Metaverse Standards Forum
Power Transformers and Reactors – Quality Testing, Training and Preventive Maintenance

Last Update: May 21, 2025

Status: Approved for Public Distribution

Version: 1.0

Reviewer	Due Date	Status	Contact
Industrial Metaverse Working Group	March 06, 2025	Complete	industrial_metaverse@lists.metaverse-standards.org
MSF Domains (Peer Review)	March 27, 2025	Complete	oversight@lists.metaverse-standards.org
Use Case Taskforce	May 21, 2025	Complete	use_case_task_force@lists.metaverse-standards.org

The purpose of this template is to provide a structured framework for collecting and documenting use cases within the Metaverse Standards Forum (MSF). Use cases are essential for understanding real-world scenarios where metaverse technologies are applied and where interoperability challenges may arise. This template guides MSF members in providing a concise yet comprehensive description of a use case, including its title, identifier, and summary. It also encourages contributors to list the benefits of the use case, identify actors or entities involved, and describe the use case scenario in detail, emphasizing interactions, challenges, and requirements. Additionally, it prompts the inclusion of relevant technical information, such as implementations, success metrics, and challenges faced. This template aims to facilitate the gathering of valuable use-case data to inform standards development and foster collaboration within the MSF community.

MSF members and MSF Domain Groups are invited to submit use cases.

NOTE: Organizations such SDOs who want to submit and add a use case would need a sponsor that is an MSF member. This process is established in order to have a contact person in MSF that can handle discussions and resolve open issues within regular meetings.

Eligible submitters:

- MSF Domain Groups
- MSF Members (Principal and Participant)
- External Organizations with Liaison Agreements (with the support of a MSF member that acts as sponsor)

- Standard Development Organizations (with the support of a MSF member that acts as sponsor)

Minimum Requirements for MSF Member Submissions not part of a Domain Group:

- Minimum required number of proposers: 3
- Minimum required number of supporters: 5

NOTE: Use cases submitted by SDOs and Liaison Organizations would also need to fulfill the same requirements (and would need a sponsor) unless they are submitted by a Domain Group.

MSF: *Metaverse Standards Forum*
POG: *Pre-qualified Organizations and Groups*
SPP: *Standards Related Publications and Projects*
DWG: *Domain Working Groups*
WG: *Working Group*
SDO: *Standards Development Organization*

Use Case Title

Power Transformers and Reactors - Quality Testing, Training and Preventive Maintenance

Use Case Identifier

MSF2024-PT&Rs-001

- Version 1.0
- Year of Release: 2025

Summary of Use Case

Description: This Use Case helps Power and Utility entities introduce Power Transformers and Reactors (PT&Rs) engineers and main users to 4 key possibilities, where 3D and extended reality could come into play through designing and delivering inclusive, user-friendly and accessible metaverse experiences:

- PT&Rs quality testing (leveraging AR and VR)
- Engineers training (pre-commissioning and installation of PT&Rs at client site)
- Main users training (focused on how to install, run and use PT&Rs)
- Preventive maintenance monitoring (empowered by 3D and XR devices)

Benefits:

Several benefits could be realized from delivering this use case, including (but not limited to):

- Bridging the gap between virtual and real-world PT&Rs in areas of quality testing, training, and preventive maintenance, and hence reducing (to the extent feasible) the need for constant site visits and physical presence to continue the delivery of those core activities
- Cost savings and spend efficiencies, due to doing away with the constant need for physical presence at classrooms for conducting engineers training, facility for performing quality testing, and client site for main users training and preventive maintenance for carrying out core activities
- Opportunity for scaling inclusion and addressing the accessibility needs of various participants, via adopting a metaverse-centric delivery approach
- Accelerated receipt of feedback from metaverse trainees, leading to swift responses and continuous enhancements to PT&Rs metaverse experiences and actual functionalities

Contributors and Supporters

- Industrial Metaverse Working Group
- MSF Domains (Peer Review)
- Use Case Taskforce

Keywords

Power Transformers and Reactors; PT&Rs; Extended Reality; XR; XR Devices; Metaverse; Metaverse Platforms; 3D; Digital Twin; Internet of Things (IoT); Inclusive; Accessible, and User Friendly

Actors/Entities

- **SDOs:** define standards to be considered by PT&Rs manufacturers in their design specifications to enable an inclusive, interoperable, and accessible metaverse
- **PT&Rs Design and Delivery Teams at the Manufacturer:** in addition to considering SDOs standards, if any, in core design specifications, the team envisions principles around those standards, to enable the design and delivery of holistic metaverse experiences for the relevant actors. The envisioned principles provide considerations for the different phases of the PT&Rs life cycle (particularly at prototyping, testing, development, full-scale manufacturing and delivery stages)
- **XR Software Providers:** create and deliver PT&Rs metaverse experiences in line with the design principles envisioned by the PT&Rs Design and Delivery Teams at the Manufacturer, and accompanied by user guides on how to interact with those experiences
- **XR Device / Hardware Developers:** develop customized XR devices / hardware that are capable of supporting PT&Rs experiences accompanied by user guides
- **PT&Rs Technical Writers:** develop user guides for technical audiences (i.e., distributors), that delineate how to navigate and engage with the deployed PT&Rs metaverse experiences

- **Distributors (includes key sellers and resellers):** create non-technical PT&Rs user guides, and customized metaverse experiences (if required), for non-technical audiences to fit the needs of the various users down the chain
- **Users:** companies and consumers acquiring PT&Rs, and who should receive guidance (i.e., non-technical), to better experience the metaverse applications
- **Consumer Protection Agencies / Regulators:** access to assess reasonableness and comprehensiveness of PT&Rs guidance provided to metaverse users
- **Assurance Providers:** including certification authorities (CAs), attestation providers and auditors reporting on compliance levels with the set metaverse standards

Detailed Description of Use Case/Scenario

Preconditions:

- **SDOs Collaborate with Industry and Academia in Defining Metaverse Standards:** that fit the needs of the Power and Utilities sector. These standards will then act as guidance and pave the way for PT&Rs Design and Delivery Teams at the Manufacturer, and the wider PT&Rs ecosystem to devise their own metaverse design principles cascaded from those standards.
- **PT&Rs Design and Delivery Teams at the Manufacturer Define Metaverse Design Principles:** based on applicable SDO standards, if any. These concerned teams should also play an active role in clearly communicating and ensuring the translation of metaverse design principles by XR Software Providers into experiences on their respective metaverse platforms, and XR Device / Hardware Producers into their produced XR hardware, gadgets and devices.
- **Key Distributors (includes sellers and resellers) Inherit from PT&Rs Manufacturers the Responsibility to Cascade the Metaverse Standards and Manufacturer Design Principles:** and their technical engineers, marketing, sales and distribution teams should therefore be equipped with the necessary skills to design and deliver user guides and metaverse experiences, and to follow-up and coordinate the performance of preventive maintenance (based on signals / requests received from users related to the deployed metaverse experiences).
- **Two Groups of Users are Direct Beneficiaries:** of PT&Rs metaverse experiences and should be clearly defined at the outset:
  - Companies acquiring PT&Rs with engineering expertise and background (i.e., a technical audience), and with the right capability to operate and oversee preventive maintenance based on the guidance and metaverse experiences defined by the PT&Rs Design and Delivery Teams at the Manufacturer
  - Consumers acquiring PT&Rs with no engineering expertise and background, and who rely on non-technical guidance and metaverse experiences provided by key distributors to establish a basic understanding of PT&Rs functionalities. This group will also require continuous support to operate and maintain PT&Rs. Despite the preventive maintenance part of PT&Rs being visible through the preventive maintenance command-and-control application in the metaverse, consumers will still need to liaise with key distributors to conduct PT&Rs periodic checks, maintenance, and performance optimization activities.

Main Flow:

1. **Digital Twin Creation:** XR Software Providers create a Digital Twin of the actual PT&Rs manufactured, in coordination with PT&Rs Design and Delivery Teams at the Manufacturer
2. **Develop Metaverse Experiences:** The Digital Twin is then used by the XR Software Providers to develop PT&Rs Metaverse Experiences in their respective Platforms, while keeping device and hardware compatibility in mind
3. **Establish Custom Capabilities**: XR Device / Hardware Producers establish custom capabilities in developing Gadgets, Glasses and Accessories, if required, to Enhance Accessibility to PT&Rs Metaverse Experiences in inclusive and interactive ways
4. **Deliver "Train the Trainer" Programs:** Distributors deliver technical PT&Rs "Train the Trainer" Programs directed at key sellers and resellers upon their acquisition of PT&Rs, enabling them to navigate PT&Rs metaverse experiences in the respective platforms, and using XR devices / hardware effectively
5. **Customized PT&Rs Metaverse Experiences:** allow Users to access customized PT&Rs Metaverse Experiences matching their expertise and background (i.e., technical vs. non-technical audience), while being provided an opportunity to offer continuous feedback to improve the Metaverse Experiences.
6. **Support Consumer Protection Agencies / Regulators Review:** PT&Rs Manufacturers, XR Software Providers, and XR Devices / Hardware Producers and Distributors (The Ecosystem) should support Consumer Protection Agencies / Regulators in their review of User Guides, Metaverse Experiences, and XR Devices and Hardware developed for both technical and non-technical users. The scope of review may include a number of areas, including data privacy and safety, and threats and harms management.
7. **Support Assurance Providers Evaluations:** The Ecosystem should support Assurance Providers in their performance of Attestation and Certification Services, and Independent Audits of Metaverse Principles, Design Documents, and Manifests supporting the experiences, XR devices, and hardware provided to users.

Postconditions

- **PT&Rs Manufacturers Should Strive for "Interoperability by Design":** as Strategic Proposition to Allow Users / Distributors the Autonomy to Experience PT&Rs across different Metaverse Platforms.

Implementations and Demonstrations or Technical Feasibility

Implementations and Demonstrations

- The current technological infrastructure and capabilities of the Industrial Manufacturing sector position the sector well to create and deliver PT&Rs metaverse experiences for the following reasons:
  - Digital Twins have been in use for a number of years among some of the leading Industrial Manufacturers such as Siemens. For example, Siemens Energy simulates power plants using Digital Twins enable clients to better predict maintenance requirements and schedules. Check: Top Use Cases of Digital Twins - Landvault Blog
  - 3D technology has also been in use by PT&Rs Manufacturers for some time, a trend that aligns with the metaverse's recent traction in the Industrial Sector. Army Technology reported in Q2 2024 that General Electric (GE) has the highest number of

patents filed in several strategic areas, including 3D technology (General Electric sees highest filings and grants during May in Q2 2024).
    - GE has also filed for a metaverse patent in Q2 2024. Titled “Systems and methods of servicing Equipment” (Patent ID: US20240198979A1), the patent “describes a robotic assembly designed to service engines by capturing environmental information using an environmental capture device. This information is then used by computing devices to inspect the engine before and after repair operations to check for any repair equipment or parts left behind.” Check General Electric in metaverse: Theme innovation strategy
- Although GE’s metaverse patent leans more towards the Digital Twin aspect of the metaverse, it still provides an inspiration for agreeing on a global and more inclusive metaverse definition and exploring PT&Rs-specific metaverse applications in the near future

Technical Feasibility

For technical feasibility, the following requirements should be met:

- Proactive alignment between concerned stakeholders (i.e., PT&Rs Manufacturer, XR Software Provider, and XR Device / Hardware Producers) regarding the roles and responsibilities each will play to implement the use cases
- Clarity in the metaverse use case requirements shared by the PT&Rs Manufacturers with the concerned stakeholders
- Deployment of mechanisms (e.g., Objectives and Key Results) by PT&Rs Manufacturers to oversee last-mile execution, ensuring the full realization of metaverse principles in the created metaverse experiences, and the manufactured XR devices and hardware.
- Agreement between PT&Rs Manufacturers and concerned stakeholders on patenting and intellectual property considerations for the metaverse experiences developed or custom devices and hardware manufactured
- Timely securing of necessary lab and regulatory clearances in jurisdictions where the use cases will be developed, and the devices / hardware will be manufactured
- For high-quality design and delivery of the metaverse experiences and associated XR devices / hardware, engineers with the right technical background and expertise should play a leadership role in administering the process
- Universal agreement among PT&Rs Manufacturers and the concerned stakeholders on the definition of the metaverse and the underlying technologies (e.g., Digital Twins and Sensors) that constitute a metaverse experience for PT&Rs specific contexts

Challenges:

- **Low Priority for Metaverse Experiences:** Some PT&Rs Manufacturers, like many other industries, may view creating metaverse experiences as “nice to have” rather than a strategic and game-changing proposition leading to underbudgeting of metaverse related initiatives
- **Diverse Opinions on the Definition of the “Metaverse”:** For example, some of the leading PT&Rs Manufacturers may genuinely define a Metaverse Experience as one based on a Digital Twin. In the purview of those PT&Rs Manufacturers, the Metaverse is

used to create solutions or tackle issues for Physical Equipment and Infrastructure, while others may view it as an enabler for creating (or solving issues with) digital assets and virtual / unreal experiences

- **Limitations in Fully Exemplifying PT&Rs Physical Capabilities:** from a geometrical, physics and spatial standpoint in the virtual world / Metaverse
- **Interoperability Across Platforms:** the format chosen for building PT&Rs experiences may not be interoperable across platforms, formats (e.g., USD), and environments (e.g., the Web)
- **Data Privacy and Security:** PT&Rs Experiences must ensure that Sensitive User Data is Protected against Unauthorized Access and Breaches. The challenge lies in implementing robust encryption methods and maintaining privacy in a remote environment
- **Scalability:** PT&Rs Metaverse Platforms' inability to Handle a Large Number of Remote training and simulation Sessions by users from diverse geographies without Degrading Performance. Scalability issues also Can Lead to Delays and Reduced Reliability of the PT&Rs Experiences

Requirements:

Technical and Functional Requirements

- **Establish dual AR and VR compatibility**, to overcome the limitations of fully exemplifying closer to real-world PT&Rs experiences for the developed use case. This dual compatibility is expected to enable the following:
  - VR compatibility should provide an opportunity to interact with the experience in the Metaverse via a Digital Twin model, while acknowledging susceptibility to inaccurate depiction of the real-world experience
  - AR compatibility should allow simulating real-world PT&Rs in more physically, geometrically, and geospatially meaningful ways exploiting the capabilities of XR hardware and devices
- **Multi-user / Player**: The experiences built should be designed to meet multi-user / multi-player and group requirements, including local and international access capabilities
- **NDE, Cameras, and Sensors (i.e., IoT):** The technologies used should be compatible and with the required extensions to support NDE, allowing the use of cameras and sensors to train engineers and staff on how to function, fix, and predict maintenance needs for PT&Rs users
- **Non-technical User Functionalities:** given that the PT&Rs may be used by various audiences, including households (for light-weight PT&Rs), the functionalities should be user-friendly for non-technical users to experience and benefit from what is being offered
- **Product Accessibility by Design:** where custom-made gadgets, hardware and accessories for accessing PT&Rs experiences should be mindful of people with disability needs
- **Notifications**: deploy real-time alert mechanisms to notify users of new features and functionality updates through accessible Platform dashboards. This enhances transparency and helps actors accurately identify changes in the Platform features and functionalities.

- **Regulatory Compliance Frameworks:** ensure that the PT&Rs Metaverse Experiences Comply with relevant Legal and Regulatory Requirements, including Data Protection and Privacy Laws. This would Prevent Legal issues and Enhance User Trust by ensuring lawful uses in the Metaverse.
- **Scalable Solutions:** develop Scalable Solutions that can Handle a Large Number of Remote training and simulation Sessions without leading to Performance Degradation, while also maintaining the reliability and efficiency of the PT&Rs Experiences even as the number of user sessions grows.
- **User-Friendly Interfaces:** design Intuitive and User-friendly Interfaces for Delivering PT&Rs Experiences. Improve User Satisfaction and encourage more users to participate in the experiences.

Interoperability Requirements:

- **Cross-Platform Compatibility:** the underlying infrastructure and formats used to create and deliver the experiences should be architected and provided in a manner that supports progress towards interoperability in the metaverse, and it is highly preferable that it be based on open-source standards applicable to PT&Rs, if any.
- **APIs and Data Formats:** support interoperability between various PT&Rs Metaverse Platforms through APIs and standardized data formats to enhance compatibility and enable seamless interaction in the Metaverse.
- **Standardized Protocols:** Implement Standardized Protocols for PT&Rs Metaverse Platforms to ensure high degrees of interoperability. This facilitates seamless Metaverse Experiences, reducing confusion and improving User Experience.

Other Key Considerations:

- **Privacy:** options for users to manage, download, and consent to how their data shall be or not be used to improve experiences. Also, all applicable laws and regulations concerning data use, consent and privacy should be disclosed so users are aware to which jurisdictions they are submitting their details and fulfilling its regulatory requirements.
- **Robust Cybersecurity Measures:** against breaches and unauthorized access. This includes encryption, secure access controls, and provision of audit trails for regular security audits.
- **Identity Verification:** users should be provided with an option to choose how they would like to represent their identities in the PT&Rs Metaverse Platform (e.g., through custom-made avatars) and control their visibility features.
- **Networking and Latency:** devise appropriate network infrastructure that supports real-time integration and information flow between the physical device (PT&Rs) and the Metaverse Platform, while accommodating the various users' network speeds
- **Ownership:** provide PT&Rs Users with the ability to maintain oversight on their data and avatar usage, storage, and sharing to ensure continuous compliance with the consent they have granted.
- **Digital Ethics:** develop a universal code of conduct that helps PT&Rs users abide by and maintain professional and constructive interactions in the Metaverse
- **Provenance:** establish robust tracking mechanisms that provide users with real-time updates on the health of their data, with clear trails showing how the data is being used by authorized parties within and outside the PT&Rs Metaverse Platform. Users should also be notified on a timely basis of data manipulation attempts and kept informed of emerging

threats and harms, and the protective measures required to continuously uphold data integrity

- **Accessibility:** build advanced in-app features that enable PT&Rs users to unlock functionalities that cater to their specific disability needs, for example, hearing, visual, sensory, and speech needs among others

Relevant Domain Working Group (WGs):

- NA

Relevant Pre-qualified Organizations and Groups (POGs):

- **Institute of Electrical and Electronics Engineers (IEEE):** develops global standards for a wide range of industries, including a forthcoming standard for the metaverse (www.ieee.org).
- **International Electrotechnical Commission (IEC):** prepares and publishes international standards for all electrical, electronic, and related technologies, and, through the Joint Technical Committee 1 (ISO/IEC JTC 1) it develops standards that support the creation of industrial metaverse applications (www.iec.ch).
- **International Organisation for Standardization (ISO):** develops and publishes international standards, including a forthcoming standard for the metaverse (iso.org).

Relevant Specifications, Publications and Projects (SPPs):

The following standards and specifications can contribute to enabling consistent development of PT&Rs Metaverse Experiences:

- Forthcoming P2048: Standard for Metaverse: Terminology, Definitions, and Taxonomy
- ISO/IEC 18038: Sensor Representation in Mixed and Augmented Reality (MAR)
- ISO/IEC 18039: Mixed and Augmented Reality (MAR) Reference Model
- Forthcoming ISO/IEC DIS 24931-1 Information Technology Metaverse – Part 1: Concepts, Definitions and Terminology

Related Use Cases

- NA

Metaverse
STANDARDS FORUM™

Additional Comments

- This document is a living artifact and may be subject to revisions on a periodic basis to reflect the future state of Power Transformers and Reactors – Quality Testing, Training and Preventive Maintenance, and or based on feedback received from MSF stakeholders that warrants an update in the future.