283775/2020/O/o PED/TI/RDSO

Reasoned Document for Final Draft Specification of 38/53/63MVA single Phase transformer of 2X25kV system

SN	Spec. Clause No.	Specification description	Comment of Firm	RDSO Remark on the comment
1.	1.5.1	Suitable air cell/separator arrangement of high quality material shall be provided in the conservator to ensure that the transformer insulating oil does not come in contact with air.	**M/s ABB** We would recommend the addition of a cell/separator leak detector to the conservator to detect cell rupture/damage or significant air leakage to the fluid side.	Firm suggestion may be accepted as it is monitoring of the aircell
2.	1.5.2	**Oil level gauge:** It shall be of magnetic type having a dial diameter of 250mm. The gauge shall have markings corresponding to minimum oil level, maximum oil level and oil level corresponding to oil temperature of 30^0C, 45^0C and 85^0C. The oil level indicator shall be so designed and mounting that the oil level is clearly visible to an operator standing on the ground.	**M/s ABB** We would recommend the addition of low and high fluid level alarms to the oil gauge requirement. This will give warning if there is a significant loss of fluid due to major leakage and also warning if during long periods of overload at high ambient there is risk to the transformer for overpressure or rupture of the conservator cell /separator.	Firm suggestion may be accepted as it is a monitoring of the system.
3.	1.5.3	**Silica gel breather** It shall be complete with oil seal and connecting pipes. The connecting pipes shall be secured properly. The container of the silica gel breather shall be of transparent flexi glass or similar material suitable for outdoor application. Orange Silica Gel (round balls 2 to 5mm) with quantity of two DTO-8 silica gel connecting with flanged mounting two pipes control through two different valves as per DIN:42567 & IS:3401 to be provided.	**M/s ABB** We would recommend the use of: Self-Dehydrating silica gel breather. The breather shall be able to automatically regenerates the own silica gel and report the status of the regeneration through LEDs and suitable communication. The selection of suitable breather should be based on the total quantity of oil in Transformer and its application. All the external parts of the breather shall be suitable for outdoor use and & resistive to transformer oil. It should also be able to withstand the site conditions like ultraviolet rays, pollution & saline atmosphere. The breather shall be suitable to work on ambient temperature of -20°C to +80°C. The equipment must be capable to withstand all possible environmental conditions. Control box degree of protection shall be at least IP65. The type pest certificate for the same must be submitted. Breather should also be equipped with a manual regeneration button to test the regeneration functionality. Control box shall be equipped with Analogue output signal (4-20ma) for the silica gel saturation & USB / RS 485 port for downloading the operational data logged by the unit. Required software supporting the analog and digital functions shall also be provided. Supply of Laptop/PC for above software is not envisaged.The equipment shall operate at input	Firm suggestion of self-dehydrating breather may be accepted as an optional requirement in the specification, so that for any remote or very humid location, it can be utilized by Indian Railways, if required.

			supply of 230V AC, 50 Hz. Any converter if required shall be supplied with the equipment. The breather shall also be equipped with suitable protection against overvoltage. Type Tests reports must be submitted for offered breather. The supply shall have a minimum 5-year manufacturing experience and minimum 2 performance certificate of more than 1 year of successful operation shall be available from state / central Indian utility 1. No need of replacing silica gel for minimum 10 Years 2. No silica gel visual inspection, replacement & disposal. 3. Full control of drying agent saturation status. 4. SCADA connectivity for signals displaying the silica gel saturation level. 5. No environmental impact for silica-gel disposal 6. Total cost of ownership reduction.	
4.	1.5.4	**Pressure relief device:** It shall be designed to operate to release internal pressure at preset value without endangering the equipment or operator and shall be of instantaneous reset type. Shroud Pressure relief Device will be used and have provision of discharge of oil from PRD to safe place by closed pipeline. This avoids hazards of fire and it is safe to persons working near Transformer & it is environmental friendly.	**M/s ABB** Given the very frequent occurrence of short circuits and overloads, we recommend the use of a smart pressure relief valve. The PRD shall be capable of continuously indicating the pressure in main tank through 4-20mA analog communication. The PRD shall have provision of digital communication through Modbus or similar protocol. This shall be suitable for integration with SCADA if required. Also, if required PRD should be capable of giving soft alarm in system. This device detects and reports pressure increase as well as pressure relief valve operation. Evolving problems due to frequent short circuits may possibly be detectable well prior to tripping of transformer and the need for unexpected outage avoided. Also, the possible discharge of oil may be avoided.	Firm suggestion may be accepted as an optional requirement with the conventional PRV, since the manufacturers of smart PRV are limited in India at present, it is mainly imported item.
5.	1.5.8	**Buchholz relay:** It shall be of double float type, with two shut - off valves of 80 mm size, one between the conservator tank and Buchholz relay and the other between the transformer tank and Buchholz relay. The relay shall have one alarm contact and one trip contact, none of the contacts being earthed. The contacts shall be magnetic switch or micro switch type, electrically independent and wired up to the marshaling box. A testing	**M/s ABB** Given the very frequent occurrence of short circuits and overloads, we recommend the use of a smart gas pressure relay (Buchholz relay). Along with the conventional features, Buchholz relay shall be suitable for remote indication of the parameters being measures as defined below. a) The Buchholz relay shall be capable of continuously communicating the oil level through 4-20mA analog output. b) The Buchholz relay shall have provision of digital communication through Modbus or similar protocol. This shall be suitable for integration with SCADA if required. The protection class of Buchholz relay shall be at	Firm suggestion may be accepted as an optional requirement with the conventional Buchholz, since the manufacturers of smart Buchholz relay are limited in India at present, it is mainly imported item.

		petcock shall be brought down through a pipe for the purpose of sampling the gas, if any, collected in the Buchholz relay.	least IP65. This device detects and reports accumulating volume of gas as well as normal Buchholz functions. Evolving problems due to frequent short circuits may possibly be detectable well prior to traditional alarm and tripping of transformer and the need for unexpected outage avoided.	
6.	1.5.12	Thermo Siphon Filter System is to be provided for absorbing the moisture present in the insulating oil with the natural convection. The full details for installation and subsequent maintenance have to be furnished to RDSO and the consignee	**M/s ABB** We recommend exclusion of this clause. In case specifically required we recommend use of online transformer oil drying system which is universally accepted and are more reliable. Thermosyphon Filters are primitive solution which does not find much relevance with improved design and use of air cell.	Comments of the firms may be accepted to remove the requirement of the thermo syphon filter as the Aircell has been added with the transformer.
7.	1.5.14	**Fibre Optic Winding Hot Spot Temperature Monitor:** Fibre optical winding hot spot temperature monitor to be provided with the transformer windings, connected in addition to the winding temperature indicator in parallel to measure transformer winding hot spots in real time and activate control of the cooling system. The Fibre to be given high strength casing through jacketing and Fibre Optic shall be governed by IEC-60076-2 (Ed.3.0)	**M/s ABB** We recommend that the fibre optics are also used to monitor the hotspot temperature in service to validate the effects of harmonics. Additionally, the temperature rise information (with and without harmonics) from a design review meeting together with the FAT fibre optic results (without harmonics) should be used: • To set the winding temperature indicator to simulate hotspot gradient with harmonics • Determine if the transformer FAT results meet the allowable temperature rise limits for the service situation with harmonics.	The Fibre optic winding Hot Spot temperature is kept functional during the Type Testing and is also functional on the site also. No change in the specification is required in view of the firm suggestions.
8.	3.2.1	The tank for the transformer shall be of bell type construction with flanges on the outside and shall have a flat top .The flanges of the upper and lower tanks shall be jointed by bolts, nuts and suitable plain/spring/beveled washers. A suitable gasket and metallic stoppers shall be provided between the flanges of upper and lower tank so as to prevent leakage of Insulating Oil. The tank shall be so designed that the winding and core get fully exposed when the bell tank cover is lifted.	**M/s ABB** The tank for the transformer shall be of **Conventional** type construction with flanges on the outside and shall have a flat top .The flanges of the upper and lower tanks shall be joined by bolts, nuts and suitable plain/spring/beveled washers. A suitable gasket and metallic stoppers shall be provided between the flanges of upper and lower tank so as to prevent leakage of Insulating Oil. The tank shall be so designed that the winding and core get fully exposed when the bell tank cover is lifted. As per Clause 6.1 of recent CBIP manual, ***"All transformer reactor tanks should generally be of conventional type"***. The Bell tank is not generally recommended. It is asked only if there is a facility limitation to lift the active part for full inspection purpose. ABB recommends not to expose the active part to the	As per CBIP manual on transformer issued in April 2013, publication no. 317 - "All transformer reactor tanks should be generally be of conventional type i.e. tank body with top cover, Bell shaped construction can be specified for 100MVA and higher rating transformer unless otherwise mutually agreed between Purchaser and Manufacturer.

			atmosphere and thus bell type tank is not recommended. Also, there could be hot spots on bolts at the curb of bell and the damage to the gaskets can cause leakage in long term operation. The oil head is also more at the curb joint in case of Bell type tank which also increases the chances of oil leakages.	This manual does not make a mandatory requirement for the bell tank below 100MVA, Considering the possibilities of the overhauling of the transformer at the site, the bell type transformer tank has been used in the Indian Railways, and thus the bell type tank is recommended for this rating also.
9.	3.2.4	The tank shall be fitted with an under carriage and mounted on eight bi-directional swiveling type flanged rollers for being rolled on 1676 mm (5' 6") gauge track on which it shall also rest in the final position	**M/s ABB** We would recommend that 4 bi-directional rollers is sufficient for a transformer of this size **M/s TBEA** Four/eight rollers shall be used based on the size and weight of the transformer.	Eight rollers to be provided as per the specification considering for the easy movement of transformer at the TSS location when required.
10.	3.2.6	The rubberised cork/gaskets used in the transformer shall conform to IS: 4253 (Part - II).	**M/s TBEA** We propose to use Nitrile Butadiene rubber as it has better performance over SRBC gasket.	Firm comment may be accepted for incorporation in specification.
11.	3.4.1	The core shall be built from high permeability Cold Rolled Grain Oriented (CRGO) silicon steel laminations conforming to IS: 3024. The flux density in any part of the core and yokes at the principal tapping with primary winding excited at the rated primary voltage and frequency <u>shall not exceed 1.55T. T</u>he manufacturer shall furnish calculations to prove that this value shall not be exceeded. The core has to be preferably of boltless design to avoid the possibility of local heating.	**M/s ABB** We would recommend that the normal flux density is limited to 1.7 T rather than 1.55 T. The core steel grade used should have tested single strip loss results at 1.7 T (50 Hz) less than 1.25 W/kg. Additionally, in order to avoid local heating and flux concentration, the core should use step lapped core joints and laminations should not have holes such as for manufacturing alignment nor have bolts (insulated or otherwise) through the laminations. The Bidder shall submit the Flux Density Calculation along with the design review and the same specified parameters shall be verified during physical stage inspections by methods as specified in the stage inspection procedure. Indian transformer manufacturers shall use core material as per above specification with BIS certification. Modern core steels have a saturation flux density > 2.0 T. Hence normal flux densities of 1.7 T are still very safe. Even with system highest voltage applied continuously to the transformer, the flux density of 1.89 T is comfortably below saturation and excessive heating. This is provided a modern core design is used with step lapped joints and no	As per CBIP manual on transformer issued in April 2013, publication no. 317, Para no. 2.9.1 (page 11), Maximum Flux Density shall not exceed 1.9 Tesla. In addition to these, the use higher flux density will have advantages that it shall reduce the size of the transformer which shall be beneficial to Indian Railways for space saving for the TSS. Considering the above and reason mentioned by the firm, the comment of M/s ABB may be accepted in view of the reasons mentioned. In the specification it may be mentioned as flux

			lamination holes or through-bolts giving local flux concentrations. The use of the modern steels can be assessed with submission of typical B-H curves and assessment of the core exciting current at tender and factory assessment testing stages. We can offer some suggestions/information on this via our application engineering team if it is of interest. **M/s TBEA** We understand that this is because of tap on primary for primary variation.	density shall not exceed 1.7T. Comment of M/s ABB that "Indian transformer manufacturers shall use core material as per above specification with BIS certification" may be added in the specification to ensure quality.
12.	3.4.3	The core shall be electrically connected to the tank.	**M/s ABB** We recommend that the core, core clamps and tank should be insulated from each other with a single location conscious earth connection. The insulation shall be high temperature, non-deteriorating (non-cellulose) material. The earth connection shall be accessible without draining any oil, behind a cover-plate to allow the connection to be opened for testing of the insulation resistance at 2.5 kV. This will ensure that the core is earthed in service at one point only to avoid any possible circulating currents. It also allows the insulation integrity to be verified periodically during POH or in response to adverse DGA signatures. For a transformer that is subjected to frequent short circuits, this arrangement is recommended.	Firm comment may be accepted for adding in this para. Already in the specification 2kV insulation test is mentioned between core laminations and core clamping bolts.
13.	3.4.6	Manufacturer shall, preferably have the core cutting facility in their works and proper monitoring and quality control to avoid any mixing with defective /second grade materials.	**M/s ABB** We recommend that it is not necessary to have the core cutting facility at the manufacturer's works if the appropriate monitoring and quality control systems are in place. We recommend adding a requirement to perform and analyse a core resistance test across the lamination steps of the completed core to assess for this. This will ensure that the core is earthed in service at one point only to avoid any possible circulating currents. It also allows the insulation integrity to be verified periodically during POH or in response to adverse DGA signatures. For a transformer that is subjected to frequent short circuits, this arrangement is recommended.	As per the specification it is not a mandatory requirement, so any change is not required in the specification. The no load losses are already defined in the specification, which are measured during the routine testing of the each job. For addition of CORE resistance test any reference standard has not been linked with the comment, so cannot be accepted.
14.	3.5.1	The winding shall be of concentric disc or interleaved for the primary, and disc or	**M/s ABB** We recommend that the winding type be changed to: The windings shall be of an axially	As per the specification transformers design is

		helical/cylindrical for the secondary windings.	clamped concentric winding design. Windings shall not be multi-layer type which rely on epoxy dot bonding to interlayer paper/pressboard cylinders to maintain short circuit axial force withstand. Winding types shall be axially clamped disc, helical or single/double layer types of substantial radial depth. Due to the very frequent short circuits, it is necessary to have windings with substantial radial dimension and are firmly axially clamped. Distribution transformer type multilayer windings using diamond dot interlayer papers to bond to the turns for axial force withstand are not secure enough for this transformer duty.	accepted which passed all the type test including the dynamic stability short circuit test in a laboratory, the design is not accepted on the basis of the theoretical calculations. Therefore, the type of the transformer winding may be decided by the transformer manufacturer after ensuring that the all the parameters mentioned in the specification are fulfilled with that design. The clause shall be modified accordingly.
15.	3.5.2	The windings shall be made of continuous electrolytic copper conductor, paper insulated to class - A insulation. The conductor shall not have sharp edges which may damage the insulation.	**M/s ABB** Thermally upgraded insulation, while still class A material has a better thermal lifetime performance. For a transformer that is subject to high levels of harmonics, the winding hotspot is at risk of higher values and more sensitive to increased harmonics. Thermally upgraded paper is more resistant to the impact of the higher winding hotspots. Epoxy bonded continuously transposed cable which includes enamelled strands is particularly suitable for transformers with harmonics and high short circuit demands. Its small strands are helpful to reduce the increased eddy losses from the harmonics while the epoxy bonding of the strands dramatically increases the short circuit withstand strength.	As pre the IS: 2026 (Part:14): 2018, Para 3.6, Thermally upgraded paper is cellulose-based paper which has been chemically modified to reduce the rate at which the paper decomposes. Also as per the para 5.6 of IS:2026 Part – 7, The purpose of thermally upgrading insulation paper is to neutralize the production of acids caused by the hydrolysis (thermal degradation) of the material over the lifetime of the transformer. This hydrolysis is even more active at elevated temperatures, and published research results indicate that thermally upgraded

				insulation papers retain a much higher percentage of their tensile and bursting strength than untreated papers when exposed to elevated temperatures. In view of the above, The comment to use thermally upgraded paper may be accepted. Option for epoxy bonded continuously transposed conductor shall also be added in the specification, since for normal single phase transformers CTC conductor are already being used by RDSO approved vendors from many years.
16.	3.5.9	The axial pre - compression on the windings shall preferably be double the calculated axial thrust that may be set up under dead short - circuit condition so as to ensure that the windings do not become loose due to frequent short circuits in service.	**M/s ABB** We recommend that: The short circuit withstand can be determined by either: 1. Winding dynamic force response to the electromagnetic field calculations for this specific design. 2. Electromagnetic field calculations alone with standardised dynamic response factors. It is strongly preferred that the short circuit withstand is based on the design specific dynamic response behaviour method. For dynamic for calculations: The transformer short circuit withstand should be preferably analysed and demonstrated using and including: Dynamic force response calculations derived from electromagnetic leakage field plots. The dynamic response calculations shall be specific to the windings of this transformer. The dynamic response is to account for the compressible nature of the insulation materials within and outside the windings. Winding offsets to account for manufacturing tolerances and errors Winding offsets to account for the pitch of any	As per the specification, the dynamic stability of every design is tested by the short circuit test in a laboratory, the design is not accepted on the basis of the theoretical calculations. Also, the suggestion of the firm has not been supported by any national or international document, thus in the specification it is not feasible to incorporate.

			helical or layer windings Determination of winding resonant frequencies which should not coincide with 50 Hz or its multiples. The axial pre-compression force for the windings shall be based on the maximum axial dynamic response and the minimisation of mechanical stress in the system. To account for the high frequency of short circuit events, the allowable withstand stresses shall be reduced to 80% of the normal material withstand levels. For electromagnetic field only calculations: If the transformer short circuit withstand is not analysed with the individual design specific dynamic force response then the forces shall be determined by use of electromagnetic field plots which also include: Winding offsets to account for manufacturing tolerances and errors Winding offsets to account for the pitch of any helical or layer windings. The electromagnetic forces from the field plot shall be increased by a factor of 1.5 to account for the dynamic winding response. The axial end force shall be the greater of the 1.3 times the electromagnetic end forces or the peak axial compression force within the winding. Additionally, the stresses so determined shall not exceed one third of the material maximum permissible stresses or 50% of the allowable withstand levels given in IEC 60076.5, whichever is lower. The axial pre-compression of the windings will be significantly higher than double the end thrust due to the electromagnetic force calculation. This is due to the dynamic nature of the short circuit forces and hence the “bounce back” reaction forces from the windings. For geometrically balanced windings, the electromagnetic forces at the ends appear relatively small but the actual resultant dynamic forces are much larger. While these are sometimes estimated by experience, for transformers subject to frequent short circuits, it is necessary to perform an actual dynamic force calculation for the specific windings of this transformer and design accordingly. Please see the comments in the general recommendations about short circuit withstand integrity. We would be pleased to offer our application engineering team to deliver some technical	

			training on short circuit withstand of power transformers including “self-supporting” windings behaviour, dynamic force calculations and learnings for short circuit testing	
17.	3.5.10 3.5.20	During short circuits, the stresses actually set up in conductors, spacers, end blocks, clamping rings and such other parts of the transformer shall not exceed one third of the maximum permissible values.	**M/s ABB** Given the Annexure 4 force calculation expected accuracy, we can understand the very low 33% withstand limit. Typically, modern practice would determine forces via electromagnetic field plots and dynamic oscillation factors. For transformers with this high frequency of short circuit events we would recommend that the winding dynamic response is directly calculated for this individual design and the resonant frequencies are determined and controlled. Given this much more accurate, well proven approach the stress limitations can be increased substantially. Inner windings experience radial buckling forces that include free buckling modes of failure. These are often the lowest withstand mode of radial failure. Such free buckling failures are independent of the number or spacing of mechanical supports inside the winding. Additionally, any supports that are tight inside the winding when new will shrink over time with the normal thermal aging of the transformer insulation. Hence, they will no longer remain tight throughout the transformer life. For these reasons, we believe it is essential to design the windings to be “self-supporting” against radial failure and not rely on the inner supports for short circuit withstand. Supports are in place for transport and geometry and cooling performance control but not for short circuit withstand. This is especially import for transformer with heavy and high frequency short circuit duty.	As per the specification , the dynamic stability of every design is tested by the short circuit test in a laboratory, the design is not accepted on the basis of the theoretical calculations. Also, the suggestion of the firm has not been supported by any national or international document, thus in the specification it is not feasible to incorporate.
18.	3.5.14	In order to cater for shrinkages that may occur in service, substantial clamping rings shall be provided at the tops of the windings, being pressed down upon them by means of adjustable pressure screws or oil dash pots or any other suitable device, so as to maintain a constant pressure and obviate the need for any retightening in between successive periodical overhauls.	**M/s ABB** Our understanding of this clause is that uniform clamping force and uniform axial dimension is required upon the whole circumference of the coil or set of coils during pressing before and immediately after the dry out process.	No remarks required.

19.	3.5.15	The coil and core assembly shall be retightened after oil impregnation. The manufacturer shall ensure that there is no further shrinkage of the coil assembly in any additional cycle after the final curing.	**M/s ABB** We recommend that an additional alternative process could be considered: If the core and coils are vapour phase dried to less than 0.4% moisture and it can be demonstrated with data records that the manufacturing systems and controls are sufficiently strong then the final tightening post impregnation may be deleted.	The specification mention the requirement that there shall be no further shrinkage, comment is a manufacturing procedure practice which manufacturer to ensure, no need to add in the specification.
20.	3.5.17	The core and winding of the transformer have to be dried preferably using Vapour Phase Drying (VPD). To ensure the removal of moisture from the transformer the PI value after drying has to be achieved equal to or more than 2 (two) in the manufacturing at the works	**M/s ABB** We recommend that vapour phase drying is used and either the moisture level of a sample block from the vapour phase or later DFR (dielectric frequency response) measurement is used to demonstrate that cellulose moisture content is <0.5%. We would not recommend that PI >2 for moisture assessment criteria for a new transformer in the supplier's factory. It is not a sensitive measure for this new transformer stage. Additionally, modern, good quality, new transformer oils often have very high resistivity and this results in PI < 2 even for very dry, clean, high resistivity transformers. PI should be measured as a benchmark only for future PI measurements.	The measurement of PI can be done the inspector during the testing of job, the cellulose moisture content measurement can be done at the manufacturing stages by the manufacturer itself, it is not needed to make it a part of the specification.
21.	3.7 3.7, 3.7.1 3.7.3 3.7.4	Porcelain type OIP Condenser bushing	**M/s ABB** We would recommend that dry type condenser bushings are used employing resin impregnated paper or synthetic material rather than OIP condenser bushings. This will significantly reduce the safety risk of a possible fire. We would also recommend the use of polymer shed on the outdoor side of the bushings rather than porcelain. For the 12 kV bushings we recommend that solid moulded resin/polymer bushings are preferable for the same reasons as given for the Dry type condenser bushings. RIP/RIS bushings if damaged or if subject to internal failure tend to act as a plug maintaining a seal for the transformer oil away from the atmosphere. This reduces the risk of fire. OIP bushings tend to shatter, fall into the transformer internals and leave an opening to the atmospheric oxygen into the transformer and hence fire risk. The polymer sheds are much less fragile than porcelain and hence less likely to be damaged or shatter. Additionally, in the event of a bushing failure the explosive velocity of porcelain shrapnel is a high risk for personnel	The use of Dry type/composite type bushings is a separate policy decision, may be decided separately when the sources of Indigenous make are easily available.

			injury/death. The polymer sheds do not shatter and remove this risk entirely.	
22.	3.7.7	Adjustable arcing horn shall be provided on both the primary and secondary bushings.	**M/s ABB** We recommend replacing arcing horns with surge arresters as per modern practice	Arcing Horn and surge arrester both are provide in Indian Railway's taking extra protection.
23.	3.11.3	In case of use of headers, isolating valves of size 80mm shall be used between tank and headers.	**M/a TBEA** In case of use of headers, isolating valves of size 80mm (minimum) shall be used between tank and headers.	Firm comment may not be accepted as any specific size with reason has not been commented. Also, a standard size is required to be specified for uniformity in all the transformers of same rating.
24.	5.1(14)	The temperature rise over an ambient temperature of 50^{0}C both at rated and overload conditions shall not exceed the value indicated below: 1. Winding: 50 ^{0}C at rated load, and 60 ^{0}C for overloads as specified in Clause 5.1.1(11) (temperature measured by resistance method). 2. Top oil: 45 ^{0}C (temperature rise measured by thermometer). 3. Current carrying parts in air: 40 ^{0}C (temperature rise measured by thermometer).	**M/s ABB** We recommend that the specification of winding hotspot temperature rise limits should be added to this clause. If the more modern aspects of winding gradient hotspot factors recommended for Clause 6.3.1.2 are included and consideration included for the effects of harmonics plus the use of fibre optic probes measured hotspot results are included, then we would recommend the following revised temperature rise limits: At Rated load (with harmonics included): Top Oil Temperature rise = 50 C Average winding Rise (by Resistance) = 55 C Winding Hotspot Rise = 68 C via the highest of techniques in comments for Clause 6.3.1.2 At Overload (with harmonics included): Winding Hotspot Rise = 80 C via the highest of techniques in comments for Clause 6.3.1.2 We would be pleased to explain the background and basis of these recommendations via a video conference discussion with our application engineering team.	The winding hotspot temperature rise limits is already mentioned in the other clause, may be mentioned in this clause also. The temperature rise limits are verified during the type testing of the transformer which is conducted at the works of the manufacturer, not at TSS location. The requirements mentioned in the specification are sufficient.

25.	5.1 (15)	Ability to withstand short circuit Thermal ability: 5 s Dynamic ability : 0.5s	**M/s ABB** We recommend changing duration for dynamic short circuit test from 0.5 seconds to 0.25 seconds as per standards	For dynamic stability, in the IS: 2026-2011, part-5 (para 4.2.5.5), the duration of 0.25second is mentioned for dynamic stability and for thermal stability in Para 4.1.3 it is mentioned that the duration of the current I to be used for the calculation of the thermal ability to withstand short circuit shall be 2 s unless a different duration is specified. The para in the Final Draft may be modified.
26.	5.1(16)	Flux density at rated voltage and frequency at principal tapping Shall not exceed 1.7 tesla	M/s ABB We recommend that the flux density limit should be 1.7 tesla.	Accepted. Reason mentioned in the comment at SN 11.
27.	5.1(17)	Current density in the windings at rated current shall not preferably not exceed 2.5 A/mm2	M/s ABB The suggested current density limit is very low. We recommend that this limit is removed. The Current Density Limit of 2.5 A/mm2 is very low. This low limit is not necessary with modern power transformer design. Such a low limit would only be considered for older type distribution type transformer multi-layer windings without cooling ducts. For power transformer clamped windings with disc and helical windings much higher current densities are readily suitable. More importantly, the cross-sectional area and current density should be determined by correct short circuit withstand strength and suitably limited winding hotspot gradients in the presence of the stated harmonics. Suggestions for these characteristics are given in other comments	The requirement mentioned in the specification is a preferably requirement not a mandatory requirement. So no change is required in the specification. For any Indian Railway Transformer the design of the transformer is verified by the short circuit, temperature rise test, load loss, no load loss & impedance tests, so manufacturer may use the density as per their need suitable for their winding type.
28.	6.2.1.3	Pressure test: Every	M/s ABB	The firm comment is

		transformer tank, radiator and conservator tank shall be subjected to an air pressure corresponding to twice the normal static head of oil or to the normal static head of oil or to the normal static oil head pressure plus 35 kN/m^2 (0.35 kgf/cm^2), whichever is lower, as measured at the base of the tank. The pressure shall remain constant for 1 h to indicate that there is no leakage.	We recommend that the "air pressure test" should be replaced with "pressure test". Ie do not perform the test with a vessel full of compressible gas. Alternatively, this test could be deleted and only rely on the test in Clause 6.2.1.1 which is of the same pressure levels. Performing a pressure test with the vessel filled with gas can be dangerous as the energy stored in the large volume of compressible gas is very large. In the event of an unexpected rupture there can be a dangerous "explosive" style release of energy. The pressure test is best performed with the vessel filled or almost filled with liquid (incompressible) and the overpressure is applied to a small gas space above the liquid. The stored energy is then dramatically reduced making the situation non-dangerous. This will also allow the test to also simulate the normal static pressure head profile of pressure making it more representative of the real service environment.	not accepted. The air pressure test should be conducted on the transformer tank during the manufacturing stage, so that any leakage, if there, can be rectified. If only oil leakage test is mentioned, which is done final stage, It will not easy to rectify that.
29.	6.2.2.3	Transformer Tank: following tests shall be conducted: (i) The pressure test and vacuum test shall be done as per the clause no. 6.2.1.2 & 6.2.1.3 of this specification. (ii) The Dye Penetration (DP) Test at the jacking and lifting pads.	**M/s ABB** A cumulative core resistance test across the stacked height of the laminations of the completed core could be added to this clause. This would allow assessment of core steel insulation quality throughout the core as well as edge burr suitability.	The suggested test is for manufacturing stage test which is not done on each job moreover, if any test is added in the specification, its acceptance limits has to be specified, already no load losses are mentioned, it is not required.
30.	6.3.1.2 item3	The ambient temperature shall be measured using alcohol in glass thermometers only.	**M/s ABB** We recommend that measurement of ambient temperature by use of thermocouples or electronic thermometers is also allowed. The more modern, accurate and safer practice of measuring ambient temperature is via the use of thermocouple or electronic thermometers. This allows remote and even continuous readings to be taken without endangering personnel to the transformer under test	The firm comment may be accepted as per the latest measuring practices being followed during the testing.
31.	6.3.1.2 item7	The temperature of the hot - spot in the winding shall be the sum of the temperature of the top oil and 1.1 times the temperature rise of the winding above the average oil temperature.	**M/s ABB** We recommend that the winding hotspot should be based on K*H *(the temperature rise of the winding above the average oil temperature), where K is the maximum of • 1.3 • The design review meeting demonstrated value of hotspot factor (50 Hz) • The temperature rise test measured value	The suggestion of the firm has not been supported by any national or international document, thus it is not feasible to incorporate in the specification.

			derived from the fibre optic probes H is the increase in hotspot gradient due to the service harmonics as established at the design review meeting and the winding information The winding temperature indicator should be set in accordance with the values above. Modern International standards recognise and give guidance that hotspot gradient factors are significantly higher than 1.1, typically at least 1.3 is considered appropriate but up to 1.6 is not unusual depending upon the design details. Here, the measured hotspot factor at 50 Hz can be determined via the use of the included fibre optic probes. Additionally, for transformers that are subjected harmonics, the hotspot factor will be significantly increased. This harmonic increase can be determined from the FAT 50 Hz fibre optic results plus knowledge from a design review meeting of the winding details and harmonic levels	
32.	6.3.1.3 .1 item1	A quantum of power equal to the sum of the measured losses viz. No- load loss and load losses measured at lowest tap position, corrected to 75^0C plus 10% of such sum shall be fed to the primary winding of the transformer with the secondary windings short-circuited.	**M/s ABB** We would recommend that the load losses supplied should be the measured 50 Hz load losses (corrected to 75 C) plus the additional losses equal to the additional eddy losses from the service harmonics. The additional harmonic eddy losses should be based on the measured 50 Hz eddy losses and the agreed calculations from the design review meeting. Normally, the total losses equal to the sum of the no load losses and the load losses is supplied rather without an additional 10% losses. However, in the case of transformers experiencing service harmonics the additional harmonic eddy losses should be added for the test.	Already in the specification, it is mentioned that 10% addition on sum of the load and no load losses, the basis of the agreed calculations from the design review meetings cannot be standardized.
33.	6.3.1.3 .1 Item 4,7,8 6.3.1.3 .2 6.3.1.3 .3	• The measurement of hot resistance shall commence as soon as possible after switching off. The first reading of the resistance shall be taken before the expiry of 90 s from the instant of switching off and the first ten readings shall be taken at intervals of 15 s apart. Thereafter, another ten readings shall be taken at intervals of 30 s apart. • The temperature of the ambient, top oil, the top and bottom radiator header oils	**M/s ABB** We would recommend that the fibre optic probes are measured at: • 30 sec intervals for the first 15 minutes of the temperature rise • 30 min intervals (whenever the oil temperatures are measured) for the duration of temperature test. • 1-minute intervals when the current is returned to rated current. 30 second intervals from the time of shutdown The fibre optic probes will give the most accurate measured value (direct measurement) of hotspot temperature at 50 Hz. These should be used as much as possible. They are also the best source of data to determine the winding time constant.	Firm comment is acceptable as this can be measured by the data logger and give accurate measurements.

		shall also be recorded at half - hourly intervals through out the test starting from the instant power supply is switched on to commence the test till it is switched off. • The WTI and OTI readings shall also be recorded at half-hourly intervals right from the instant the power supply is switched on to commence the test till it is switched off. • After power supply is switched off, the readings of OTI and WTI shall be recorded at intervals of 1 min apart for 30 min.		
34.	6.3.1.7	The temperature rise of the oil, windings and current carrying parts in air under both the overloads conditions stipulated in Clauses 6.3.1.3.2 and 6.3.1.3.3 above shall not exceed the values stipulated in Clause 5.1 (14) of this specification. The winding hot - spot temperature under the overload conditions shall not exceed 115^{0}C.	**M/s ABB** We believe that the reference to Clause 5.1 (14) should be Clause 5.1 (12). We recommend that a winding hotspot temperature rise limit is added to clause 5.1 for both rated load and overload. It should be clear whether these limits include harmonic current temperature increases or are for 50 Hz load only. For the limit given for winding hotspot, it is recommended to express it as a temperature rise rather than temperature otherwise the ambient temperature needs to be included. We have also suggested some changes to the allowable temperature rise limits given in clause 5.1 based on modern knowledge and more accurate data for winding hotspot calculation, inclusion of the effects of harmonics and the use of fibre optic probes	Already specification mention that for overload condition
35.	6.3.1.9	Determination of the thermal time constant of the WTI: The thermal time constant of the WTI shall be determined for comparison with the thermal time constant of the winding of the transformer with respect to the transformer oil. For this purpose, the indications of the WTI and the OTI shall be recorded every 1 or 2 min during the first 1 h from the instant the transformer is loaded. From the slope of the curve plotted with the time on the X - axis and the difference	**M/s ABB** We recommend that some reference to the use of fibre optic probe results to determine winding time constants should be included.	The required changes to be made in the exiting para has not been suggested in the comment.

		between the readings of the WTI and OTI at the particular time on the Y - axis, the thermal time constant of the WTI shall be determined. This value shall not vary appreciably from the thermal time constant of the winding as calculated theoretically and as ascertained from the slope of the cooling curves		
36.	6.4 Item 10	Dielectric tests comprising: 1) Separate- source voltage withstand test. 2) Induced over voltage withstand test.	**M/s ABB** We recommend that the RSO test should be made a type test. Additionally, if the supplier has suitable lightning impulse design software to demonstrate the developed voltages including waveforms then we suggest that the results of the software outputs could be accepted instead of RSO tests. We note that for the 2x25kV single phase autotransformer, that RSO assessment may not be necessary as there are very few voltages that can be measured. We suggest that the scope of the RSO measurements should be added to this clause.	The comment for the acceptance of the software outputs instead of RSO test is not accepted. The reason for mentioning the RSO test only in type test is not justified, thus the comment of the firm is not accepted.
37.	8.0	The offer shall include the training of two personnel of the Indian Railways free of cost at the manufacturer's works in India or abroad and at the maintenance depots/workshops on a Railway system or other public utility where transformers of similar/identical design are in operation. The total duration of training for each personnel shall be 2 weeks of which approximately one week will be at manufacturer's works and one week on a Railway system or other public utility. If the country of manufacturer is not India, the cost of travel to that country and back will be borne by the Indian Railways. Other details shall be settled at the time of finalizing the contract/Purchase Order.	**M/s ABB** We recommend that the scope and type of training required is given in this clause. eg Installation procedures, maintenance procedures, familiarisation with accessories and features etc.	Firm comment is justified and clause may be modified in the final draft.
38.	9.9	If any transformer has been received at site in a damaged condition and in the opinion of	**M/s ABB** We would recommend that transport acceleration measurement using transport impact	"Transport acceleration measurement" is not

		the Railway's Engineer at site it is required to be repaired at the successful tenderer/manufacturer's works, the transformer shall be taken back to the works promptly and after repair, all necessary tests including the routine tests shall be done on the complete transformer in the presence of and to the satisfaction of the Railway's Engineer prior to returning the transformer to site. Such tests are necessary to ensure that the quality of the workmanship during repairs is satisfactory and shall be done free of cost. Any tests, as decided by the Railway's Engineer at site shall also be conducted on the transformer at site free of cost.	recorders is added. Additionally, that factory and site SFRA testing is performed to confirm the integrity of the transformer from damage. The allowable accelerations during transport should be required in the offered returnable schedules.	described in the comment, also the existing para of the specification is more clear, thus no change is required.
39.	Annexure2	FOS	**M/s ABB** We recommend that the quantity of fibre optic probes is increased to ensure redundancy and correct location for winding hotspot of both windings. We would also recommend that during the design review meeting that the supplier must demonstrate the temperature rise and fluid velocity of every disc to ensure that the winding hotspot location is correctly located and understood.	Firm comment is accepted for getting more accurate results. The clause shall be modified as, one probe per phase of HV & LV winding. For the hotspot location specification already mention to submit the details for hot spot.
40.	Annexure4	Force calculations	**M/s ABB** We recommend that these force calculations are replaced with the requirement to perform electromagnetic field plots and design specific dynamic response calculations. Please see more detailed comment against the other clauses.	The suggestion of the firm has not been supported by any national or international document, thus in the specification so it is not feasible to incorporate.
41.	General	---------------	**M/s ABB** We have made a number of significant recommendations in areas including: • Short circuit force calculation withstand and consideration of frequent short circuit faults. Calculation and control of dynamic winding response during short circuits. • Understanding and limiting of temperature rise particularly for the use of winding hotspot including the effects of harmonics	Noted The design of the Traction transformer is done by the transformer manufacturer, technical specification is a requirement which is verified by the certain

			• Scope, Benefits and importance to include a detailed design review meeting • Use of modern "dry type" condenser bushings and solid resin/polymer bushings to further reduce fire risk and improve safety. • Determining transformer quality from and analysing FAT results. We realise that these may be significant considerations whose reasons/benefits cannot easily be described in a few sentences. Therefore, we offer as part of our specification feedback to deliver to Customer Knowledge Training on the above topics The Indian Ministry of Railways.	tests which are mentioned in the specification The remarks on the comments on the specific clause has already been mentioned at respective clauses.
42.	General		**M/s ABB** Given the frequent and severe short circuit duty of the transformers, we recommend the use of the latest technology and analysis techniques for short circuit withstand. The recommended aspects include: • Calculation of electromagnetic forces using field plots. • Design specific dynamic response of the windings to be determined. • Inclusion of winding offsets to account for manufacturing tolerances and pitch of helical windings. • Use of modern mechanical withstand limits associated with high density, high grade materials • Consideration of free buckling modes of radial failure • Design of inner windings that do not rely on inner supports for radial buckling withstand ("self-supporting" windings). This ensure ongoing short circuit withstand and withstand of free buckling failure. • Reduction of withstand limits to account for the frequency of short circuit. • Use of epoxy bonded continuously transposed cable Detailed assessment of short circuit testing requirements	Noted The design of the Traction transformer is done by the transformer manufacturer, technical specification is a requirement which is verified by the certain tests which are mentioned in the specification The remarks on the comments on the specific clause has already been mentioned at respective clauses.
43.	General		**M/s ABB** These transformers are subjected to high levels of harmonics in service. The harmonics significantly increase the winding hotspot temperature being concentrated at the winding ends. However, the harmonics cannot be supplied during factory acceptance testing (FAT). We therefore recommend that a detailed analysis is conducted including how they are managed by appropriate winding design. This aspect and others should be prescribed for the design review meeting. Further, it is important to understand, simulate by calculation and correct the 50 Hz measured losses and temperature rise from the FAT to the service situation. This is facilitated and made more accurate with the use of fibre optic probes during FAT to have accurate winding hotspot measurements.	Noted The design of the Traction transformer is done by the transformer manufacturer, technical specification is a requirement which is verified by the certain tests which are mentioned in the specification The remarks on the comments on the specific clause has already been mentioned at respective clauses.

			In at least some transformers we would recommend that service measurements of the fibre optic probes including the harmonics losses should be conducted to validate the simulations and impacts on the WTI readings.	
44.	General		**M/s ABB** For transformers of this type which include harmonics, frequent short circuits, a short circuit type test, nitrogen injection systems & thermo-syphon equipment, fibre optic probes etc, we would recommend a detailed design review meeting. In addition to the criteria described in CIGRE Brochure 529 and IEC 60076 the design review meeting should define broad scope and expectations including: • Short circuit calculations for design specific dynamic forces and control for frequent short circuits. • Effect of harmonics in service (which cannot be supplied at the supplier factory). • Temperature rise details including temperatures and fluid velocity of every disc of the main windings • Assessment of the true winding hotspot gradient both without and with harmonics • Correction of FAT temperature rise results to the values expected with harmonics in service The use and placement and measurement of fibre optic probes.	Noted The design of the Traction transformer is done by the transformer manufacturer, technical specification is a requirement which is verified by the certain tests which are mentioned in the specification The remarks on the comments on the specific clause has already been mentioned at respective clauses.
45.	General		Our understanding from the specification that management of fire risk (inclusion of nitrogen injection and fire extinguishing system) is of importance. We would therefore recommend the use of modern technology bushings: • Dry type condenser bushings (resin impregnated paper/synthetic - RIP/RIS) instead of OIP. These dry type bushings tend to act as a plug when they or the transformer suffer an internal failure whereas OIP bushings shatter and expose the transformer internal to oxygen (fire risk) or contamination (porcelain and burnt paper). • Solid resin/polymer bushings rather oil filled porcelain bushings - same benefits as the RIP bushings. In general, we would also recommend polymer sheds for the outdoor side of al bushings instead of porcelain as this removes the safety risk for personnel of shrapnel like pieces of porcelain in the event of failure.	Noted.