Figure 3 shows examples of the cooling air calculation.

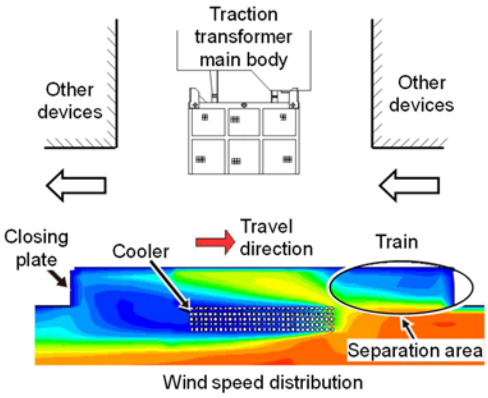
2.3.4 Protection of coolers

As described in section 2.3.3, natural air cooling type coolers need to be located close to the sides of the train to draw in wind caused by the traveling train, while taking into consideration stones and other flying objects.

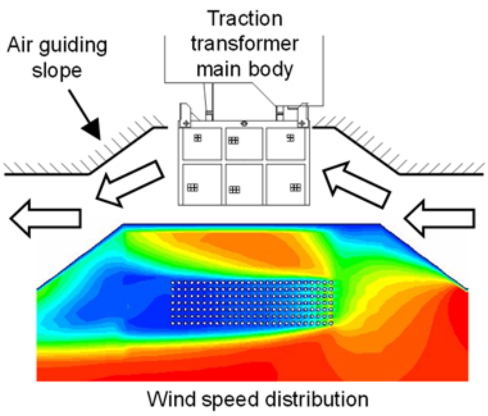
3. Use in Japan

Natural air cooling type transformers having the characteristics described in section 2.2 have been widely used for narrow-gauge line trains in Japan because their characteristics are highly evaluated. We delivered 814 natural air cooling type transformers from the first one in 1980 to February 2021 (Fig. 2 and Fig. 4).

During use for more than 40 years, there have been no malfunctions due to cooling by natural air cooling type transformers, and so our transformers are regarded as highly reliable. Regarding maintenance, too, it has been demonstrated that no cleaning is required.



(a) Existing structure



(b) Air intake structure

Fig. 3 Examples of calculation for cooling air

4. Expansion and Application to Asia

Regarding expansion of the market to Asia, we proposed the natural air cooling type to India where there is high demand for railway services. In India, air pollution is serious and awareness of energy-saving (e.g., reducing exhaust gas emissions) and the environment has been rising. In recent years, in particular, there is strong demand to reduce the energy consumed by the trains themselves in addition to reducing energy for train maintenance.

Furthermore, trains operate in an environment containing a lot of dust, feathers, and oily dirt and so cleaning and maintenance of general forced air cooling type transformers is costly. Although the natural air cooling type is an appropriate method for dealing with such problems, it has not been widely recognized in the Indian market. Accordingly, we explained to customers the technologies and track records of the natural air cooling type, the difference in energy consumption between the natural air cooling type and the existing type, and the noise reduction ratio. As a result, the natural air cooling type was introduced to Delhi metro trains in 2016 (Fig. 5).

After being used for one year, the transformers on actual trains were subjected to a temperature rise test and the conditions were checked. Figure 6 compares the results of oil temperature measurement on actual trains and simulation results. The oil temperatures are within the allowable range (less than 100C) and equal to the simulation results, thus verifying the design (Fig. 7).

Figure 8 shows the results of checking the condition of the natural air cooling type coolers. The same as in Japan, it was confirmed that no dust, feathers, or oily dirt had attached and the coolers were in good condition.

Fig. 4 Natural air cooling type transformer for type 683 train (JR-West)

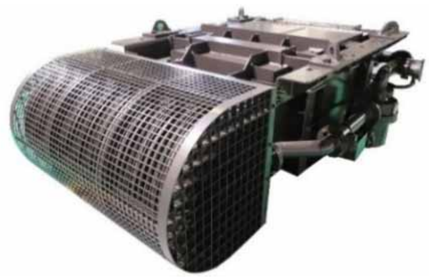


Fig. 5 Natural air cooling type transformer for the RS13 train (India Delhi metro)

These results demonstrate that even in a severe environment like in India, natural air cooling type coolers can be used without problems.

5. Expansion and Application to Europe

5.1 Rooftop natural air cooling type coolers

To expand the product to other overseas markets, we proposed the natural air cooling type in the European market. Although the service environment in Europe is similar to that in Japan, traction transformers are installed in different locations. In Japan, they are installed under the train floor in general, whereas in Europe traction transformers and other electrical components are installed on the train roof because station platforms are low and barrier-free low-floor trains are used. Consequently, natural air cooling type coolers are also installed on train roofs.

When these coolers are installed on the open train roof instead of in closed sections under the train floor, more wind caused by the traveling train can be drawn in. However, we had no experience of installing the natural air cooling type cooler on the roof and did not know the relationship between train speed and wind while traveling. Accordingly, we performed fluid analysis simulating train conditions to check the conditions of rooftop wind caused by the traveling train.

Figure 9 shows an example of the calculation. The results show that more wind can be drawn in while the train is traveling compared to underfloor installation, and that the flow pattern is also different. Therefore, we designed and developed light-weight rooftop natural air cooling type coolers suitable for installation on the train roof.

5.2 New business with SNCF

SNCF has been procuring new trains for its TGV high-speed trains and commuter trains. For environmental reasons and to use utilize resources effectively, it has been actively updating older trains; it replaces only the electrical components while reusing the bodies of such trains. Accordingly, for its T4 tram trains (Fig. 10), energy-saving, lower noise, and reduced life cycle costs were demanded.

The rooftop natural air cooling type transformers developed by Mitsubishi Electric Corporation matched the requirements of SNCF and were selected because our traction transformer technologies were highly

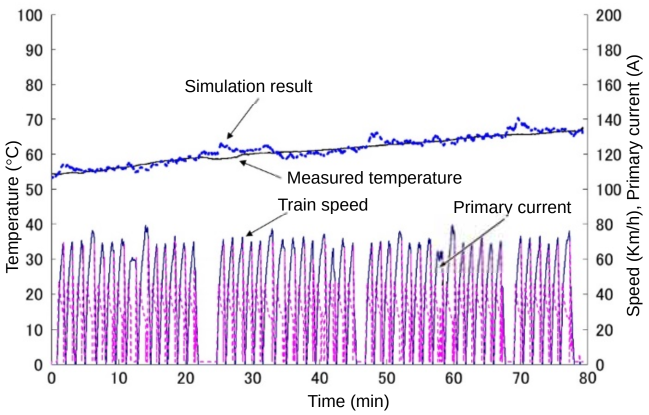


Fig. 6 Comparison of oil temperature between measurement and simulation

Fig. 8 Condition of cooler after one year of operation on the RS13 train (India Delhi metro)

Fig. 7 Measurement on main line

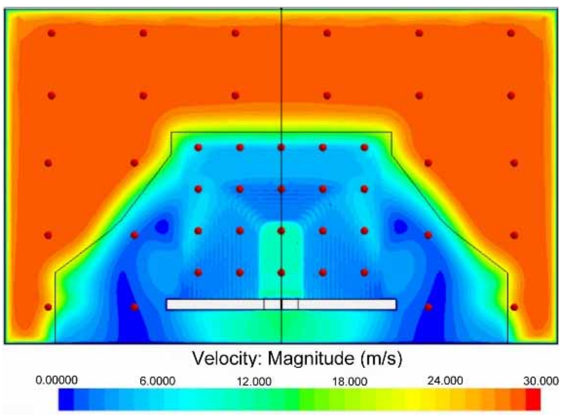


Fig. 9 Example of calculation for rooftop-type natural air cooler

Fig. 10 Type T4 tram train

Table 1 Comparison of existing transformer and natural air cooling transformer on the Type T4 tram train (Comparison of same capacity, impedance, and mass)

Item	Existing transformer	Our transformer
Size (Longitudinal direction)	2,493 mm	2,125 mm
Reliability	Malfunction once every five years	Almost no malfunction in 30 years
Noise level	80 dB(A)	67 dB(A)
Maintenance	• Parts maintenance • Replacement of blower motor bearing • Cleaning of coolers, etc.	• Bearing replacement not required • Cleaning of coolers not required
Loss (efficiency) @ rating	27.3 kW (96.2%)	14 kW (98.0%)
Mass	2150 kg	2150 kg

regarded; we became the first Japanese manufacturer to do business with SNCF. Table 1 compares the existing transformer and our natural air cooling type transformer for T4 tram trains.

In update work, the interfaces with trains needed to be completely matched while maintaining the superiority over the existing type. In addition, because the train conditions and the positional relationship of the rooftop natural air cooling type transformers with other devices could not be changed, we designed and manufactured them while carefully considering the wind conditions caused by the traveling train in the surroundings.

One year has passed since this prototype transformer entered operation and the trains are running in good condition without problems.

Currently, we are manufacturing traction transformers using technologies for rooftop wind caused by the traveling train for trains operating near Paris. We will continue working to expand the technologies in the future.

6. Conclusion

As environmental awareness grows, railway services are becoming more important as an eco-friendly means of transportation, and our natural air cooling type transformers have been highly valued by our customers.

We will continue working to expand the application of environment-friendly natural air cooling type transformers and contribute to society.

References

(1) Mitsubishi Electric Corporation: Natural Air Cooling Type Traction Transformers, Denki Hyoron, 101, No. 3, 74 (2016)

(2) S. Hayamizu., et al.: Natural Air Cooling Type Traction Transformers, Mitsubishi Denki Giho, 92, No. 11, 647–650 (2018)