Fuji Advanced Transformer Reassembled at Site (FATRAS)

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1. Introduction

The steady growth of power demand in recent years has increased demand for transformers with higher voltage and larger rated power, which inevitably enlarges their size and mass. Environmental restrictions are becoming severer year by year. When installing transformers in hydropower stations located in mountainous areas or substations located in urban and suburban areas, transportation costs will increase particularly when widening roads, reinforcing bridges, removing obstacles, etc. are required. To minimize the total transformer costs, including equipment, transportation and onsite installation costs, Fuji Electric has developed and implemented an onsite reassembled type transformer (FATRAS: Fuji Advanced Transformer Reassembled at Site), which allows use of a general-purpose low-platform trailer for inland transportation.

2. Features of FATRAS

In general, after a transformer is completely assembled and tested at the factory, only external components and accessories are disassembled for transporting. When there are severe restrictions on the transportation, such as if the transformer is located on a mountainous area, a special three-phase construction type or a bank of three single-phase units are utilized and the transformer is transported with special freight cars (Schnabel or garter wagons) for inland transportation.

FATRAS makes it possible to use general-purpose low-platform trailers without adversely affecting environmental shipping restrictions.

Figure 1 shows a conceptual workflow of FATRAS. At the factory, the transformer is completely assembled as a normal three-phase unit and tested to verify its performance and quality. Then, some main components, such as cores, windings and tanks, are disassembled so that a general-purpose low-platform trailer may be used. The number of the components disassembled is reduced as much as possible for easier onsite reassembling. In a temporary dust-proof air-conditioned building at the site, the core and windings are reassembled and the divided tanks are combined. After the tank is completed, external parts, such as bushings, coolers, etc. are mounted. After drying the windings and insulation, the transformer is filled with oil and then tested to reconfirm that its performance and quality are equivalent to those before disassembling at the factory.

Table 1 shows a comparison of the 500kV 1,000MVA layout for FATRAS and for conventional three single-phase units.

3. Construction of FATRAS

3.1 Core

As shown in Fig. 2, a five-legged three-phase core construction is utilized for FATRAS. The core construction is such that, after removing of the upper yokes and windings, it can be split into four parts at each center of the main legs. For transportation, the lower core part is held in place by custom jigs and placed in the transportation tank to prevent deformation of the core or changes in the joint-gaps during transportation. Onsite assembling does not require erecting the cores as they are shipped upright, and only requires adjusting and fitting the split core parts together and mounting the upper yokes.

3.2 Winding

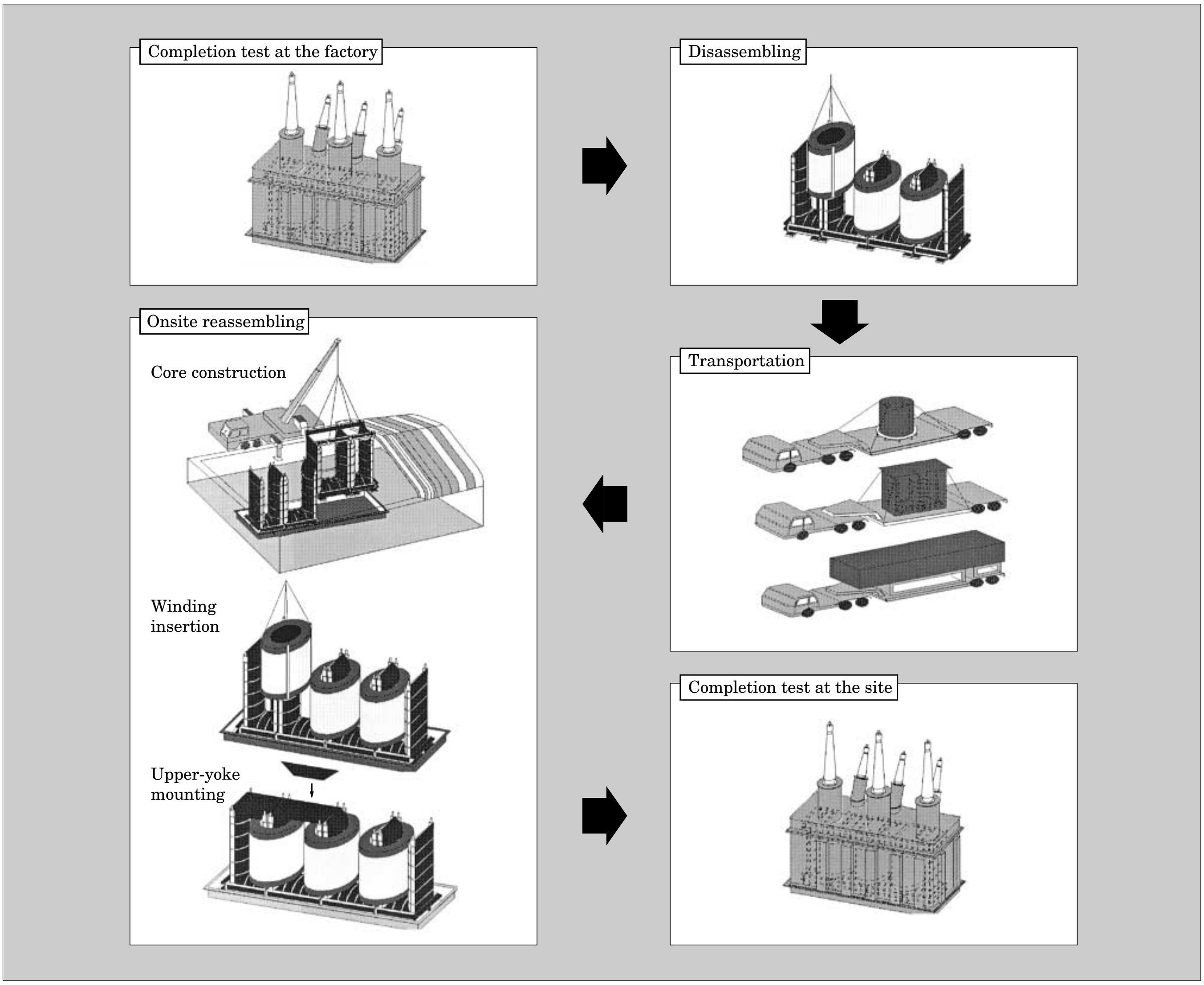
To simplify disassembling and reassembling, the HV, LV and tap windings are constructed in a single unit for each phase. The winding assembly is packaged in a high-polymer film to protect from moisture and dust during disassembling at the factory, shipping, and reassembling at the site. Existing openings of the package are bonded with tape for airtight sealing and easy handling.

Figure 3 shows a photograph of the packaged winding assembly.

3.3 Tank

The tank is divided structurally into three parts, i.e., upper, middle and lower parts, in consideration of the transportation limits. The lower tank is used as the base for assembly of the core, and the middle tank

Fig.1 Overview of FATRAS



is used as a transportation tank for the yokes and tap leads. Figure 4 shows a conceptual view of the tank construction.

4. Reliability Verification Tests

The core and windings of FATRAS are disassembled after testing at the factory, and then reassembled at the site. This procedure is very different from that of the conventional transformer. Therefore, the following tests specific to FATRAS were carried out to verify reliability for practical use.

4.1 Core performance test

Two reduced-scale (1/5) models, a main-leg-split type (for FATRAS) and a conventional type, were made of a three-phase 250MVA five-legged transformer. The tested core characteristics, i.e. no-load loss, excitation current etc., were confirmed as substantially equivalent for both the conventional type core and the main-leg-split type. Figure 5 shows the five-legged three-phase core model during testing.

4.2 Core transportation test

After disassembling the upper yokes, a U-shaped core is fitted to transportation tank. Actual 250MVA core models were transported for 400km and then reassembled to compare the core performance both before and after the transportation. No gap or damage was found on any section of the core. In addition, the electric performance tests yielded good results. Figure 6 shows a photograph of the core being transported.

4.3 Wound film package test

The water content in the winding insulation surface layer is one of the most important indicators for transformer insulation capability. During the process from factory disassembling to transportation and then to onsite assembly, FATRAS mainly concentrates on preventing the moisture or water absorption of internal transformer parts. To confirm the moisture

Table 1 Comparison of FATRAS and a bank of three single-phase units for 500kV 1,000MVA

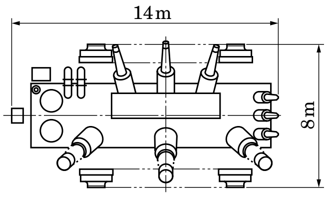
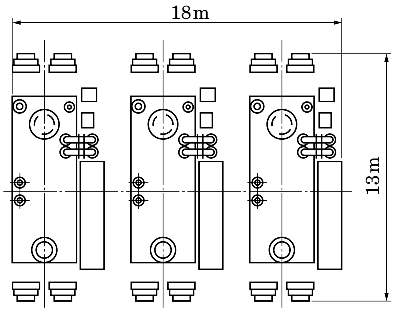
Item	FATRAS	Three single-phase units
Plane drawing		
Maximum transportation mass	⟨Core⟩ 38t (26%)	146t (100%)
Installation area	112m^2 (48%)	234m^2 (100%)
Transportation method	Large low-floor trailer	Special freight car and trailer

Fig.2 Split structure of three-phase five-legged core

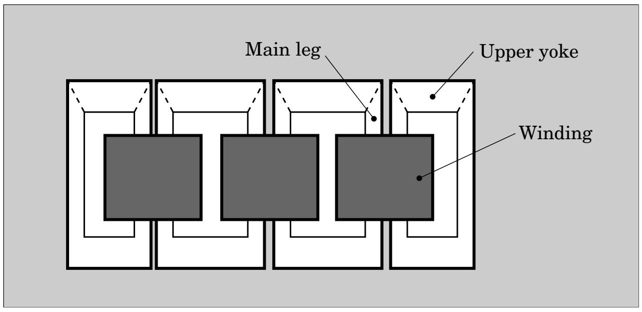
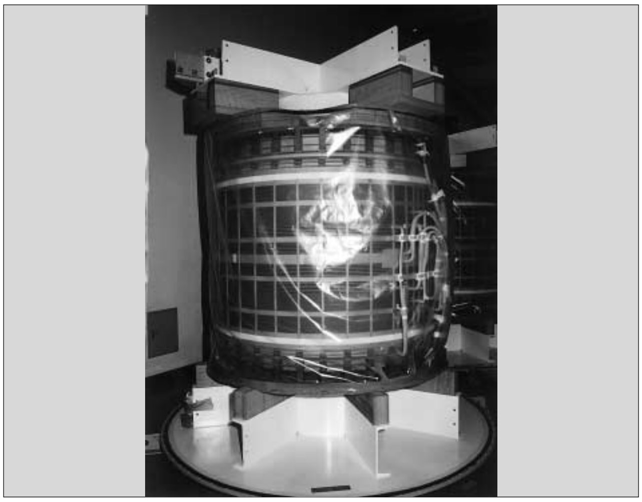


Fig.3 Winding assembly packaged with film

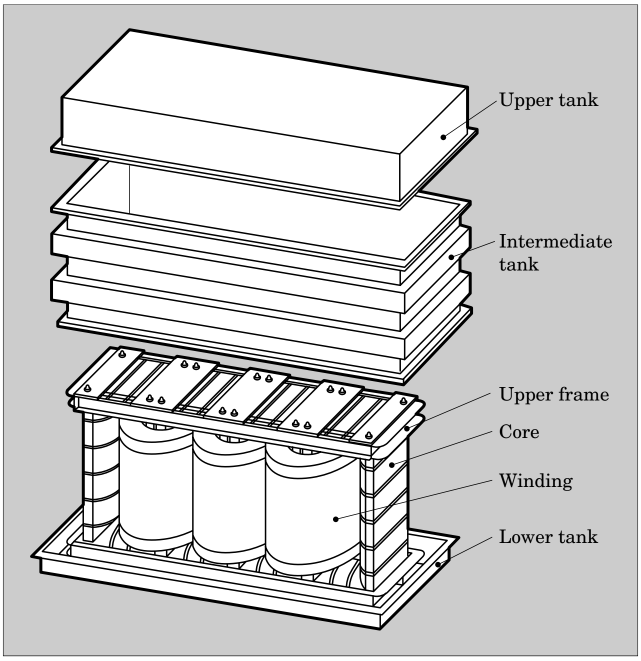


prevention effectiveness of the wound film package, the film was wrapped around an actual winding model. It was confirmed that there is no increase in water absorption during 60 days of an actual field test.

4.4 Onsite assembly model test

With the actual size model, trial assembly of the core and windings was carried out using mobile cranes. The ease of reassembling and control for dimensional tolerance were satisfactory. A no-load test and short-circuit impedance voltage test on the reassembled unit confirmed that the core and windings were in good condition.

Fig.4 Tank construction



5. Quality Control

5.1 Transportation

The core and windings are put in dedicated transportation tanks that are filled with dry air to prevent moisture absorption. During transportation by trailers, shock impact acceleration and trailer speed were continuously recorded. After delivery to the site, the deformation and rusting of the core parts as well as the displacement and deformation of the winding bodies were visually checked and verified that there

Fig.5 Testing of the five-legged three-phase core model (split type)

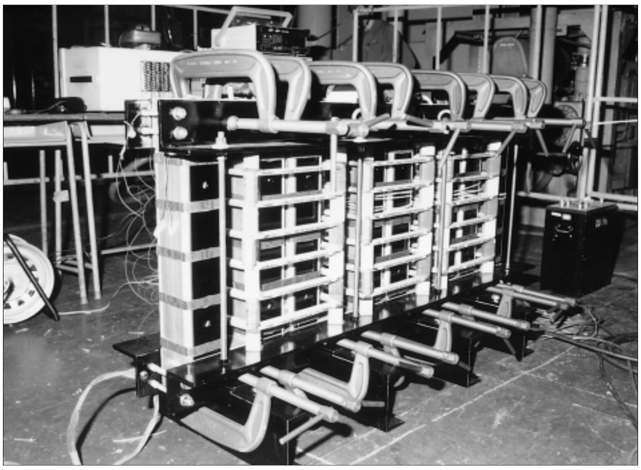


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Fig.6 Testing of the core component transportation

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Fig.7 System flow of high-vacuum refrigeration drying and hot-oil circulation drying

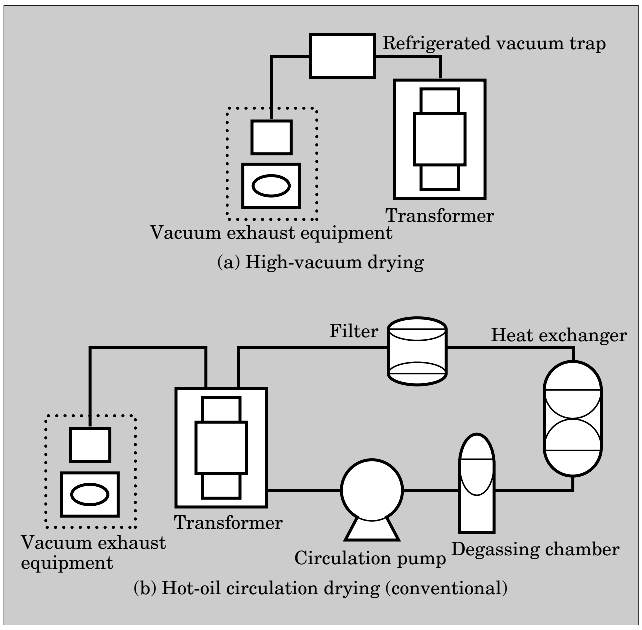

Fig.8 Dust-proof and air-conditioned building

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Table 2 Tests specific to FATRAS

Test item	Test method	Control value
Low voltage excitation test	Measure excitation current at low voltage	+30% or less of the factory data
Low voltage impedance test	Measure impedance at low voltage	±3% or less of the factory data
Long duration AC voltage withstand test	Measure internal partial discharge with ERA method	Not more than external noise (100 pC)

Fig.9 Onsite completed FATRAS

were no problems.

The control criteria for transportation are listed below.

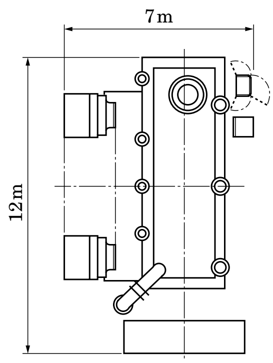
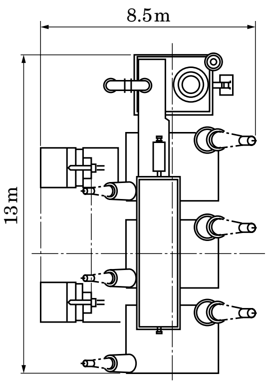
(1) Shock impact acceleration : 29.4m/s^2 {3G} or less (horizontal and vertical)

(2) Trailer moving speed : 40km/h or less

5.2 Moisture prevention for the winding insulation material

To prevent moisture absorption, the windings remain packed in film from the time of factory disassembling until completion of onsite reassembling. By sampling pieces of insulation at each stage of the re-assembly, the moisture content was monitored. After reassembling is complete, an oil treatment was performed with the high vacuum refrigeration drying

Table 3 Comparison of FATRAS and the special three-phase unit for 275kV 250MVA

Item	FATRAS	Special three-phase unit
Plane drawing		
Total mass	235t (73%)	320t (100%)
Maximum transportation mass	20t (29%) ⟨Core⟩	70t (100%)
Installation area	84m^2 (76%)	110m^2 (100%)
Transportation method	General low-floor trailer	Special freight car and large low-floor trailer

method. This method can avoid overheating of the system, reduce the required energy and save construction space as compared with the conventional hot-oil circulation drying method. Figure 7 shows a system diagram of the high-vacuum refrigeration drying and the hot-oil circulation drying.

5.3 Dust-proof air-conditioned building

The core and windings are reassembled onsite in a dust-proof air-conditioned building temporarily setup at the site. Environmental conditions inside this building are substantially equivalent to those at the factory, to maintain the same quality as at the factory. Specifications of this building are listed below.

(1) Relative Humidity : 50% or less
(2) Temperature : (23 – 9) to (23+7) °C
(3) Dust quantity : 20CPM (counts per minute) or less

The ceiling of the building can be opened, and the heavy cores and windings hung down from outside of the building with a wrecker crane. Inside the building, a hoist crane is installed to move the upper yokes and the associated equipment.

5.4 Special tests for FATRAS

The most critical concern of FATRAS is reassembling the core and windings, and therefore, the tests shown in Table 2 were carried out in addition to normal onsite tests. The results of the low-voltage exciting test and the low-voltage impedance test were compared with the factory test data. A long duration AC voltage withstand test was also carried out satisfactorily.

6. Practical Application

A 275kV 100MVA and a 275kV 250MVA transformer were delivered as FATRAS in 1997, and have been operating successfully. The specifications of the 275kV 250MVA unit are listed below.

(1) Type: three-phase 60Hz on-load tap-changing transformer
(2) Cooling: ODAF(oil-directed air-forced)
(3) Rated power: 250MVA
(4) Rated voltage: 275/77kV
(5) Sound level: 60 dB

Figure 9 shows the external view of the 275kV 250MVA transformer after completion of onsite reassembling. Table 3 compares FATRAS and the special three-phase transformer.

7. Conclusion

Practical application of FATRAS has been described. The results of the onsite tests have confirmed the same quality as the factory tests.

FATRAS has the following advantages.

(1) The transportation cost can be greatly reduced because transportation measures such as road widening, bridge reinforcement, etc. are not needed.
(2) FATRAS can reduce the installation space required in a substation, and therefore reduce the onsite construction cost.

Shipping and onsite installation costs will rise especially for transformers of hydropower stations in mountainous areas and of substations in urban and suburban areas, and therefore the demand for FATRAS will increase.

The authors intend to further enhance the performance and reliability of FATRAS in future.