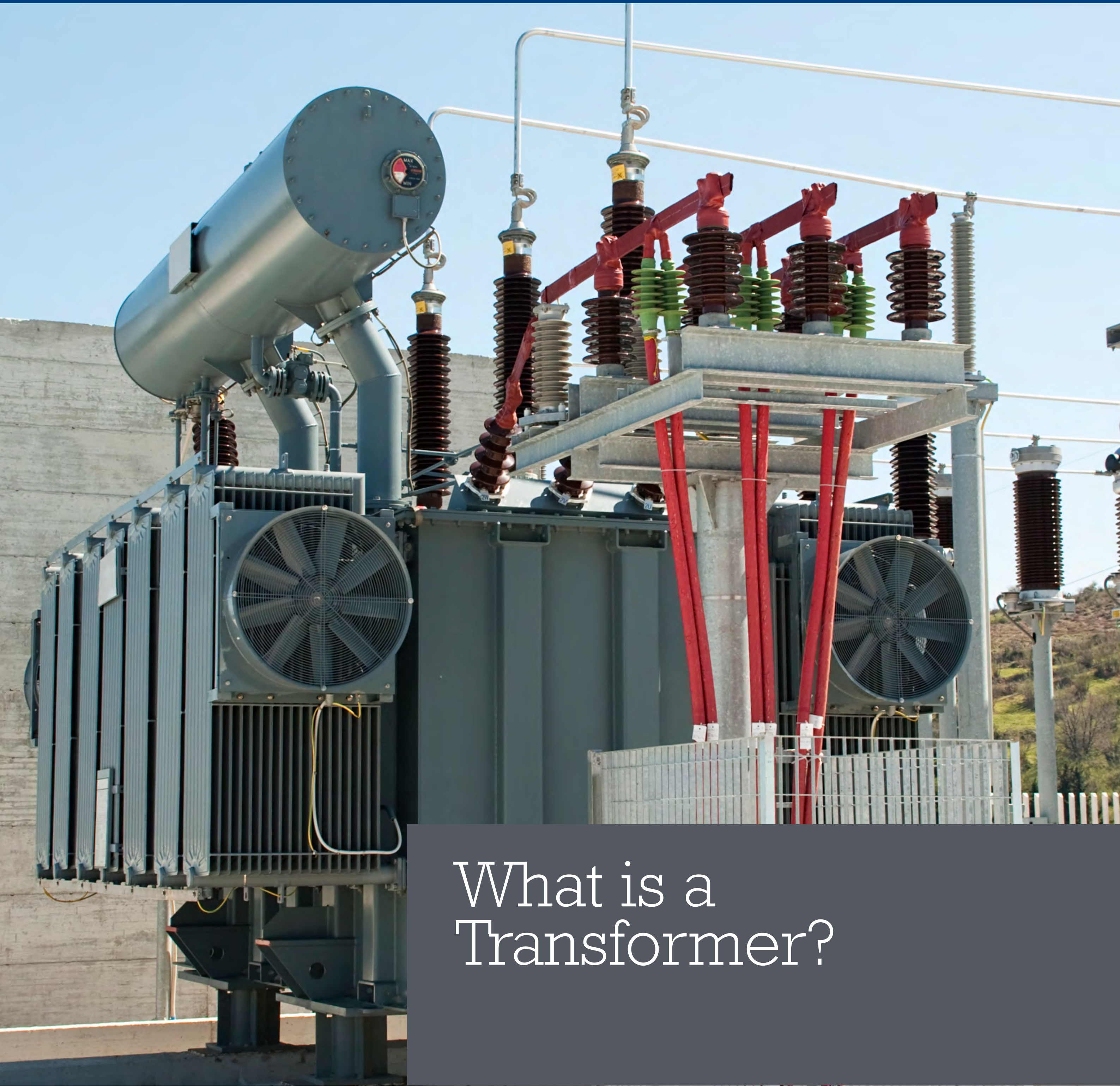
Making sense of risk
Risk engineering
Asia Pacific



What is a Transformer?

Liberty Specialty Markets

What is a transformer?

A transformer is a device that takes electricity, turns it into a magnetic field, then turns it back into electricity again. Transformers, and their close cousins, surge reactors, make most long distance electrical transmission possible.

The most efficient way of producing large amounts of electricity is to locate the power plants at large sites that could take advantage of economies of scale. On the other hand, once the electricity was produced, it needed to be sent over long distances to consumers.

Main and standby transformers on their foundaions

Electrical power is generated instantaneously, it cannot be readily stored. Most major power generation and distribution systems use alternating current, though some long distance systems employ high voltage direct current.

As electricity moves through distribution wires, energy is lost by a form of "friction". For a given current, the longer the cable, the greater the loss, limiting the distribution area. If there was a way to decrease the current losses (known as "line losses") then it would be practical to transmit power over long distances from producer to consumer.

Alternating current's characteristics enable a producer to change the potential and current relationship for a given amount of power. This process is known as "transformation", and the devices that accomplish this are called "transformers".

A transformer allows a power producer to raise the voltage in a given system, which will lower the current for the same rating. The higher the voltage, the lower the current and the lower the line losses.

Transformers are used to raise voltage ("stepping up") to a level which minimizes the line losses from the producing end, and are used in substations further down the line to "step down" the voltage to a level which is practical for industrial and everyday use.

For most power generation projects, transformers are "Critical Items". A "Critical Item" is a piece of equipment which, if lost or damaged, could cause unacceptable delays to the project because of its cost, role in the plant, size, weight or replacement time. With average lead times ranging from six months to a year or more, transformers qualify as critical items on that basis alone.

This paper will introduce the basics of transporting large transformers and share our experience with the challenges they present.

Construction

A transformer consists of a wire coil connected to a generator (the "primary") and another wire coil attached to the consumer (the "secondary"). The ratio between the number of turns of wire in the primary and the secondary coils determines the degree to which the voltage is stepped up or down.

Transformer windings

The conductors are insulated and wrapped around a steel core. However, the core is not solid. To prevent energy losses during the transformation process, it is made up of thin sheets of low-loss silicon steel riveted together, creating a "sandwich". The cores are usually stacked coils separated with wood or cardboard wedges. The core stacks are torqued down to form a rigid column. Transit vibrations can dislodge the wedges if the stack is not properly torqued. If there is some freedom of motion, the cores can rip apart upon first start due to electrical and magnetic forces.

As the transformer operates, it generates heat. Smaller transformers are cooled by air passing over the body of the unit, but larger units are filled with special, highly refined mineral oils that insulate as well as cool.

The core and coils are attached to a plate which provides structural support, terminals and control devices. This, in turn, is placed inside a steel casing (or "tank").

The tank is fitted with lifting lugs and jacking points, as well as foundation pads where the unit will rest after installation.

Preparations for Shipment

Water can damage insulation, cause degradation of the coils, and even short-circuits. For this reason, lengthy drying processes are applied before shipping to remove all traces of water and water vapour.

Manufacturers normally fill the tank with oil to the point where it covers the windings, with the space above the windings filled with nitrogen or dry air. The tank is then completely drained of oil and pressurized to approximately 2.0 lbs/in2 (0.14kg/cm2). A bottle of compressed gas with appropriate gauges is usually fitted to the side of the unit to maintain this pressure during transportation.

Pressure regulator and gauges

Nitrogen bottle and regulator

Valves are closed and drains plugged, before a leak test is carried out to ensure the tank is vapour tight.

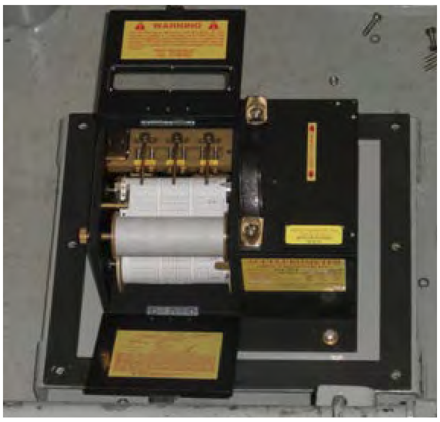
Finally, the manufacturer will perform a Frequency Response Analysis (FRA) before shipment to establish a baseline "fingerprint" of the coil winding condition. FRA is a non-destructive testing method which can be used to determine winding condition and is an important reference should there be any damage during shipment.

Method Statements

A well planned transportation method statement is essential for the safe movement of critical items like transformers. Method statements should include general arrangement diagrams of the equipment, lifting diagrams, inland transportation routes, trailer particulars and configuration, lashing plans including equipment, ship particulars, loading diagrams, stowage plans and seafastening plans. Liberty Risk Engineers review these method statements in order to see what areas can most benefit from our global transportation expertise.

Impact Records

Impact recorders (sometimes known by the trade name "Shocklog") are devices that monitor and record the time and magnitude of any impacts the unit may experience during transportation. They can be either mechanical or electronic. They serve the same purpose as the "black boxes" carried on commercial aircraft.



Mechanical Impact Recorder

Mechanical impact recorders can be simple or complex. Simple impact recorders are inexpensive, but don't provide the location, time or size of an impact, they only confirm that an impact occurred. The more complex units use a strip chart to record the time, magnitude, and direction of an impact and are operated by a mechanism that moves the chart underneath a set of pens. Before using the strip chart, fresh batteries and a supply of paper sufficient to last the entire voyage should be installed.

Electronic impact recorders provide more data and flexibility than the mechanical type, and enable users to download a more detailed report, with accurate information concerning time, accelerations and direction of an impact. Since there are no moving parts, this type of device is not vulnerable to suffer mechanical failure, though care must be taken to ensure that batteries do not run out of electricity.

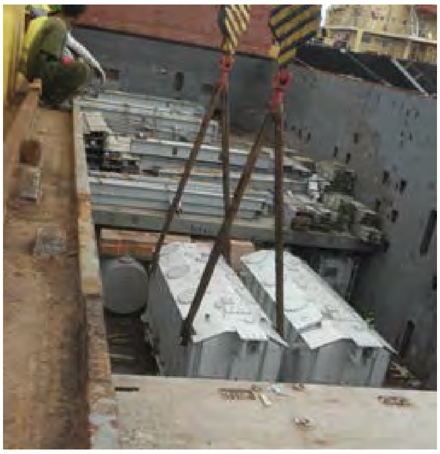
Electronic Impact Recorders

For transformer shipments, it would be prudent to ensure that more than one impact recorder be installed on each unit. In the event of damage, having more than one impact recorder, location allows times (and location) of impact to be checked more accurately, and provides a backup in case one of the recorders is damaged.

In the event of damage or a claim, the data from the impact recorders is beneficial to determine the size, location and time of the impact and the extent of damage and any liability.

Rigging

Developing a proper rigging procedure for transformers whose lifting points are below the center of gravity to a single hook above requires care and experience. There are multiple ways to rig from the hook to any point.



Transformers being lifted from ocean vessel cargo hold

Generally, the stability of the entire system is dependent on the relationship between the rigging angle as it hangs from the hook and the angle between the center of gravity of the load to its lifting locations.

When handling loads in this manner, it is best to enlist the services of an engineering consulting firm with experience of rigging systems.

Transformer being lifted into place by Lane Cane

Land Transportation

Transformers are very sensitive to shock. For road transport, the vehicle speed should be regulated according to the condition of the road surface. For straight stretches of road, maximum recommended speeds are:

- Complete paved road: <50 km/hr
- Secondary Road: <30 km/hr
- Unpaved Road: <10km/hr

Many power plant transformers are too heavy to be moved on conventional trailers. Hydraulic platform trailers or self-propelled mobile transporters (SPMT) are often used to move them overland. These devices can carry large loads, are highly maneuverable, and reliable. As with any conventional trailer, ensuring that the unit can support the intended load is very important. Choosing an experienced and reliable contractor is essential.

Transformers secured to SPMTs using Chains and Binders (T) and Wires and Turnbuckles (B)

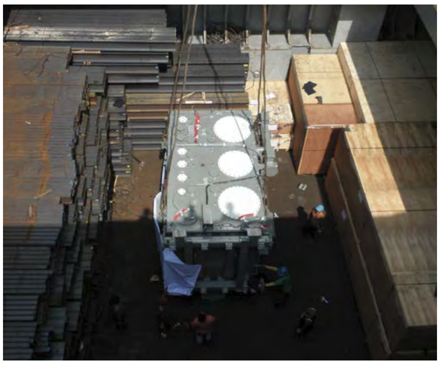
From our experience with North American railways, power transformers undergo scattered impact loads (tens of milliseconds duration) during a trip. These impacts arise by engaging of rail cars and by acceleration and deceleration of the trains. Despite dampers and suspensions in the rail car junctions, these maneuvers may produce strong impacts in the longitudinal direction. Extra care must be taken when designing packing methods for rail transport. An accumulation of small jolts can result in significant damage. To reduce this exposure, we recommend that empty (or "bumper") rail cars be placed in the front and in the back of the rail car carrying the transformer.

When a transformer arrives at its final destination, the manufacturer will recommend that a number of tests be performed and signed-off to determine internal integrity prior to use.

Sea Transportation

Sea transportation differs from land transportation, because ships have six degrees of motion.

The unit can be accelerated in three dimensions, requiring it to be restrained and lashed to prevent any motion.



Transformer in a vessel's cargo hold

When a transformer is loaded onto a ship, either by using the ship's cranes or an outside crane, the rigging must be attached to the designated lifting points. Before placing the unit in the cargo hold, the ship's staff must be sure the location is strong enough to support the unit. Placing a transformer on a tank top or between deck is the best choice, flatracks have been known to cause problems.

To protect the bottom of the unit, the transformer should be placed on top of sheets of plywood. Once in place, a transformer should be secured by welding stoppers around each of the edges to prevent slippage. In addition to the stoppers, the unit should be lashed by attaching chains or steel wires to the lifting points and securing them with a chain binder or turnbuckle. Chain blocks should never be used for lashing.

"How many lashings should be applied?" is a common question. As a general rule, the total added strength of the individual pieces of lashing gear on each side of the unit should be equal to the weight of the unit. For example, if a 100 ton transformer is being shipped by sea, and is secured by 10 wires or chains on each side, the safe working load of each of those lines should not be less than 10 tons.

Insurance

Insurance for transporting power transformers is a difficult subject. Normally, carriers bear a limited standard liability and the manufacturer is required to engage an insurance company for further protection.

Most insurance policies reflect responsibilities only for factual damage on equipment and since transformers are complex structures with many inner components that will work in normal operation at the highest permissible stress, it is virtually impossible to make sure that nothing has moved after a mishap without disassembly of the coils and core.

Companies that purchase transformers require a manufacturer's warranty. Therefore, any kind of impact or dislocation will require the unit be returned to the manufacturer for further evaluation. Once back at the factory, a FRA test will provide information about the condition of the coils.

There is no fully conclusive test available to detect minor insulation damage or displacement in the inside of the winding packages of a transformer so it will almost always have to be disassembled.

Risk Engineering

At Liberty, we believe that applying practical experience and proven engineering techniques to help our clients lower their risk exposure is an essential part of our service. Our in-house Risk Engineers can develop or review method statements and plans to help find the optimum arrangement for any mode of transportation. We have the capability to analyze any transportation plan, whether the route is across town or around the globe.

Liberty aims to assist clients to help prevent a claim from happening. But if a claim occurs, our Risk Engineers can coordinate claim support and technical advice. We also can work with the Insured to determine resolution options, such as alternate means of transportation, changing supplier priorities and running cost benefit analyses to determine the best solution for all parties.