commonly the amplifier which can be substituted for the sub-exciter, and the other parts are constructed in a very small sizes. Further, the installation can be made at a corner of the synchronous machine room. Consequently, these troublesome problems as mentioned above are perfectly solved away and it becomes very simple and highly reliable.

The actual applications of this device are all such that manufactured and delivered along with the Fuji Denki synchronous machine of large capacity. However, it is quite possible to apply this device by some reconstructions to be existing synchronous machine. At present, the further investigations are being carried out and it is expected that in the near future, the more excellent performances will be available.

Introduction of Products

154 kV 81,000 kVA PERFECTLY SHIELDED OSCILLATION-FREE TYPE "FAHRBAR" TRANSFORMERS

By

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One of the transformer engineer's visions—to save the time of drying the unit again or of assembling it at the site and simplify the crane facilities has come true by the birth of "Fahrbar" transformers, with which it has become feasible to maintain high insulation strength attained by means of thorough drying at the factory.

These "Fahrbar" transformers were first developed in Europe. It is reported that the Siemens Schuckert Works has built a unit of this design having a capacity of 245 kV 200 MVA recently. Unlike Europe, transportation facilities in Japan is confronted with various unfavorable conditions, which have hampered the growth of building large sized units. Our company, since 1945, however, pioneered in the effort of taking up "Fahrbar" design of large capacity transformers and has been successful in producing 187 kV 78 MVA units, 161 kV 78 MVA units, 66 kV 81 MVA units, etc.

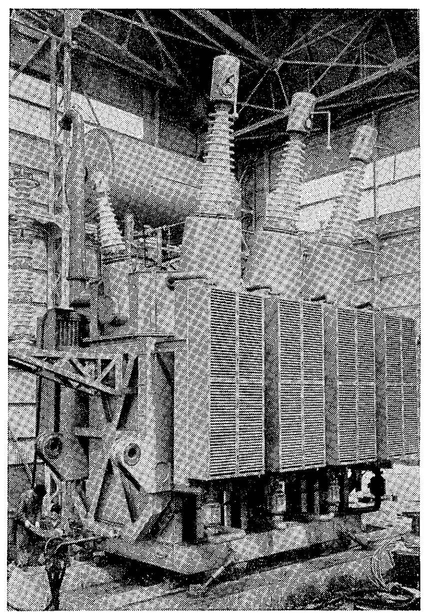

Fig. 1. 154 kV 81,000 kVA Perfectly shielded oscillation-free type "Fahrbar" transformer

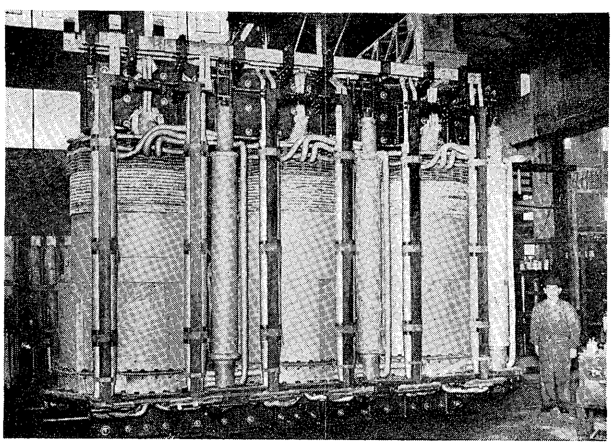

Fig. 2. Interior view of 154 kV 81,000 kVA transformer

The 154 kV 81 MVA "Fahrbar" transformer delivered to the Tokyo Electric Power Company and introduced herein is a record transformer in voltage and capacity transported on a narrow gauge track. Furthermore, as far as the design of perfectly shielded and non-oscillation design is concerned, it may well be called a record product in the world.

I. SPECIFICATION AND CHARACTERISTICS

Three phase core-type, outdoor use, forced-oil, air circulation with air-blast cooling, perfectly shielded oscillation-free Fahrbar transformer:

Output	81,000 kVA
Voltage	Primary (delta) 12.6 kV Secondary (star) 154–147 (R)–140 (F) kV
Neutral point	$1/\sqrt{3}$ reduced insulation with BIL No. 8 lightning arrester
Insulation level	Primary BIL No. 20, Secondary BIL No. 140
Impendance	11%
Iron loss	130 kW
Copper loss	340 kW (at 147 kV, 75 °C)
Efficiency (at unity power factor)	99.42% at 100% load 99.47% ,, 75% ,, 99.47% ,, 50% ,,
Oil quantity	37,000 *l*
Total weight	154 ton
Dimensions	width 7865 mm depth 4950 mm height 8200 mm

II. WINDINGS

There are a good many number of distinctive features in the construction of windings adopted in the design, outstanding of which being as follows.

a. Both high and low voltage windings are built in multiple concentric cylindrical layers, between of which is packed with insulating paper to form a strong integrated body. Concentric layer-windings have a better oil circulation than disc coil-windings, affording a good cooling effect to insure the safety in the adoption of insulation packing system. As a result, reduction in dimensions, economy in materials, improvement of efficiency and further the reduction of impedance have become possible.

b. To make a logical utilization of the effect of $\frac{1}{\sqrt{3}}$ reduced insulation of neutral point, high voltage windings are placed in such a manner that their neutral layer side comes to the inner side and their heights are made to come down toward the outer periphery, in what is called trapezoid windings. This helps the space of core window become of effective utilization.

c. At the outer periphery of the high voltage windings is placed a static shield connected to the line terminal and covering the whole height of the windings for the purpose of maintaining a linear distribution of impulse voltages over the

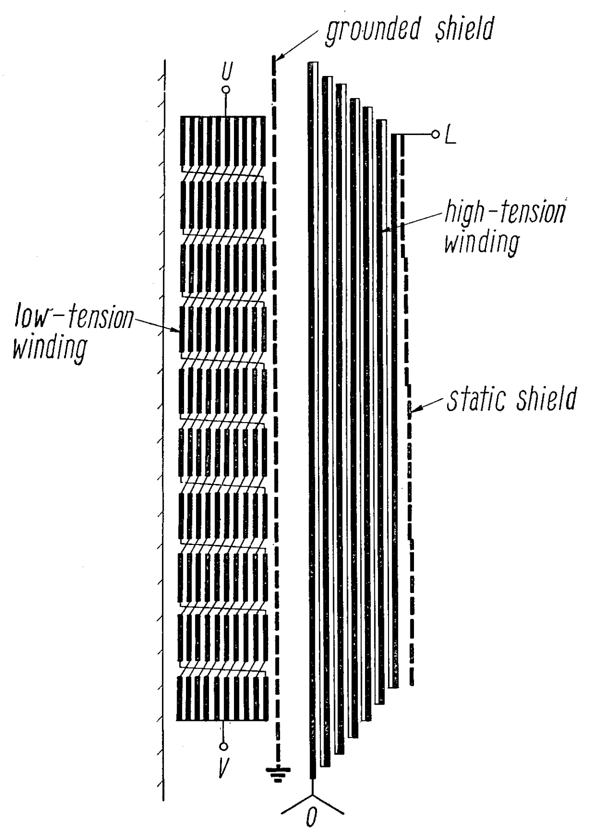

Fig. 3. Arrangement of Windings.

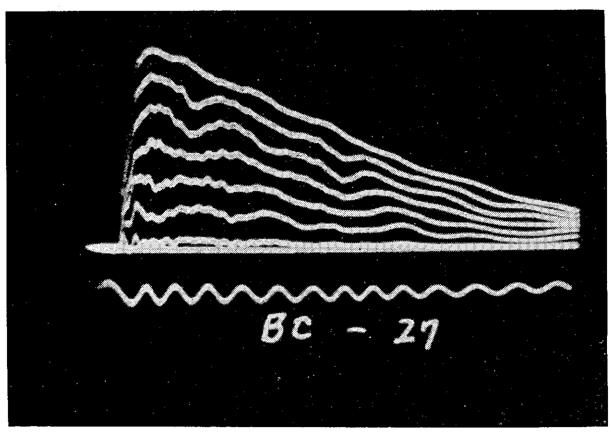

Fig. 4. Full wave voltages in HV winding of 81,000 kVA transformer with HV neutral grounded and LV terminals grounded through 500 Ω. (single phase test)

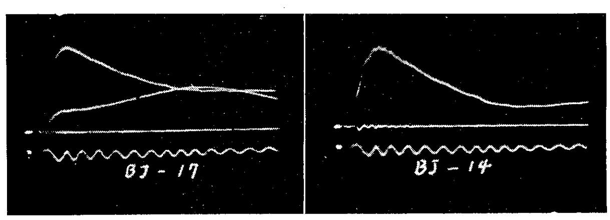

Fig. 5. Static transferred with voltage HV to LV in 81,000 kVA transformer with HV neutral isolated and LV isolated. (three phase test) Without grounded shield (left) With grounded shield (right)

windings. This makes the graded insulation logical.

d. Between the high voltage and low voltage windings grounded shield is provided to negate completely the component of impulse voltages tending to shift statically from the high voltage side to low voltage side, thus perfectly protecting the low voltage windings from the intrusion of impulse voltage entering into the high voltage side.

e. High voltage tap coils are wound from top to the bottom with three conductors in parallel and form a neutral layer. The concentration of leakage fluxes at each tap is thus minimized.

f. Because of larger currents, the low voltage windings are divided into ten parallel circuits and their circuits are transposed at proper positions midway so as to prevent the occurrence of unbalanced currents.

III. IMPULSE VOLTAGE CHARACTERISTICS

In Fig. 4 are given oscillograms of voltages to the ground of each layers of U phase when impulse voltages were impressed on the U terminal while V and W terminals were grounded. It indicates that the voltage to the ground diminishes linearly as it approaches the grounding point, testifying the oscillation-free of the apparatus justly. Fig. 5 illustrates the effect of the grounding shield for the component statically shifting to the low voltage side. The left oscillogram shows the case where no grounding shield was provided, whereas the right one with the shield. In the latter case, the shifted voltages were completely absorbed, revealing the effect of the ground shield clearly. A impulse test voltages, a full wave (with neutral point grounded and opened) 750 kV and a chopped wave (with neutral grounded) 870 kV were employed, but the tests were conducted satisfactorily without any failure.

IV. EXTERNAL CONSTRUCTION

As the tanks are to be used as a car body during the transportation, equivalent load tests were conducted according to severe standards to make assurance doubly sure. They are able to withstand the vacuum test. It is also possible to carry out vacuum drying with a self tank as the case demands.

The cooling equipment is of unit cooler system, consisting of 7 efficient U fin coolers in normal use and 1 spare. They can be changed over depending on the load. The rotating part of the oil pump is completely placed in the oil flow to eliminate the fear of oil leakage.

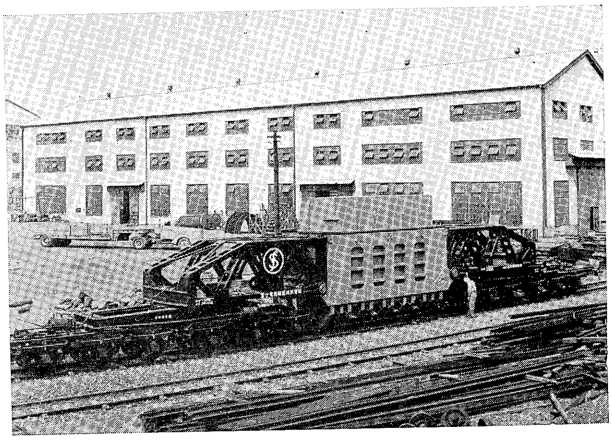

Fig. 6. Transportation style of 81,000 kVA "Fahrbar" transformer.

The inertia equipment is a three chamber type OC conservator with a dial type oil gauge and equipped with a de-oxidation device, keeping the oil always clean. High voltage bushings are oil filled and sealed, and are fitted with a dial type oil gauge. Low voltage bushings are of flexible top construction and are easy connectable to the bus. They are also constructed to avoid any undue strain.

In addition, various thermometers, a bursting tube, a bushing type current transformer and a neutral point lightning arrester are compactly fitted to the unit, forming a graceful appearance.

V. TRANSPORTATION AND FIELD ASSEMBLY

This type of transformer, being of "Fahrbar" design, is convenient for transportation and easy for field assembly in a short duration, resulting in a great saving in expenses.

In transportation, the body is filled with nitrogen gas and closed with a temporary cover, and then shipped sidewise on a special drop-center-freight car. On arrival at the site and after replacing nitrogen with de-gassed oil, a regular cover, conservator, bushings and radiators are mounted to the body with replenishment oil necessary to complete the assembly.

The above is a brief explanation of the 154 kV 81,000 kVA "Fahrbar" transformer.

Attempt is still going on in our company to build transformers of far greater capacity of "Fahrbar" design. They can be carried with high insulation strength reached at the factory retained and with ease and speed to economize the installation.