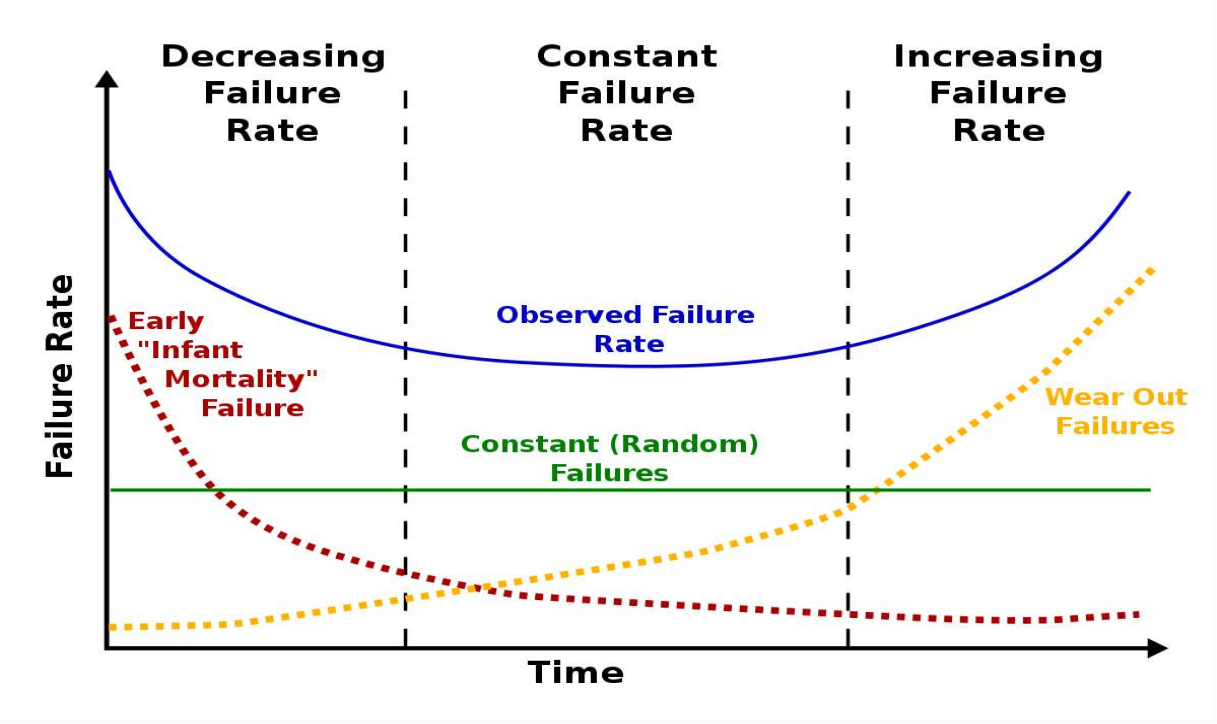
current transformers, cooling equipment etc.) shall be provided on the components themselves.

30.0 RESPONSIBILITIES OF MANUFACTURER AND UTILITY/ USER DURING WARRANTY PERIOD OF TRANSFORMER :

30.1 The long term performance of transformer depends on design/technology, quality of material used, robustness & consistency of manufacturing process, installation, operation and maintenance etc. The erection, testing and commissioning of transformer shall be performed under strict supervision of representative of OEM and provisions specified in **Chapter 5– Transportation, erection, testing & commissioning of the document "Standard Specifications and Technical Parameters for Transformers and Reactors (66 kV & above Voltage Class)" issued by CEA** shall be followed.

30.2 Transformer failure generally follows the Bathtub Curve as shown below:



30.3 As can be seen from the Bath Tub curve, the "Infant mortality" failures, which are caused due to manufacturing related defects/issues that occur in the first few years of service (say 1 or 2 years). But continued successful operation of transformer primarily depends on operating conditions and O&M practices being followed by utilities. Improper

maintenance or negligence on the part of user e.g. non-replenishment of saturated silica gel, non-release of air trapped after air-cell commissioning, oil seepages, lack of routine maintenance, failure to check tan-delta & capacitance of winding and bushing, absence of thermal scanning of terminal interfaces, lack of DGA monitoring etc., can also lead to serious consequences. It can therefore be said that the responsibility of manufacturer and maintenance & monitoring obligations of the end user are equally important for a long and trouble free service life of transformer. Moreover, any abnormality observed during operation needs to be addressed immediately. The transparency in sharing of information, mutual co-operation and discussion on issues/problems between user and manufacturer are the only way to resolve many of these problems. The manufacturer can take this as an opportunity to understand the issues and can improve on the design & manufacturing practices. Similarly, the utility has the opportunity to understand the deficiency from their side and should rectify/try to improve on their actions as a responsible user. There is no single conclusive test based on which utility should take drastic steps regarding replacement/rejection of component/equipment.

30.4 The utilities should create their maintenance plans so that they adhere to the recommended O&M procedures of the OEMs.

30.5 When failures or operational problems occur within the warranty period, the manufacturer must take all necessary measures to help minimize operational difficulties and outages whenever possible. The following abnormalities should be brought to the notice of manufacturer and the manufacturer shall respond/ attend immediately, investigate and rectify the problem or advise the utility for further course of action.

a) Fault inside the transformer and OLTC (including oil migration) involving a shutdown of transformer at site after commissioning is to be attended by manufacturer immediately. It is the responsibility of the OEM to take immediate necessary action (e.g. any replacement/repair of component required with co-ordination from any third party, if required) for bringing back the transformer into service. The root cause analysis shall be undertaken by OEM and details shall be shared with utility for the benefit of both user and OEM.

b) In case of DGA Status 3 (as per IEEE-C57.104) i.e. the concentration of any fault gas is exceeding the values in Table -2 of IEEE-C57.104

(Refer Chapter 6 of the document "Standard Specifications and Technical Parameters for Transformers and Reactors (66 kV & above Voltage Class)" issued by CEA) or the abnormal trend in variation of key fault gases is observed, the utility should immediately consult OEM for advice and for further course of action.

The transformer with DGA Status-3 does not necessarily give any conclusive information regarding health of transformer or indicate that transformer is faulty. It can only be concluded that its behaviour is somewhat unusual and warrants additional investigation and/or precautions. The transformer should be placed under increased surveillance. Other diagnostic tests should also be conducted to supplement the DGA for taking further course of action in consultation with manufacturer.

c) In case, the winding tan delta goes beyond 0.005 or increases more than 0.001 per annum w.r.t. pre-commissioning values, the utility is to inform manufacturer for advice and for further course of action.

d) In case, the tan delta of bushing(s) goes beyond 0.005 or increases more than 0.001 per annum w.r.t. pre-commissioning values when measured in the temperature range of 10°C to 40°C (If tan delta is measured at a temperature beyond above mentioned limit, necessary correction factor as per IEEE shall be applicable.), the utility is to inform manufacturer for advice and for further course of action.

e) In case, the moisture content goes above 10 ppm at any temperature during operation including full load, the utility is to inform manufacturer for advice and for further course of action.

f) Any major deviation in Sweep Frequency Response Analysis (SFRA) should be brought to the notice of manufacturer for advice and for further course of action.

g) Leakage of Oil from transformer shall be construed as a serious quality lapse on the part of the Original Equipment Manufacturer (OEM). No leakage of oil is expected during the operating life of the transformer and that should be ensured accordingly by OEM during design & construction of tank & other gasketted joints. In case of any leakage of oil during warranty period, the same shall be reported in writing to the OEM immediately and OEM shall have to attend and rectify the leakage within a period of 30 days from the date of notice, at the cost of the OEM.

h) The utility shall carryout all diagnostic tests just before completion of warranty period to ensure the healthiness of transformer and any abnormality in test results shall be informed to the manufacturer for immediate action and advice.

31.0 PHYSICAL INTERCHANGEABILITY OF TRANSFORMER OF DIFFERENT MAKE

Block foundation shall be adopted to facilitate the physical inter-changeability of transformers of different make on same foundation thereby the outage time of replacement of spare/new transformer would be minimized. The design shall take into account the provision of soak pit and oil collecting pit for transformer. The details are given at **Annexure-N.**

32.0 LIST OF CODES/ STANDARDS/ REGULATIONS/ PUBLICATIONS

The list of Codes/Standards/Regulations/Publications which are generally used for manufacturing, testing, installation, maintenance, operation etc. of transformer is given at **Annexure-P.**

Chapter-2

Design Review

CHAPTER-2

DESIGN REVIEW

1.0 Introduction

Design Review is a planned exercise to ensure both parties to the contract- manufacturer and purchaser- understand the application, purchaser specifications, applicable standards and Guaranteed Technical Particulars (GTP) furnished by vendor. It is a scrutiny of design (specific aspects of the electrical, mechanical and thermal design), materials & accessories and manufacturing processes so as to ensure that offered guaranteed technical particulars, are thoroughly met to ensure quality and reliability. The exercise broadly facilitates and emphasize the following:

- Manufacturer understands the application, project requirement, the purchaser's technical requirement, and specifications to ensure that the design meets / complies those requirements.

- Purchaser understands that manufacturer uses proven materials, design tools, methodology and experience to assure that the product will meet purchaser's requirement in all respect.

- Identify any new (prototype) features introduced by manufacturer and evaluate their reliability and risks.

- To understand relevant design margins (calculated design withstand strength versus stress during tests and long service) to meet test requirements and life time performance as per manufacturer's design practice and experience.

- A good opportunity for a clear & mutual understanding and to exchange experiences that can be used to improve the current design and future specifications.

- Allow the purchaser to have clear understanding of the design, technical capabilities, experience of manufacturer and the manufacturing & testing facilities of manufacturer.

- Clarifications of various tests and mutual agreement on method of tests and special acceptance of tolerance (e.g. Wave shape of impulse wave, connection for switching surge test etc.).

- Mutual agreement between the purchaser & the manufacturer for the confidentiality of information, which are proprietary in nature.

- Transportability to site. Any constraint and stringent limitation is to be highlighted, if any.

- Service conditions. If any abnormal service condition exists customer has to point out.

2.0 Stages of Design Review (DR)

Design Review (DR) may be required at following stages depending on the nature of contract:

(A) Pre-Tender Design Review

- Technical capability and manufacturing experience of vendor

- Factory capability assessment by buyer as required (CIGRE TB 530: Guide for conducting Factory Capability Assessment for Power Transformers can be a good reference)

(B) Tender Stage Design Review –Technical Evaluation of offer

- The bidder has to comply with the parameters provided in the specification/document. Deviation, if any, shall be clearly brought for the information of the purchaser. The purchaser shall scrutinize the deviations in line with the technical & commercial requirement and shall evaluate the bid accordingly.

(C) Contract Design Review

The design review shall be carried out for the offered design of transformer under the scope and Manufacturer shall submit all design documents and drawings required for the purpose.

- Purchaser in consultation with the manufacturer shall carry out Design Review (DR) of parts and accessories (make, model, specifications for bushing, tap-changer, instruments etc.) as per technical requirements and specifications for enabling the manufacturer to order key raw materials and major accessories.

- Review of the electrical design including dielectric, losses, short circuit, noise and thermal performance and mechanical layout design including lead routing and bushing termination after route

survey (if any) shall be carried out for enabling the manufacturer to order key raw materials and major accessories.

- Typical data/parameters indicated in the **Annexure-C** shall be filled by the manufacturer and reviewed by the purchaser during design review.

- Examination of all relevant type test reports of transformers including its fitting and accessories.

- Checking of drawings and documents for the scope listed in **Annexure-I.**

3.0 Mode of Design review

- Design review is initiated by purchaser or appointed representative. Purchaser should ensure that those participating representative in the review on his behalf have the necessary expertise to understand and evaluate the design and production considerations under the proposal.

- Minutes of design review will be part of contract documents, but the discussions and information exchanged during design review process shall be kept confidential and purchaser or appointed representative shall not disclose or share design review details to anyone without written consent of Original Equipment Manufacturer (OEM).

- After completion of design review, a summary report indicating list of items with actions required to be taken is to be sent to manufacturer for correction and inclusion of any omissions.

- Purchaser may also visit the manufacturer's works to inspect design, manufacturing and test facilities at any time.

- Manufacturer, if desired by purchaser, should give in advance sufficient design data to purchaser to prepare for the design review meetings.

- **"Guidelines for conducting design reviews for transformers" CIGRE Technical Brochure 529-2013 may be followed. The document/brochure broadly covers the following:**

  - ❖ The manufacturer should demonstrate how their design will function reliably within the operating requirements including

transient conditions and meet the performance guarantees and present evidence of calculations/analysis performed in order to ensure that the specified requirements will be met.

- The manufacturer should describe the core design, explaining how it will perform within the operating parameters. Core flux density at rated and maximum voltage and frequency shall be reviewed with special reference to the maximum permissible limit to avoid overfluxing in any part of the core assembly including magnetic shunts and safety margins for the particular core construction type employed.

- The manufacturer should describe each of the windings in sufficient detail to provide a clear understanding of the physical arrangements.

- The manufacturer should demonstrate how the insulation is designed to withstand the imposed stresses, i.e. indicate insulation structure, corresponding stress and resultant dielectric strength, including safety factors (margins).

- The manufacturer will provide a list of the make and type of insulating materials used for the windings, leads and supports.

- The manufacturer should describe how the windings will be adequately cooled.

- The manufacturer should present a description of the thermal model of the windings and a summary of the calculated temperatures for the various specified ratings/loading, including any overload and cooling conditions. The calculation of hot spot temperatures of the tank, core etc. to be discussed and demonstrate their experience by using 2D or 3D electro-thermal calculation using Finite-Element Method (FEM) etc.

- The manufacturer should demonstrate the ability to withstand the electromagnetic forces and the thermal stresses produced during the flow of a short-circuit current without damage.

- The manufacturer should describe the general assembly and mechanical features for the core mechanical construction, coil clamping including the clamping pressure used for sizing and providing short circuit withstand capability and maintenance of winding compression during coil drying, core drying and assembly.

- ❖ The manufacturer will describe their methods for moisture removal from the insulation ensuring the design dimensions of the coils are achieved and moisture content is <0.5%.

- ❖ The manufacturer should describe the arrangements used for the winding leads and interconnections.

- ❖ The manufacturer should describe how they achieve the control of the leakage flux outside core and coils assembly, including Type of shielding (collectors, rejectors), design and materials used.

- ❖ The manufacturer and customer should have a mutual and clear understanding for the requirements for the sound level. Accurate calculation of core & tank resonance frequencies allows accurate prediction of the noise level at the design stage and later avoids serious noise level problems later.

- ❖ The manufacturer should provide general construction including tank details, details of gaskets, location of manholes & PRD, external cooling system, conservator/preservation system, provision for fire protection system etc.

- ❖ The intended shipping process should also be reviewed.

4.0 Calculation of Losses, weight of core and current density of winding conductor

For the benefit of the utility the formula for calculation of No-Load loss and Load loss, weight of core and current density of winding conductor has been provided below. In addition, a typical example of calculation of flux density, core quantity/ weight, no-load loss and weight of copper has been provided in **Annexure-F**.

Calculation of no-load losses:

- No-Load losses = core loss in W/kg corresponding to flux density as per lamination mill test report (extrapolated) x net weight of core x building factor

- Flux density (T) = rated voltage (v) $x10^4$/ (4.44 x no. of turns x net core area (cm^2) x frequency (Hz))

- Net core area = [{0.785x (nominal core diameter)^2 x filling factor}- area of cooling duct, insulation] x space factor

- Building factor = extra loss factor over the test report value due to handling and fabrication stress (>1)

- Space factor = Reduction factor (depends on thickness) to take care of the insulation provided over the laminations (<1)

- Filling factor = per unit area occupied by core material in the nominal core circle area (<1)

- Nominal diameter of core = diameter of circle touching the corners of lamination steps

Calculation of load-losses at reference temperature & principal tap position:

- Load loss at principal tap = I^2R loss + Winding Eddy loss + Structural stray losses

- I^2R loss = Resistance at 75°C x (phase current)^2 x no. of phases

- Resistance (R)= Resistance of winding (R_W) + Resistance of leads (R_L)

  $R_W = W \times D \times \pi / (k \times S)$
  $R_L = L / (k \times S)$

  Where,

  W= Number of turns
  D= mean winding diameter
  S= cross section area of all parallel conductor
  K= Electrical conductivity of conductor/leads for reference temperature of 75°C.
  L= Length of lead

Winding eddy losses = Estimated from empirical formulae or electromagnetic software

Structural stray losses = Estimated from empirical formulae or electromagnetic software.

Calculation of weight of core:

Weight of core = (Total periphery of core) x (net core area) x (density of CRGO material)

Calculation of current density of winding conductor:

Current density = A/S
Where A= Current in winding for specified tap position
S= (Cross-sectional area of the individual conductor) x (no. of parallel conductor)

[The individual conductor area needs to be adjusted for corner radius as per IS 13730 (part 27)]

5.0 References:

(a) CIGRE Technical Brochure No. 529 -2013 Guide lines for conducting design reviews for Power Transformers
(b) CIGRE Technical Brochure No. 673-2016 Guide on Transformer Transportation
(c) IEEE Standard C57.156-2016 Guide for tank rupture mitigation of oil immersed transformers
(d) CIGRE Technical Brochure No. 530-2013 Guide for conducting factory capability assessment for Power Transformers
(e) IEEE Standard C57.150-2012 Guide for Transformer Transportation
(f) IS 2026 Power Transformers-Part 5 Ability to withstand short circuit

Chapter-3

Quality Assurance Programme

CHAPTER- 3

QUALITY ASSURANCE PROGRAMME

1.0 INTRODUCTION

The best way to achieve continuous improvement in quality in any manufacturing organization is to develop a quality plan and the persons responsible for quality implementation should religiously follow the defined quality plan.

Quality of a transformer can be improved by taking effective steps at the initial stage itself which include 'use of high quality raw materials' and 'improved manufacturing processes'. It is needless to mention that the performance of a transformer largely depends on the excellence of design. However, all good designs may not yield good end products unless they are well supported by good materials, good and healthy machines and skilled workmen (operators)/ workmanship.

To ensure that the equipment and services are in accordance with the specifications, the transformer manufacturer shall adopt suitable Quality Assurance Programme (QAP) to control such activities at all points, as necessary. Such programmes shall be outlined by the manufacturer and shall be finally accepted by the Purchaser or its authorised representative after discussions. The Quality Assurance programme shall be generally in line with latest ISO-9001 (Quality Management System), ISO-14001 (Environmental Management System) and OHSAS 18001 (Occupational Health and Safety Management System). A Quality Assurance Programme of the manufacturer shall generally cover the following:

a) Organisation structure for the management and implementation of the proposed Quality Assurance Programme
b) Quality System Manual
c) Design Control System
d) Documentation Control System
e) Qualification and experience data for key Personnel
f) The procedure for purchase of materials, parts, components and selection of sub-supplier's services including vendor analysis, source inspection, incoming raw material inspection, verification of materials purchased etc.
g) List of manufacturing facilities available
h) Level of automation achieved and list of areas where manual processing exists

i) List of areas in manufacturing process, where stage inspections are normally carried out for quality control and details of such tests and inspections.
j) System for shop manufacturing and site erection control including process controls and fabrication and assembly controls
k) System for Control of non-conforming items and for corrective & preventive actions based on customers' feedback.
l) Inspection and test procedure both for manufacture and field activities
m) System for Control of calibration of testing and measuring equipment and the indications of calibration status on the instrument
n) System for Quality Audits
o) System for indication and appraisal of inspection status
p) System for authorising release of manufactured product to the Purchaser
q) System for handling storage and delivery
r) System for maintenance of records
s) Furnishing of quality plans for manufacturing and field activities detailing out the specific quality control procedure adopted for controlling the quality characteristics relevant to each item of equipment/component
t) System of various field activities i.e. unloading, receipt at site, proper storage, erection, testing & commissioning

The manufacturer shall use state-of-the-art technology and dirt, dust and humidity controlled environment during various processes of manufacturing and testing to ensure that end product is of good quality and will provide uninterrupted service for intended life period. All manufacturers, are expected to develop their manufacturing facility at par with the leading manufacturers with best global practices. **An indicative list for facilities needed to be available at manufacturer's works has been provided at *Annexure-G*. In case the manufacturers do not have the required facilities as given in *Annexure-G*, it may be ensured by the manufacturers that the same shall be made available and put into use within two years of release of this document.**

2.0 GENERAL REQUIREMENTS - QUALITY ASSURANCE

2.1 All materials, components and equipment required for transformer manufacturing shall be procured, manufactured, erected, commissioned and tested at all stages, as per a comprehensive Quality Assurance Programme, the detailed Quality Plans for manufacturing and field activities shall be drawn up by the manufacturer/ contractor (as applicable) and will be submitted to Purchaser for approval.

2.2 Manufacturing Quality Plan will detail out for all the components and equipment, various tests/inspection, to be carried out as per the requirements of purchaser specification and standards mentioned therein and quality practices and procedures followed by Manufacturer's/Sub-supplier's/Sub-supplier's Quality Control Organisation, the relevant reference documents and standards, acceptance norms, inspection documents raised etc., during all stages of materials procurement, manufacture, assembly and final testing/performance testing. The Quality Plan shall be submitted to purchaser, for review and approval. **Typical Manufacturing Quality Plan (MQP) is provided at Annexure-E** for reference. Any change in practice or acceptance norms (with reference to various tests / parameters in respective National / International standard) would be suitably incorporated by manufacturer from time to time and submit the same for approval of purchaser / utility.

2.3 List of testing equipment available with the manufacturer for stage/final testing of transformer and test plant limitation, if any, for the acceptance and routine tests specified in the relevant standards shall be furnished by the manufacturer. These limitations shall be very clearly brought out in 'The schedule of deviations' for specified test requirements.

2.4 The transformer manufacturer, along with Quality Plans, shall also furnish copies of the reference documents/plant standards/acceptance norms/tests and inspection procedure etc., as referred in Quality Plans. These Quality Plans and reference documents/standards etc. will be subject to Purchaser's approval without which manufacturer shall not proceed. These approved documents shall form a part of the contract. In these approved Quality Plans, Purchaser shall identify Customer Hold Points (CHP), i.e. test/checks which shall be carried out in presence of the Purchaser's authorised representative and the work will not proceed without consent of Purchaser in writing. All deviations to approved quality plans and applicable standards must be documented and referred to Purchaser along with technical justification for approval and dispositioning.

2.5 All material used for equipment manufacture shall be of tested quality as per relevant codes/standards. Details of results of the tests conducted to determine the mechanical properties; chemical analysis and details of heat treatment procedure, if any and actually followed shall be recorded on certificates and time temperature chart, as applicable. Tests shall be carried out as per applicable material standards and/or agreed details.

2.6 No material shall be despatched from the manufacturer's works before the same is accepted, subsequent to pre-despatch final inspection including verification of records of all previous

tests/inspections by Purchaser's authorised representative and duly authorised for despatch.

2.7 The manufacturer shall list out all major items/equipment/components to be manufactured in house as well as procured from sub-supplier. All the sub-suppliers proposed by the manufacturer for procurement of major bought out items including castings, forging, semi-finished and finished components/equipment etc., list of which shall be drawn up by the manufacturer and finalized with the Purchaser and shall be subject to Purchaser's approval. The manufacturer's proposal shall include vendor's facilities established at the respective works, the process capability, process stabilization, quality systems followed, experience list, etc. along with his own technical evaluation for identified sub-suppliers enclosed and shall be submitted to the Purchaser for approval in sufficient time so as not to impede the progress of work on the facilities.

2.8 For components/equipment procured by the manufacturer for the purpose of the contract, after obtaining the written approval of the Purchaser, the manufacturer's purchase specifications and inquiries shall call for quality plans to be submitted by the suppliers. The quality plans called for from the sub-suppliers shall set out, during the various stages of manufacture and installation, the quality practices and procedures followed by the vendor's quality control organisation, the relevant reference documents/standards used, acceptance level, inspection of documentation raised, etc. Such quality plans of the successful vendors shall be finalised with the Purchaser and such approved Quality Plans shall form a part of the purchase order/contract between the manufacturer and sub-suppliers.

2.9 Purchaser reserves the right to carry out quality audit and quality surveillance of the systems and procedures of the manufacturer's or their sub-supplier's quality management and control activities. The manufacturer shall provide all necessary assistance to enable the Purchaser carry out such audit and surveillance.

2.10 The manufacturer shall carry out an inspection and testing programme during manufacturing in his work and that of his sub-supplier and at site to ensure the mechanical accuracy of components, compliance with drawings, conformance to functional and performance requirements, identity and acceptability of all materials parts and equipment. Manufacturer shall carry out all tests/inspection required to establish that the items/equipment conform to requirements of the specification and the relevant codes/standards specified in the specification, in addition to carrying out tests as per the approved quality plan.

2.11 Quality audit/surveillance/approval of the results of the tests and inspection will not, however, prejudice the right of the Purchaser to reject the equipment if it does not comply with the specification, when erected or does not give complete satisfaction in service and the above shall in no way limit the liabilities and responsibilities of the manufacturer in ensuring complete conformance of the materials/equipment supplied to relevant specification, standard, data sheets, drawings (approved by the Purchaser), and minutes of various meetings with customer / Purchaser etc.

2.12 Any repair/rectification procedures to be adopted to make the job acceptable shall be subject to the approval of the Purchaser/authorised representative.

2.13 The Manufacturer / Sub-suppliers shall carry out routine test on 100% item at manufacturer / sub-supplier's works. The quantum of check / test for routine & acceptance test by purchaser shall be generally as per criteria / sampling plan defined in referred standards. Wherever standards have not been mentioned quantum of check / test for routine / acceptance test shall be as agreed during detailed engineering stage.

2.14 The manufacturer/ contractor (as applicable) shall submit to the Purchaser Field Welding Schedule for field welding activities (if applicable) along with all supporting documents, like welding procedures, heat treatment procedures, Non-Destructive Test (NDT) procedures etc. before schedule start of erection work at site.

2.15 **Transformer manufacturer shall also provide Field Quality Plans** that will detail out for all the equipment, the quality practices and procedures etc. to be followed by the manufacturer's representative or authorised agency, during various stages of site activities starting from receipt of materials/equipment at site till commissioning.

2.16 All welding and brazing shall be carried out as per procedure drawn and qualified in accordance with requirements of ASME Section IX/BS-4870 or other International equivalent standard acceptable to the Purchaser. All welding / brazing procedures adopted/used at shop, will be made available to purchaser during audit / inspection. Procedures to be adopted at site will be submitted to purchaser for approval.

2.17 **All brazers, welders and welding operators employed on any part of the contract either in Manufacturer's/his sub-supplier's works or at site or elsewhere shall be qualified as per ASME Section-IX or BS-4871 or other equivalent International Standards acceptable to the Purchaser.**

2.18 Any of the offered software, if applicable shall not of β-version and be also free from all known bugs and should be with cyber security certificate.

3.0 QUALITY ASSURANCE DOCUMENTS

3.1 The manufacturer shall be required to submit the QA Documentation in hard copies and DVD ROMs/Pen Drive containing soft copy, as identified in respective quality plan.

3.2 Each QA Documentation shall have a project specific Cover Sheet bearing name & identification number of equipment and including an index of its contents with page control on each document. The QA Documentation file shall be progressively completed by the manufacturer's sub-supplier to allow regular reviews by all parties during the manufacturing.

3.3 Typical contents of QA Documentation is as below:-

a) Quality Plan for various components and accessories. A typical quality plan for key components of transformer is provided at **Annexure-E**.
b) Material mill test reports on components as specified by the specification and approved Quality Plans.
c) Manufacturer's works test reports/results for testing required as per applicable codes and standard referred in the specification and approved Quality Plans.
d) Non-destructive examination results/reports including radiography interpretation reports. Sketches/drawings used for indicating the method of traceability of the radiographs to the location on the equipment.
e) Heat Treatment Certificate/Record (Time- temperature Chart), if any.
f) All the accepted Non-conformance Reports (Major/Minor)/deviation, including complete technical details /repair procedure).
g) Customer Hold Points (CHP)/Inspection reports duly signed by the Inspector of the Purchaser and Manufacturer for the agreed Customer Hold Points.
h) Certificate of Conformance (COC) wherever applicable.
i) Material Dispatch Clearance Certificate (MDCC)

3.4 Similarly, the manufacturer/contractor (as applicable) shall be required to submit hard copies and DVD/ Pen Drive containing soft copy, containing QA Documentation pertaining to field activities as per Approved Field Quality Plans and other agreed manuals/ procedures, prior to commissioning.

3.5 Before offering for Factory Acceptance Test of any equipment, the Supplier shall make sure that the corresponding quality document or in the case of protracted phased deliveries, the applicable section of the quality document file is completed. The supplier will then notify the Inspector regarding the readiness of the quality document (or applicable section) for review:

a) If the result of the review carried out by the Inspector is satisfactory, the Inspector shall stamp the quality document (or applicable section) for release.
b) If the quality document is unsatisfactory, the Supplier shall endeavour to correct the incompleteness, thus allowing to finalize the quality document (or applicable section) by time compatible with the requirements as per contract documents. When it is done, the quality document (or applicable section) is stamped by the Inspector.

Note:- The word 'Inspector' shall mean the authorised representative and/or an outside inspection agency acting on behalf of the purchaser to inspect and examine the materials and workmanship of the works during its manufacture or erection.

4.0 QUALITY DURING INSPECTION & TESTING (including virtual inspection) AND INSPECTION CERTIFICATES

4.1 Inspection, audit, assessment, test measurement and comparison all describe the same phenomena of examining carefully to some established criteria. Inspector should be prepared with the following documents:

a) Contract documents together with technical specifications
b) Basic guideline regarding the scope of inspection
c) Approved drawings and reference standards (ISS/IEC/BS etc.)
d) Previous inspection reports of transformers of similar rating (if available)
e) Type test certificates (if already conducted).

4.2 The Inspector shall have access at all reasonable times to inspect and examine the materials and workmanship of the works during its manufacture or erection and if part of the works is being manufactured or assembled on other premises or works, the Manufacturer shall obtain for the Inspector permission to inspect as if the works were manufactured or assembled on the Manufacturer's own premises or works.

4.3 The Manufacturer shall give the Inspector ten (10) days written notice of any material being ready for testing. Such tests shall be to the Manufacturer's account. The Inspector, unless the witnessing of the tests is virtually waived and confirmed in writing,

will attend such tests within ten (10) days of the date on which the equipment is noticed as being ready for test/inspection.

4.4 Virtual Stage inspection & Factory Acceptance Test (FAT)

The conventional practice of witnessing Stage inspection and Factory Acceptance Test (FAT) of transformers as per technical specification of the utility/purchaser requires physical presence of utility's/purchaser's representative/inspector at manufacturer's works and involves considerable co-ordination efforts and planning by both utility/purchaser and manufacturers, especially in special situations like Covid-19 pandemic. The self-certification/waiver of FAT is not desirable. Under the situation like Covid-19 or if there is mutual agreement between the manufacturer & the utility/purchaser, manufacturer can offer virtual stage inspection or FAT or both, with similar experience/confidence as on-site witness, as an alternative to conventional method.

4.4.1 The resources required for virtual inspection/testing:

The following resources should form part of virtual inspection/testing:

(a) High speed Wi-Fi Internet

(b) Necessary electronic devices like Mobiles, Tabs or iPads, portable cameras, computers for test equipment or instruments, Conference call setup with laptop, cameras in test lab and test bay for clear view of the test bay as well as transformer under test, connection leads and measuring equipment etc. For better clarity and transparency, wherever possible, screens of computers for test equipment or instruments should be paralleled for direct view of the customer. Example – Loss Measurement system, PD test System, HV Test System etc.

(Note: Issues of screen blinking may be observed during chopped wave lightning impulse due to earthing issues and should be ignored)

(c) Qualified engineers well-conversant with technology shall be deployed to effectively handle online stage inspection/FAT.

(d) Online applications like Microsoft Teams, Skype, Google meet, Google hangout, WhatsApp, etc.

(e) Measuring Instruments with valid calibration certificates

(f) Recording facility of all the activities performed during stage inspection/FAT as well as photography of recording of important readings should form part of the Stage/Final inspection reports of the product.

(g) The manufacturer shall nominate a nodal officer, who shall be responsible for coordinating with the utility/purchaser and camera operators for visual arrangement/facilities spread across different locations within the manufacturer's works.

(h) Different sections like Core - coil assembly area, winding area, tank inspection area etc. shall be provided with adequate no. of cameras or portable cameras can be used for clear and proper visualisation of the test object.

(i) During stage inspection/FAT, the position of cameras (with zoom in/out facility) shall be done in such a way that the test object, measuring instruments and test equipment are clearly visible.

4.4.2 Procedure for virtual inspection / testing:

(a) Manufacturer's QA/QC in-charge will plan, verify the process checklist and ensure that the Stage inspection/Routine/FAT are conducted as per approved quality plan in line with the Technical Specification.

(b) Manufacturer will submit soft copies of Photographs and Calibration Certificates with proper index sheet duly certified from their end in order to demonstrate readiness of Transformer for inspection/testing.

(c) The Date and time and arrangement for online stage inspection/FAT shall be finalised in consultation with the utility/purchaser.

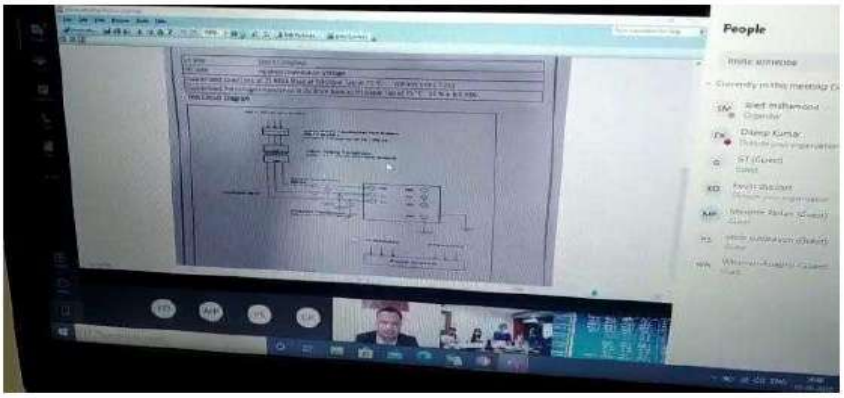
(d) Online inspection/FAT shall be done through online application platform like – Microsoft Teams, Skype, Google meet, Google hangout, WhatsApp, etc., considering the system compatibility and security in consultation with the utility/purchaser. Online recording facility of the activities performed or witnessed must be available at manufacturer's end at all time for customer's reference/review/record.

(e) Utility's/purchaser's approval shall be taken in advance for the virtual stage inspection/FAT including the specific online application platform that will be used.

(f) Whenever required the Mock trial may be carried out at manufacturer's work to get hands on experience before offering to customer.

(g) All issues must be discussed and resolved before commencement of inspection/tests.

(h) The Test circuits and Test procedure shall be shared with utility's/purchaser's inspector for clarity & better understanding.



(i) Application link and security password shall be shared with the utility's/purchaser's inspecting officer on the same day of inspection and password must be secured to maintain the confidentiality.

(j) While conducting remote FAT, due care must be taken to keep the data safe while transmitting from factory to utility's/ purchaser's inspector through a web-based application. There are various Cybersecurity requirements and InfoSec protocols, which should be adhered to for safety like Database Security, Strong Password Policy, Access Control, Restricted Access via 2-Factor Authentication for utility/purchaser, Single Session or Timed Sessions, Resetting Passwords, Password Expiry Policy, Validations for 3rd Party participants, Authentication for users/test engineers etc.

(k) All tests shall be conducted as per relevant latest standards/procedures mentioned in the Technical Specification. The readings recorded in each test will be shown to remote-end inspector live for witness/acceptance. At the end of each test, either side shall discuss the summary of test results to avoid ambiguity at later stage. During Temperature Rise test, the HOT resistance has to be measured at the time of shutdown of power supply to Transformer. The camera position shall be suitably placed, so that the readings are visible without any obstruction by the working personnel. As

far as possible, resistance measurement should be done inside the Control Room to avoid any obstructions or interfere of personnel.

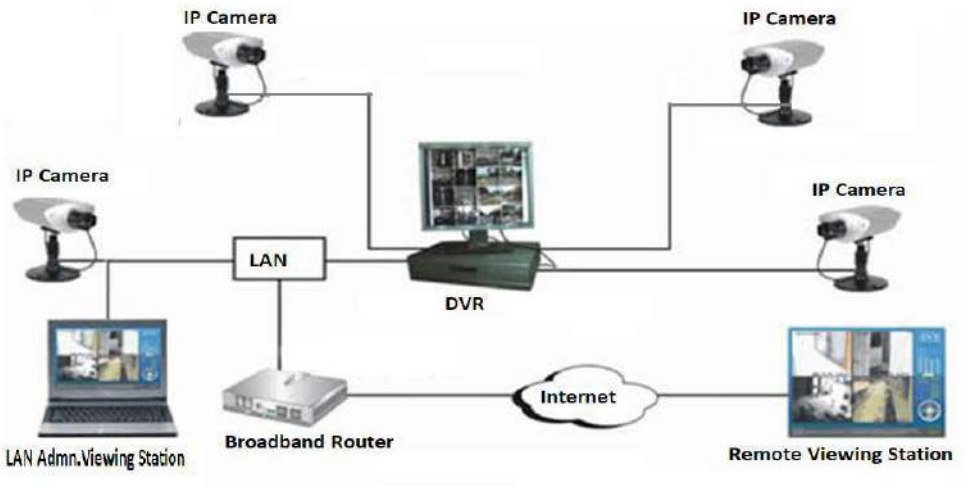
(l) During testing, one camera shall always be focused towards test bay area where the transformer is under test for online overview of connections. If one camera is not enough to see both transformer and test leads, more no. of cameras shall be deployed. This will enable complete testing connection overview to inspecting officer all the time.

(m) The camera must be operated by the authorised person of the manufacturer as per the direction of the inspection team [representatives of utility/purchaser]. The inspection team should have the facility to communicate directly with the manufacturer's representative for a thorough & effective inspection including the physical verification of the dimension, surface defect etc.

(n) The image quality shall be good enough for assessment of the condition of the transformer which may affect the quality & performance of transformer. The factors affecting image quality include:

- Poor image resolution.
- Image out of focus.
- Inadequate lighting /Glare from strong light source/shadows
- Frequent loss of connectivity between the Inspection team and the onsite Video monitors.

(o) The Two-way Audio-Video communication Scheme for stage inspection/FAT of transformer through web shall be as follows:



(p) The camera should be focused for continuous visibility of the test values in the meters so that the utility's/purchaser's inspector can see the test values throughout the Inspection.




(q) During the stage Inspection/FAT, test results/readings & test connections shall be recorded and mailed to the utility's/ purchaser's inspector.

(r) The manufacturer has to prepare test report on daily basis during testing period by the end of each day. Test Reports must be issued by the testing in charge of manufacturer indicating list of Tests carried out and the test results.

(s) For long duration tests (Temperature rise and partial discharge and impulse), manufacturer shall ensure that Cameras shall be provided near transformer under test and the Power analyser or equipment's computer so that the readings can be seen simultaneously.

(t) After completion of inspection, OEMs representative should sign off from the application.

(u) After getting stage inspection Clearance from utility/purchaser, the transformer may be moved to next stage of manufacturing process and after getting FAT Clearance from utility/purchaser, the transformer may be moved for processing of dispatch to site.

(v) All video recording of the inspection shall be done and it shall be shared with the utility / purchaser and also to be maintained by manufacturer/OEM for future reference.

(w) The MoM of the stage inspection/FAT shall be prepared by the manufacturer/OEM and all points discussed & agreed including rectification/punch points, completion date etc. shall be communicated to the utility/purchaser.

(x) Final Stage inspection report/FAT reports, supporting documents and photographs should be submitted to utility / purchaser for their future reference and record.

The online virtual inspection & testing process at manufacturer's/OEM's premises will benefit both manufacturer and the utility/purchaser in terms of time, money & manpower/human resources and would be easier and faster.

4.5 The Inspector shall within ten (10) days from the date of inspection as defined herein give notice in writing to the Manufacturer, or any objection to any drawings and all or any equipment and workmanship which is in his opinion not in accordance with the contract. The manufacturer shall give due consideration to such objections and shall either make modifications that may be necessary to meet the said objections or shall inform in writing to the Inspector giving reasons therein, that no modifications are necessary to comply with the contract.

4.6 When the factory tests have been completed successfully at the manufacturer's or sub-supplier's works, the Inspector shall issue a certificate to this effect within ten (10) days after completion of tests but if the tests are not witnessed by the Inspector, the certificate shall be issued within ten (10) days of the receipt of the Manufacturer's test certificate by the Inspector.

4.7 In all cases where the contract provides for tests whether at the premises or works of the Manufacturer or any sub-suppliers, the Manufacturer, except where otherwise specified shall provide free of charge such items as labour, material, electricity, fuel, water, stores, apparatus and instruments as may be reasonably demanded by the Inspector to carry out effectively such tests on the equipment in accordance with the Manufacturer and shall give facilities to the Inspector to accomplish testing.

4.8 The inspection by the Inspector and issue of Inspection Certificate thereon shall in no way limit the liabilities and responsibilities of the manufacturer in respect of the agreed Quality Assurance Programme forming a part of the contract.