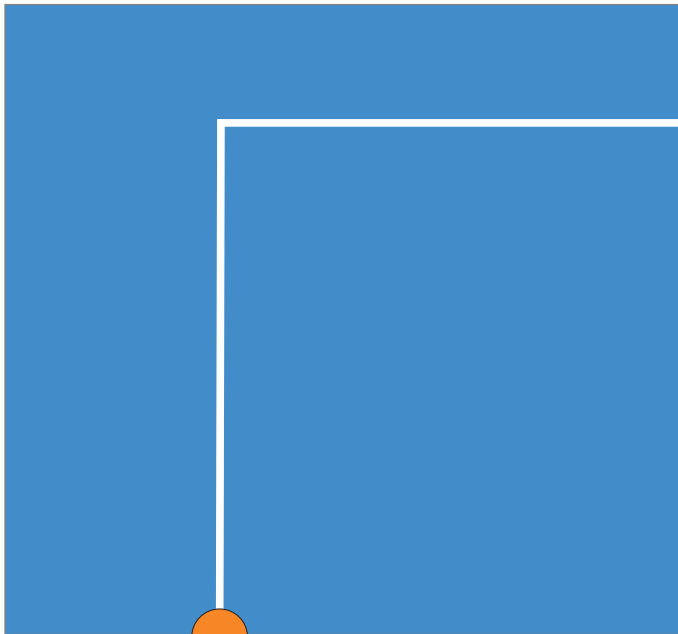


Monitoring High Voltage Power
Transformers in Transit

January 25, 2008



WHITE PAPER

Large power transformers fall in the category of Over Dimension Cargo (ODC), and require great precaution during transportation. The risk of damage increases multi fold due to:

- Long transportation cycle
- Lack of visibility into the condition and location of these high value assets during transportation.

Risk Factors:

- 1) Oversized cargo
- 2) High Fragility
- 3) Long transportation cycle
- 4) Lack of visibility into logistics chain
- 5) Human Errors

The aim of this white paper is to create awareness about various parameters that influence the health of a transformer in a logistics cycle and how monitoring transformers can help mitigate the risk.

Challenges Faced by the Transformer Industry in the Logistics Chain

Power transformers are usually very reliable, but when faults occur, a transformer can be severely damaged. Most of these damages are caused by transformer winding faults, generated by lightning and switching surges. These conditions can aggravate if a transformer experiences a mechanical shock beyond the specified impact threshold, during transportation, and lead to premature transformer failure. A few challenges faced during transportation of power transformers are:

1. Overturning of transformer trailers usually occurs due to improper trailer system, inadequate lashing, over speeding and lapses in stability calculations.
2. Mechanical shock may cause the clamping pressure of the windings to decrease. This decrease in pressure abrades the insulation, causing a short circuit and damage to the windings later during operation, and they subsequently become unable to withstand mechanical forces exerted during faults. This may reduce the overall life of the winding and lead to early rewinding. If the impacts are severe, the core may be displaced from its bracing, compromising the clearance between the active part and the transformer tank.
3. Most transformers, during transportation, are filled with nitrogen gas. Due to leakages and/or variation in temperature, the positive pressure of the gas is lost, and the transformer may require time consuming nitrogen purging to achieve the required due point inside the tank before commissioning. Most transformer manufactures use escort services to ensure positive pressure, but the system is prone to human errors.
4. Smaller transformers are sometimes transported filled with 'transformer oil' and prone to oil pilferage.
5. Transformer sites are usually in remote locations and testing facilities are not easily available to ascertain its health. Field tests which are used as the last resort do not give best results. This makes comparison of field tests with those of the factory's a daunting task.

Key Concerns:

- 1) Over turning
- 2) Mechanical Shock Damage
- 3) Internal cargo sweat
- 4) Pilferage
- 5) Remote installation sites

Transit Precautions

The logistics risk of transformers can be mitigated by thorough planning and monitoring. The following are among the key parameters that should be taken care of:

1. Proper consideration of SRT (Static Roll Threshold), axle load distribution, brake force distribution between tractor and trailer, ratio between the gross mass of the trailer and tractor, reduces the risk of overturning. The vehicle must adhere to the designated route and not travel on a road if fog, heavy rain, hail or any other such factor restricts ambient visibility to less than 500 m. Local transportation regulations should be adhered to and large power transformers should use hydraulic trailers.

2. Mechanical shocks should be monitored and logged during transportation. The logged data can assist in determining the health of the transformer as well as processing an insurance claim. The location to mount the shock recorder should be carefully selected and standardized for a given transformer design. When selecting a shock recorder the following should be considered:

Precautions:

- 1) Check transformer trailer stability (SRT)
- 2) Check tractor to trailer weight ratio
- 3) Monitor Mechanical Shocks
- 4) Nitrogen Pressure, Temperature & Humidity monitoring and control.
- 5.) Transformer oil level Monitoring
- 6.) Trailer location and over speeding monitoring

Sampling Rate: The recorder should be capable of measuring amplitude and duration of the shock along all three transformer axis. The sampling rate should be such that 'aliasing' does not occur and it allows the following analysis of the shock data :

- FFT (Fast Fourier Transform)
- PSD (Power Spectral Density) Spectrum
- EFFDR (Effective Free Fall Drop Range)

Battery Life: The recorder should provide continuous recording on a single battery for the duration of the journey.

Alarm: The recorder should trigger an alarm when the shock crosses the threshold. The user should be able to set the threshold.

Filters: The recorder should have options of programming the frequency filter or getting it set by the manufacture, to reduce recording of noise.

Tests in case of suspected concealed damage:

- 1) Magnetic Balance Test
- 2) Winding to Earth capacitance test
- 3) Sweep Frequency Response Analysis

3. The pressure, temperature and humidity of the nitrogen gas should be monitored, controlled and logged during transportation. **Dew point** may be calculated from these values, eliminating the need of expensive dew point sensors.

4. The level of oil should be monitored during transportation. The system should trigger alarm in case of oil level drop.

5. The speed and location of the trailer should be monitored. Over speeding and deviation from the designated route should raise an alarm.

6. If the shock recorder data conveys potential damage, the following tests may be performed and compared with factory test before doing a manual internal inspection of the tank :

- Magnetic Balance Test
- Winding to Earth Capacitance Test
- SFRA (Sweep Frequency Response Analysis)

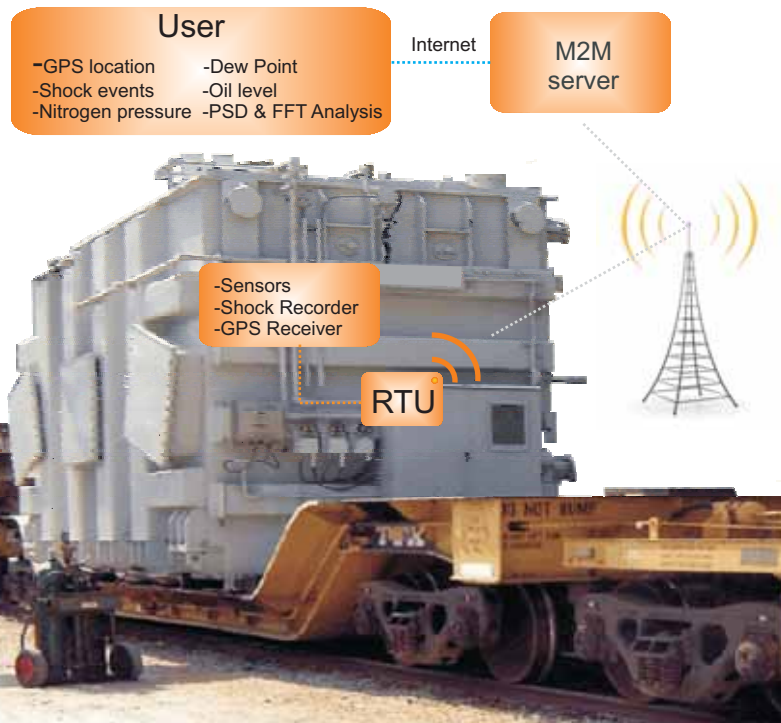
M2M to Rescue: Mitigating Risk

What is M2M?

M2M stands for Machine-To-Machine. M2M solutions enable you to remotely monitor and control your assets, from any location, over the web or LAN. A typical M2M solution comprises a family of sensors, devices, middleware and applications. It helps improve efficiency and quality by connecting the physical parameters from machines with enterprise management and information systems, and provides advanced monitoring, automation and control solutions for a range of industries.

M2M solutions for monitoring and controlling assets in logistics chain are dependent on data communication using either GSM, GPRS, CDMA, Satellite or RF communication. Recently GPRS has become the communication medium of choice as it provides availability, reliability and bandwidth at reasonable cost.

M2M & Transformer Shipment Monitoring



M2M provides:

- 1) Location
- 2) Monitoring
- 3) Control

M2M solution for transformer logistics chain should provide capability to remotely monitor and control:

- GPS location
- Alarm for over speeding
- Shock alarm
- Nitrogen gas pressure, temperature, humidity values
- Data logging
- Data analysis

The system should be expandable to cover information like:

- Oil level monitoring
- Nitrogen pressure control
- Monitoring other parameters, E.g. non contact LVDT or proximity sensors fitted on the tank wall can be used to monitor active part clearance from the wall.

M2M Monitoring Benefits in Transformer Logistics

The monitoring of the transformers using M2M provides information that helps in:

1. Reducing logistics chain risk, the system reduces human errors and provides visibility and control of your logistic chain remotely E.g. Nitrogen gas pressure control.
2. Assisting in insurance claims, system provides information on the critical parameters and time of accident. As a result, it can also help in reduction of insurance cost.
3. Better business planning and decision making. In case of an alarm, immediate action like inspection can be taken to prevent last moment surprises and losses at site. It also provides sufficient time for arranging tests at site, or time for diverting the transformer to a testing facility.
4. Preventing pilferage by raising an alarm. With GPRS bandwidth available at a low cost near real time video surveillance is also possible.
5. Data archiving and analysis to provide key information to determine transformer health. Analysis of historical data can be used to design transformers that can withstand the transportation force experienced.



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