New-Type Transformer for AC Feeding Systems

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The Shinkansen and other high-speed trains require large single phase AC power sources. That AC power is supplied from electric power companies. However, if much of the required single phase AC power is obtained exclusively from a specific phase of three-phase AC power, it affects the power utilities of the electric power companies. In Japan, since the AC electrification of railways was begun in earnest, the Scott-connected transformer that transforms a three-phase AC voltage into two single-phase AC voltages having a phase difference of 90° has been used to reduce the adverse effect of high-speed train operation on the electric power system.

During construction of the Sanyo Shinkansen that was to open in 1972, it was planned to receive the required power from an ultrahigh-voltage electric power system in order to allow for train operation at higher speeds and supply the train with the required high power stably and economically. However, since the ultrahigh-voltage electric power system is a solidly earthed neutral system, the Scott-connected transformer cannot be used for it. Therefore, as a transformer suitable for solidly earthed neutral systems, the modified Woodbridge-connected transformer, as shown in Fig. 1, was developed and put into practical use. For quite a while since then, it has been used as the standard transformer for ultrahigh-voltage electric power systems.

A modified Woodbridge-connected (conventional-connected) transformer can be designed and fabricated easily using the same technology as applied to the ordinary three-phase transformer. However, since it has a separate step-up transformer on the B phase for obtaining the same output voltage as that of A phase, an extra space is required for installation of the step-up transformer, and the wiring is complicated.

The RTRI has developed a new-type transformer whose connection is shown in Fig. 2. This new connection is simpler than the conventional connection and does not require the step-up transformer. Even so, since the transformer windings are three-phase asymmetrical ones, sophisticated transformer design and fabrication techniques are required. In the beginning, we fabricated a mini-sized model of a low-voltage transformer (Fig. 3) and tested the basic functions and performance of the model. As a result, it was found that the new connection was functionally compatible with the conventional connection. In addition, we test-designed a large-capacity transformer that was the same as the one used in the Shinkansen, except that the conventional connection was replaced with the new connection. As a result, it was found that the new connection not only saved installation space but also reduced power loss.

It was decided to carry out demonstration tests at a substation for conventional railways, so we fabricated transformers with the new connection for verification (Fig. 4). After the basic characteristics of the transformers (withstand voltage, neutral-point current, etc.) were confirmed by factory tests, the transformers were temporarily installed in the substation and the condition of power supply to a train was tested (Figs. 5 and 6). As a result, we reached the conclusion that the new-type transformer could be applied to substations for the Shinkansen.

Transformers of the new type are planned to be installed in new Shinkansen substations scheduled for construction in the future and in existing Shinkansen substations for replacement of their obsolescent transformers.

Of the present research and development, the fabrication and testing of transformers for verification were carried out jointly by the RTRI; Japan Railway Construction, Transport and Technology Agency; and JR East.

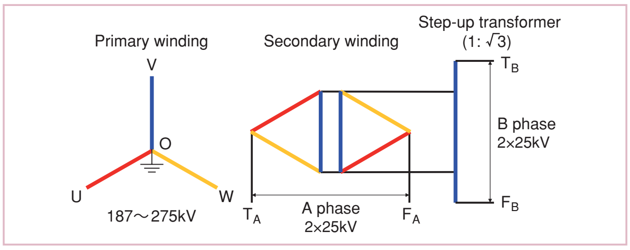

Fig. 1 Modified woodbridge connection (conventional connection)

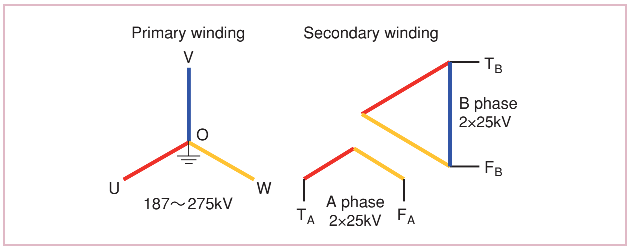

Fig. 2 New connection

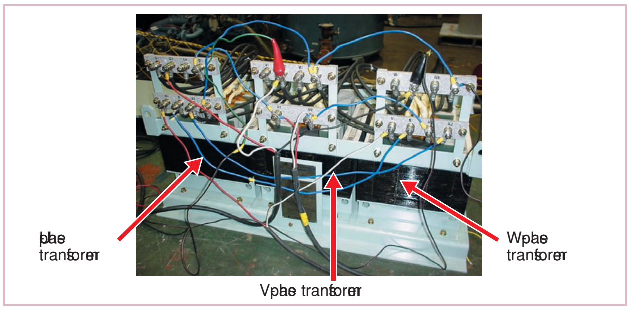

Fig. 3 Test-made mini-sized model of new-type transformer (200 V)

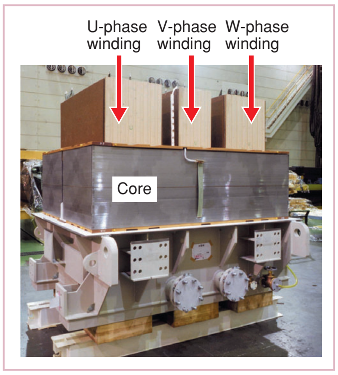

Fig. 4 Contents of transformer for verification (66kV/22kV 10MVA)

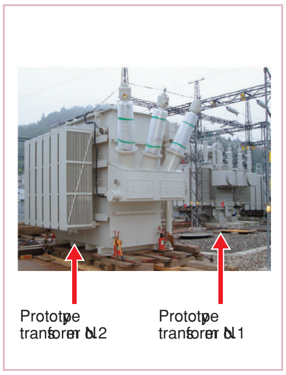

Fig. 5 Demonstration test at substation for operation of conventional railway

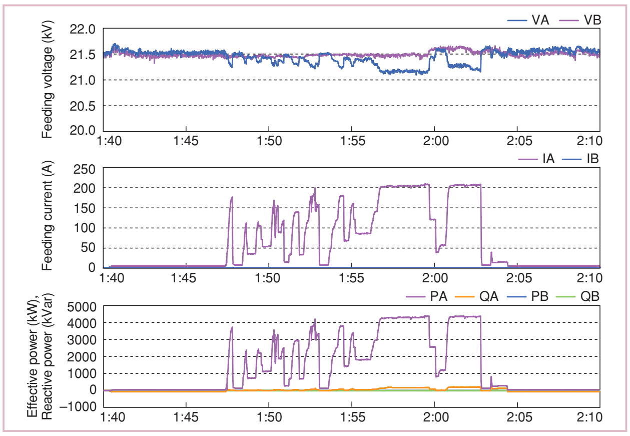

Fig. 6 Results of power supply to train