Large-capacity Disassembled-transport Transformers

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OVERVIEW: Development projects have been increasing for large-capacity transformers based on a disassembled-transport system with the aim of minimizing total cost by decreasing transport expenses and reducing on-site equipment space after assembly. Hitachi, Ltd. has been involved in these efforts since the latter half of the 1980's when it developed disassembled-transport technologies that made improvements to the core partitioning method and assembly method and reassessed moisture-proof film. These technologies was used to manufacture the 220-kV 250-MVA disassembled-transport transformer in 1989 that was subsequently delivered to the Kamishiba Power Station of Kyushu Electric Power Co., Inc.[1)] More recently, with the aim of applying this technology to 500-kV class transformers, Hitachi has upgraded elemental technologies including the adoption of new film materials and further improvements to on-site assembly methods. The single-phase prototype of 500-kV 1,000-MVA transformer has been constructed based on these enhancements and each of the manufacturing processes involved has been tested. These technologies were also applied to the 275-kV 400-MVA transformer completed in March 1999 for the Nanjo Substation of Hokuriku Electric Power Company. Hitachi's plan is to apply successively these new technologies to next-generation 500-kV 1,000-MVA–1,500-MVA transformers.

INTRODUCTION

UP to the latter half of the 1950's, limitations in conventional means of transport required that large-capacity transformers up to the 275-kV class be delivered by the disassembled-transport system. In subsequent years, however, development of the Schnabel freight car and advances in trailer systems led to the full-scale adoption of the assembled-transport system, and this situation has continued up to the present.

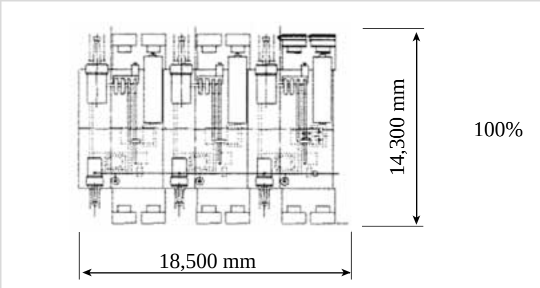
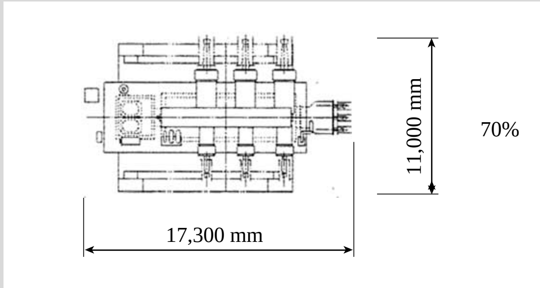
On the other hand, recent years have seen the heavy-duty transport environment becoming increasingly severe due to a gradual decrease in the number of freight depots and tougher highway driving regulations. This has created renewed interest in the 'disassembled-transport system' as it can provide significant reduction in transport expenses by the use of standard trailer transport. In addition, while assembled-transport has been used for single-phase transformer configurations due to transport restrictions, the disassembled-transport system makes it possible to achieve a three-phase integrated type for the completed transformer thereby reducing equipment installation space.

This paper describes the development of elemental disassembled-transport technologies and the results of their tests based on a single-phase prototype of 500-kV 1,000-MVA three-phase transformer.

OVERVIEW OF DISASSEMBLED-TRANSPORT TRANSFORMERS

The transport of large-capacity transformers is normally accomplished by dismantling external parts like bushings and coolers after a factory test and then loading the transformer with its contents like cores and coils housed in the main tank. In the case of a disassembled-transport transformer, however, the transformer is disassembled into main component units like cores, coils, and tank after the factory test and then reassembled at the site. A special feature of these disassembled units is that their respective dimensions and mass are set so that the units can be transported by standard low-floor trailers (see Table 1). At the time of on-site assembly, an assembly structure (clean house) is constructed to accommodate assembly of the cores and coils and the attachment of the lead cables and tank cover. Once the tank cover is attached,

TABLE 1. Comparison of Large-capacity-transformer Transport Systems (for 500-kV 1,000-MVA transformers)
The disassembled-transport system significantly reduces transport mass and installation space.

Transport system	Assembled-transport system	Disassembled-transport system
Configuration	Single-phase × 3	3-phase
Installation space	 100%	 70%
Transport form	Schnabel trailer 	Low-floor trailer  (Core transport shown)
Transport mass	100%	25%

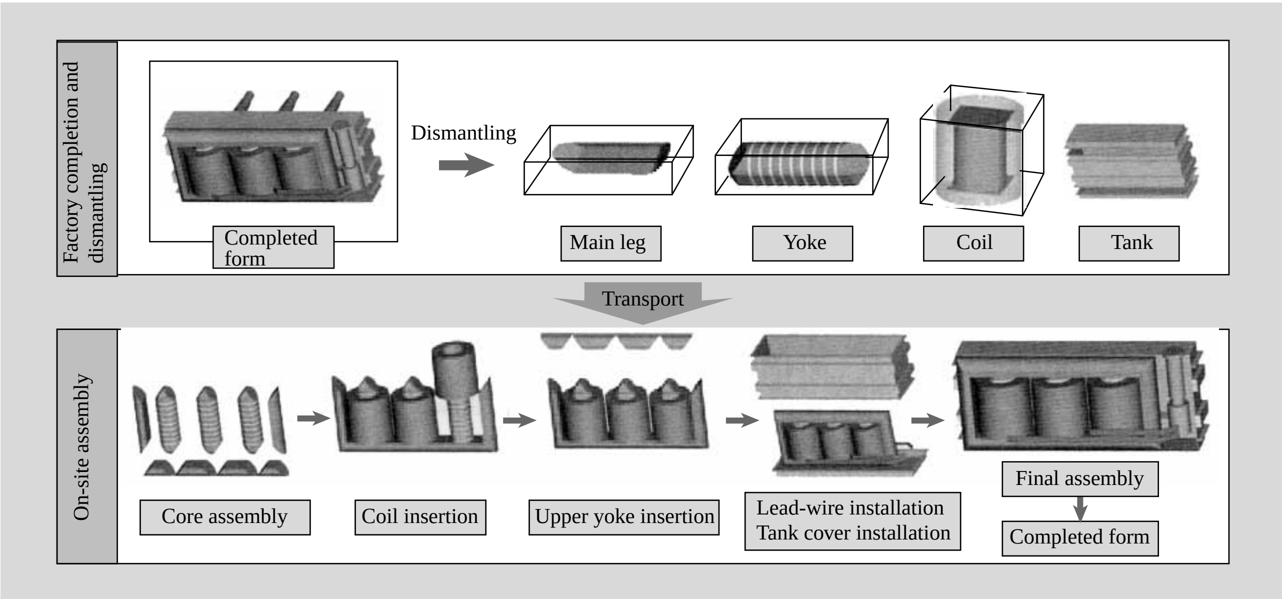


Fig. 1— Work Flow After Factory Completion of a Disassembled-transport Transformer.
Main components are dismantled and transported, and then re-assembled at the destination site.

external parts are installed, insulating oil is filled in tank, and a final test is conducted just as in the assembled-transport system. The flow of on-site assembly is shown in Fig. 1.

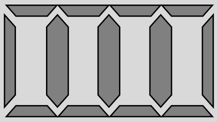
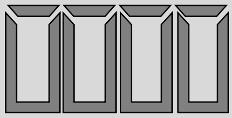
Hitachi, Ltd. is achieving stable performance and long-term reliability in these new transformers by applying the standard core structure successfully used in the assembled-transport system to its disassembled-transport system.

STRUCTURE OF A DISASSEMBLED-TRANSPORT TRANSFORMER

Cores

Here, the 'main-leg non-partitioned method' that has been successfully used so far in the assembled-transport system has been adopted for the cores. In

TABLE 2. Comparison of Core Characteristics Between the Main-leg Non-partitioned Method and Main-leg Partitioned Method
Hitachi, Ltd. has achieved stable performance (in terms of core loss and noise) by adopting the main-leg non-partitioned method.

Partitioning method / Item	Main-leg non-partitioned method 	Main-leg partitioned method 
Maximum disassembled-transport mass	100% (Transport dimensions: smaller)	125% (Transport dimensions: larger)

addition to featuring excellent core characteristics, this system can minimize transport dimensions and mass as well as simplify on-site assembly since partitioning is performed for each leg and yoke combination (see Table 2).

Coils

Coils basically take on a single-phase worth's integrated configuration so as to minimize transport and on-site work. In addition, to prevent insulators from absorbing moisture and collecting dust at the time of transport and on-site assembly, coils are packaged in film during dismantling at the factory to block out outside air (film pack). This film is completely removed just before tank fixing. In the end, therefore, no film is left inside the tank, and stable transformer insulation characteristics can consequently be achieved in the long term as well.

Tank

The tank is basically divided into three parts (upper, middle, lower) but can be divided into more or less sections in unison with transport restrictions of low-floor trailers. The lower tank section also serves as a kind of setup equipment (see Fig. 2) and contributes to simplified assembly operations.

DEVELOPMENT OF ELEMENTAL TECHNOLOGIES

Based on the results gained from the 250-MVA disassembled-transport transformer delivered to the Kamishiba Power Station of Kyushu Electric Power Co., Inc., elemental technologies have been developed in relation to the selection of film-pack materials, testing of a clean house, and improvement of core assembly technology.

We mention here that the material used in the past

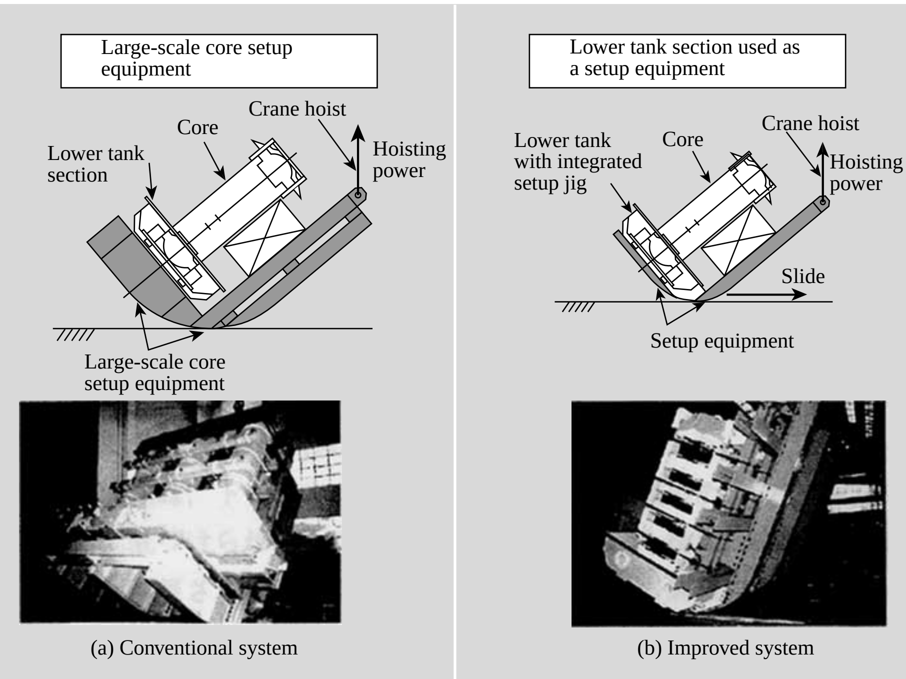


Fig. 2— Improvements in Core Assembly Technology.
Operations are simplified by using the lower tank section as a setup equipment.

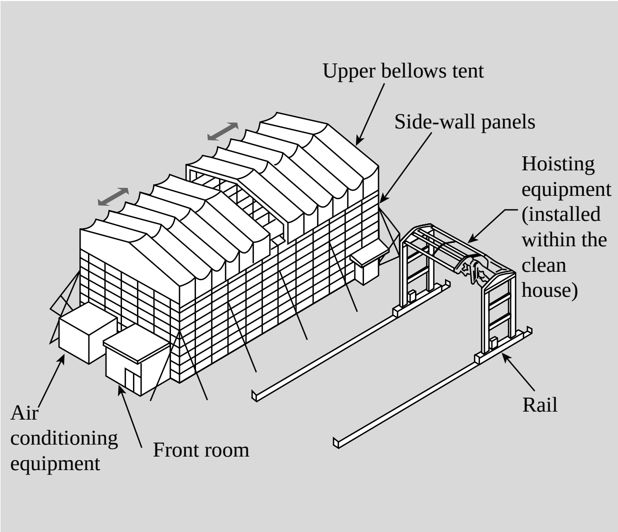


Fig. 3— Clean House Configuration.
The clean house consists of side walls, ceiling (bellows type), and front rooms and is equipped with air conditioning equipment and hoisting equipment.

for the moisture-proof film of the film pack has been fluoric material. However, the use of materials like fluorine and chlorine will be restricted in the years to come because of harmful environmental effects. We therefore conducted a study on the application of polyolefin plastic film (commonly known as polyethylene or polypropylene), which in addition to being environmental friendly, can be incinerated after removal. We found that polyolefin plastic film has low permeability and satisfies the various requirements demanded of a film pack.

On-site Assembly Room (Clean House)

A clean house was constructed within the factory and tested in terms of operability and air conditioning performance so that the same assembly environment as that in the factory could be prepared at the site in question. The configuration of this clean house is shown in Fig. 3. The bellows-type ceiling can be opened and closed as desired and heavy components can be brought in through the ceiling using a crane truck. Furthermore, with the aim of preventing the ingress of dust and moisture, the number of times that the roof is opened and closed is kept to a bare minimum, we have installed hoisting equipment within the clean house.

The air conditioning facilities here can also be used as dry-air generating equipment and dehumidifiers, and in particular, can be used to blow dry air inside the film packs during assembly so as to prevent the coils from absorbing moisture. The above configuration has demonstrated that a clean-house environment the same as that of the factory (humidity: 50% max.; dust particles: 0.2 mg/m^3 max.) can be maintained.

Core Assembly Technology

For setup work after core assembly, we have discontinued use of large-scale core setup equipment and have succeeded in reducing required hoisting power and simplifying operations by using the lower tank section as a setup equipment. As a result, the crane truck used for lowering main components like coils and cores can also be used for setup operations. In addition, by having cores slide in the setup process, operations can be performed within the transformer foundation (see Fig. 2).

VERIFICATION TEST WITH AN ACTUAL-SCALE MODEL

A single-phase prototype of 500-kV 1,000-MVA transformer was constructed and subjected to a

Test items	Check items (abnormalities in transport and assembly)					
	Coil offset	Core offset	Coil moisture	Foreign matter	Loose fixtures	Poor contacts
Core resistance	—	○	—	—	—	—
Core insulation resistance	—	○	—	○	—	—
Low-voltage impedance	○	—	—	—	—	○
Low-voltage exciting current	—	○	—	—	—	○
Insulation power factor	—	—	○	—	—	—
No-load loss & current	—	○	—	—	○	○

TABLE 3. Special On-site Test Items for Disassembled Transport
Special on-site tests for disassembled transport were performed and overall soundness after re-assembly was confirmed.

○ : Indicates check contents for each test item verification test by applying the elemental technologies described above and by conducting a transport test.

Transport Test

Cores and coils were subjected to transport-control accelerations of 29.4 m/s^2 and greater through drive tests, bad-road tests, and drop tests using a crane truck. No offsets, damage, or other abnormalities were found in the re-assembly after transport.

Performance Test After Disassembly, Transport, and Re-assembly

Re-assembly operations were performed after disassembly and transport tests and it was found that operations could be performed at each step without problem. The items shown in Table 3 were also tested in addition to standard test items to check the overall soundness of the transformer, and no problems were uncovered.

APPLICATION TO ACTUAL EQUIPMENT

Two 275-kV 400-MVA transformers were delivered to the Nanjo Substation of Hokuriku Electric Power Company as disassembled-transport transformers employing the technologies described above (see Fig. 4).

The on-site installation period for one of these transformers was reduced to 70% that of the number of days required to install the 250-MVA transformer delivered to the Kamishiba Power Station of Kyushu Electric Power Co., Inc. Also, as a large-capacity transformer employing the unit-cooler system, this transformer should meet the extremely low-noise specifications demanded by this type of transformer by applying a standard core structure in which magnetic flux flows smoothly[2)].

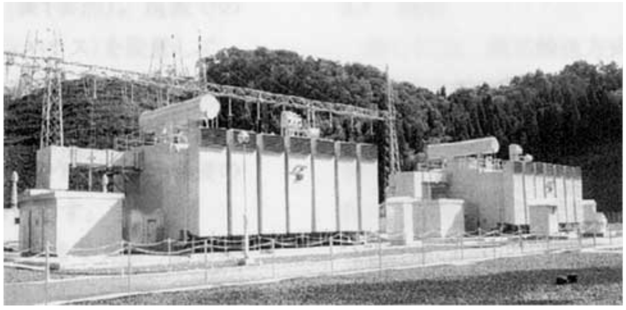


Fig. 4— View of 400-MVA Disassembled-transport Transformer Delivered to the Nanjo Substation of Hokuriku Electric Power Company.
Main specifications are as follows. Capacity: 400/400/100 MVA, voltage: 275/154/31.5 kV.

CONCLUSIONS

This paper has described recent developments in disassembled-transport transformers using a single-phase prototype of 500-kV 1,000-MVA transformer as an example. Disassembled transport is coming to be seen as one means of lowering total transformer cost. For this reason and as a countermeasure to transformer transport restrictions that are expected to become increasingly severe, Hitachi, Ltd. plans to expand the application of the technologies and know-how described in this paper.

REFERENCES

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(2) Mitani et al., “Construction of a 50 dB-class 400-MVA Low-noise Transformer, 1999 The Institute of Electrical Engineers of Japan, Power and Energy Conference (10th Meeting), 499 (August 1999).

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