Auto-Transformer (AT) for Railway Project in India

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Abstract

In cooperation with our subsidiary, PRIME MEIDEN LTD. (PML) in India, we plan to deliver a total of 192 Auto-Transformer (AT) units in the combination with the 8MVA and 12.3MVA models to Dedicated Freight Corridor Corporation of India Limited (DFCCIL) during Phase 1 of the construction period for the Western Dedicated Freight Corridor. Since short-circuit failures frequently occur and the supply of electric power is unstable in India, product specifications include various specific technical requirements regarding short-circuit strength. When the first AT unit conforming to these specific requirements was completed, the first unit underwent a short-circuit test. This was conducted before the start of mass production. At the time of designing this product, we decided to adopt a nitrogen sealed tank type because it substantially excels in maintenance. In addition, we tried to adopt materials available in India and realized a compact design in order to reduce product height for fully assembled transportation. In order to improve the product quality of PML in manufacturing half the amount of the ordered ATs, we sent our engineers for production facility upgrading and improvement of technical skills.

1 Preface

Along with the rapid economic rise of India, railroad freight transportation is increasing rapidly. Consequently, the Indian Government is pressed to improve and upgrade dedicated freight corridor lines. The Dedicated Freight Corridor Corporation of India Limited (DFCCIL) is currently promoting the construction of dedicated freight lines that vertically cross the land of India. These lines traverse a total of about 2800km named the “Western Dedicated Corridor (WDC) between Delhi and Mumbai” and the “Eastern Dedicated Corridor (EDC) between Ludhiana and Son Nagar.” This EDC’s traffic volume is particularly large. Fig. 1 shows an overview of the project. In cooperation with our subsidiary, PRIME MEIDEN LTD. (PML) in India, we are planning to deliver total 192 units of Auto-Transformers (ATs) in combination with 8MVA and 12.3MVA models with the rated voltage of 55/27.5kV in a joint venture with Sojitz Corporation and Larsen & Toubro Limited. This order is for installation and construction period for the WDC Phase 1, which is intended to construct a total of 922km of dedicated freight corridors between Rewari and Vadodara. For Japanese electric machinery manufacturers, the delivery of 192 AT units to substation facilities of a single railroad line in India is an all-time high supply

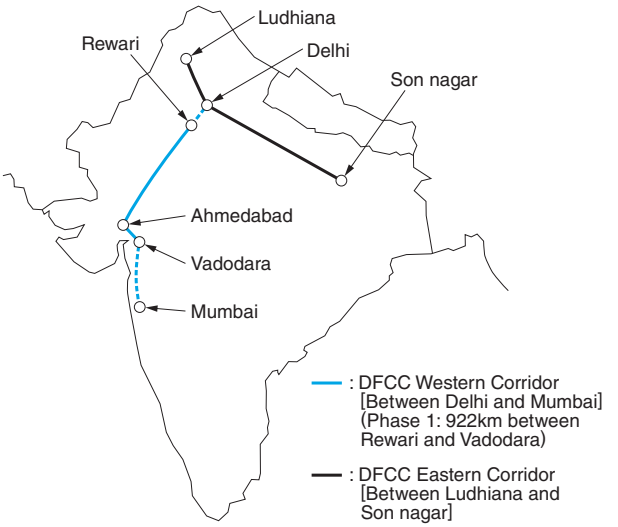


Fig. 1 Overview of Project

An overview diagram of the high-speed dedicated freight corridor projects in India is shown.

Table 1 Major Specifications of AT

The basic specifications for the 8MVA and 12.3MVA ATs are shown. A rigorous short-circuit strength exceeding the IEC 60076 is demanded.

Item		Specifications	
Model		8MVA AT	12.3MVA AT
Applicable standard		IEC 60076	
No. of phases		1	
Frequency		50Hz	
Rated power	Line	8MVA	12.3MVA
	Self	4MVA	6.15MVA
Short-circuit strength	Short-circuit current	7.27kA (25 times the rated current)	12kA (26.83 times the rated current)
	Dynamic duration	0.5s (IEC : 0.25s)	
	Thermal duration	5s (IEC : 2s)	
Rating		100% continuous, 150% 15min, 200% 5min	
Rated voltage		Primary 55kV/Secondary 27.5kV	
Cooling system		Oil-immersed self-cooled (ONAN)	
Short-circuit impedance		0.45Ω or below as seen from the secondary side	
Temperature rise limit		Top oil 45K/Average winding 50K	
Audible sound level		NEMA 68dB (A)	NEMA 69dB (A)

record. In designing these AT transformers, there were issues of information sharing with PML such as having a common design approach, manufacturing processes, and use of common materials and components. This paper introduces the AT to be delivered and how we addressed the sharing issue with PML.

2 Equipment Specifications

Table 1 shows major specifications. The customer's specifications demand that (1) the short-circuit strength (its duration) shall be more than the requirements stipulated by the IEC Standard 60076 for power transformers, (2) and that there is a requirement on the implementation of a special short-circuit test. In addition, the specification of the short-circuit strength indicates that there are specified clamping structures and winding layouts to curve electromagnetic mechanical forces generated in windings at the time of an external short-circuit fault. India has frequent short-circuiting accidents which make the delivery of the power supply unstable.

3 AT

Fig. 2 shows a conceptual diagram of the AT.

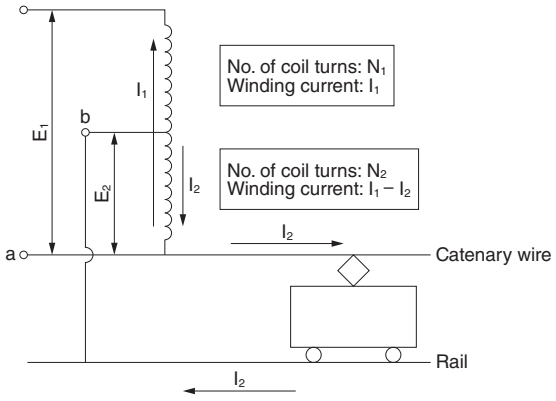


Fig. 2 Conceptual Diagram of AT

Electrical conceptual diagram of the AT is shown.

In the AT, part of the winding is shared on both the source side and the load side. In such an AT winding configuration, and on the assumption that this AT is an ideal transformer where a leakage impedance of windings can be neglected, Current I_1 flows from the source side meeting the relationship of $I_1 (N_1 + N_2) = I_2 N_2$ while a load is connected between a and b. The relationship between voltage and current is the same as that for an ordinary two-winding transformer. Based on structural reasoning for the AT, however, a part of the winding is shared between a and b and only a differential current $(I_1 - I_2)$ between the source side and the load side is carried through the section a-b. For this reason, the AT has an advantage of downsizing compared with a two-winding transformer having the same capacity. For the AT, however, there is no insulation between the source side and the load side, and a surge voltage generated on the high-voltage side can directly be transferred to the low-voltage side. It is, therefore, necessary to pay particular attention to insulation coordination. When the AT is used in a traction feeder circuit, however, the mid-point in the winding is connected to the rail and this means a neutral-point low resistance grounding. For this reason, the AT can be a transformer with stabilized insulation coordination. This type of AC traction power feeding is also adopted in Japan and we have delivered about 400 units of the ATs to Shinkansen project facilities.

4 Features of the Product

The major features of this product are as described below.

4.1 Solutions to Specific Specifications Regarding Short-Circuit Strength

According to the requirements proposed by the customer, a specific short-circuit test was carried out by a short-circuit current applied to the actual transformer. Fig. 3 shows a situation of short-circuit testing.

4.2 Adoption of a Nitrogen Sealed Tank System

In India, expansion of insulation oil caused by a temperature change is generally absorbed by a rubber diaphragm. In the case of our AT, a nitrogen-sealed chamber is provided at the top of the transformer tank so that expansion of insulation oil can be balanced by the effect of the nitrogen cushion. Compared with the diaphragm type, the nitrogen-sealed tank type is a simple structure design. Since a diaphragm and its related components can be omitted, maintenance becomes easier.

4.3 Fully Assembled Transportation

For the simplification of on-site construction work, the equipment had been designed as compact as possible so that the complete AT units can be transported safely from Japan to the site already fully equipped.

(1) In order to reduce the height during transportation, the AT has a structure where bushings are arranged sidewise.

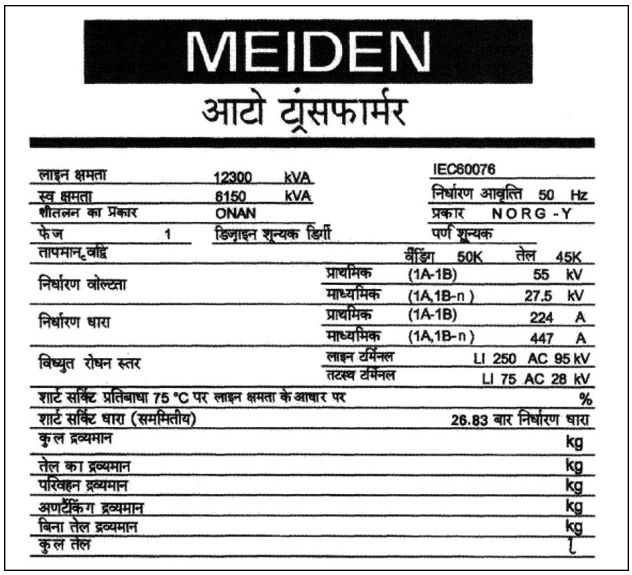
Fig. 3 Situation of Short-Circuit Testing

Short-circuit testing is shown. The short-circuit test is a feature requirement for this product's contract.

(2) For the reduction of the transformer tank height, the nitrogen tank is arranged beneath the bushing pockets. This resulted in a smaller installation space.

5 Description about PML

In March 2014, we invested in a local transformer manufacturing company in India and the company name was changed to PRIME MEIDEN LTD. (PML). Since then, we sent many engineers to enhance PML's technical capabilities and increase order entries from both inside and outside of India. Rating plates of products are specified in English and Hindi. Fig. 4 shows the Hindi portion of a rating plate. The complete rating plate written in English and Hindi was made possible by the co-operation between MEIDEN and PML. Fig. 5 shows an external appearance of the PML factory.



MEIDEN

आटो ट्रांसफार्मर

लाइन क्षमता	12300 kVA		IEC60076
स्व क्षमता	6150 kVA		निर्धारण आवृत्ति 50 Hz
शीतलन का प्रकार	ONAN		प्रकार N O R G - Y
फेज 1	डिज़ाइन शून्यक डिग्री		पर्ण शून्यक
तापमान् वृद्धि		वींडिंग 50K	तेल 45K
निर्धारण वोल्टता	प्राथमिक	(1A-1B)	55 kV
	माध्यमिक	(1A,1B-n)	27.5 kV
निर्धारण धारा	प्राथमिक	(1A-1B)	224 A
	माध्यमिक	(1A,1B-n)	447 A
विद्युत रोधन स्तर	लाइन टर्मिनल		LI 250 AC 95 kV
	तटस्थ टर्मिनल		LI 75 AC 28 kV
शार्ट सर्किट प्रतिबाधा 75 °C पर लाइन क्षमता के आधार पर			%
शार्ट सर्किट धारा (सममितीय)			26.83 बार निर्धारण धारा
कुल द्रव्यमान			kg
तेल का द्रव्यमान			kg
परिवहन द्रव्यमान			kg
अणटैंकिंग द्रव्यमान			kg
बिना तेल द्रव्यमान			kg
कुल तेल			ℓ

Fig. 4 Hindi Portion of Rating Plate

Descriptions of rating plates in English and Hindi are required. Rating plates in Hindi were made with a help from PML.

Fig. 5 PML Factory

An external appearance of the PML factory is shown.

Fig. 6 Views of Verification Test on Components

To secure good quality, Indian-made components underwent verification testing at MEIDEN.

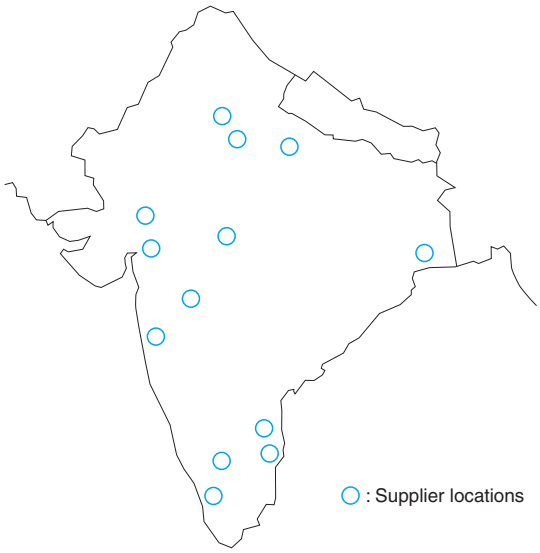


Fig. 7 Outline of Supplier Location in India

Outline of supplier locations in India is shown. We sourced parts, materials, components, and members from all over India.

6 Joint Designing and Manufacturing Policy between MEIDEN and PML

According to the term of this time contract, half of the contract amount of products are required to be manufactured by the same design in Japan (MEIDEN) and in India (PML). Transformer design is directly affected by the materials, production facilities and skills of the workers. For MEIDEN and PML to manufacture ATs under the same design and the same quality, materials, production facilities, and worker's technical skills are indispensable.

6.1 Material and Component Sharing

The advantages for maintenance work after product delivery include many kinds of components and materials in India adopted for this contract for ATs. In order to assure high quality, a verification test was carried out at MEIDEN on materials currently adopted by PML. A delegation team was organized consisting of members from our design and quality assurance Business Units (BUs). In this manner, we secured the required specifications and product quality through the quality audit of local suppliers in India and many detailed technical meetings with the suppliers. Fig. 6 shows a view of the verification test on the components and Fig. 7 shows outline of suppliers location in India with whom we conducted the quality audit.

6.2 Solutions to Facilities

In order to keep up with the same design policy, it is necessary to have manufacturing facilities at the same level. Reinforcement of facilities for the special winding processing line had already been completed, as this line is indispensable for AT production. We will further upgrade other manufacturing facilities at PML to increase the offerings of the same design models.

6.3 Skill Level of PML Workers

In the transformer production, particularly in winding processing process, many highly technically skilled workers are required. For this reason, we sent our factory engineers to PML to secure such high quality. In doing so, the technical skill level of PML workers was improved and we increased their awareness of the critical importance of quality.

7 Postscript

The high-speed dedicated freight corridor in India are a key role in major logistics infrastructure.

Our project team discussed the requirements and wishes of the end-user on the ATs repeatedly. Working with PML and the related material suppliers in India, we realized products with high reliability and quality. Going forward, by drawing on our valuable experiences from this time project, we would like to contribute to infrastructure-building projects in India. Lastly, we would like to express our deepest gratitude to the project-related staff for their kind guidance and cooperation for the success of this project from the early stage, ordering, product development, and installation.