In the early 1970's, Trench embarked on a development program to increase the application size of shunt connected, air core, dry type reactors. In the mid 1970's Trench manufactured and successfully tested an 18 MVA single phase, tertiary connected shunt reactor. The basis of the design for this reactor forms much of the present day design guidelines for Trench shunt reactors, rated as high as 100 MVA per phase or suitable for direct wye connection to 115 kV systems. The following, outlines the important technical areas which Trench addresses, in order to provide customers with highly reliable, large MVA shunt reactors.

**Thermal Criteria for Insulation**

Shunt reactors are subjected to continuous full load current when connected, and as such operate at maximum design temperature rise. Although shunt reactors can be designed with various insulation temperature classes, a 130 deg. C class, polyester insulation is most prevalent. It must be ensured that no part of the winding of the shunt reactor exceeds 130 deg. C for any significant time. Both, Trench parallel wire and Trench cable designed reactors address this important issue.

For small wire, parallel layer winding designs, Trench developed a highly accurate computer design program which precisely calculates the number of conductor turns required to carefully control and ensure that excessive current is not carried by any part of the winding. Excessive current can lead to high temperatures which would shorten insulation life expectancy. By maintaining tight construction tolerances, current distribution, verified by temperature rise tests, is kept virtually equal in all parallel winding layers.

Trench cable wound shunt reactors are not subjected to current imbalances, as all parallel conductors are twisted or transposed into a custom made cable package. The geometric profile of the cable is controlled to ensure that an exact number of turns are produced in the winding height design.

**Voltage Withstand Levels**

Shunt reactors are connected in either wye or delta configuration. This means that full line-to-line or line-to-ground voltage appears continuously across the reactor. In addition, reactors must be rated for full impulse (BIL) withstand. Trench shunt reactors are designed with conservative voltage stress parameters. Steady state voltage stress across the coil surface is well below the voltage level which could lead to partial discharges and subsequent deterioration of the external insulation. Steady state turn to turn voltage stress is also designed to be well below the level which could lead to partial discharge and internal insulation damage.
Losses

As far back as the mid 1970's, shunt reactor losses have been of concern to electric utilities. In order to minimize losses, shunt reactor specifications normally include a loss evaluation formula which is intended to optimize, or balance, the reactor total losses versus reactor cost. Now, into the century, cost of energy has risen dramatically and as such losses are of much more interest.

The largest percentage of reactor total losses originates from the conductor winding ($I^2R$). To decrease losses from this area, Trench can increase the cross-sectional winding, with a resultant lower temperature rise and lower $I^2R$ loss factor. On very large shunt reactors with inherent high field strength, stray losses can become significant. To overcome high stray loss areas, Trench shunt reactors can be designed with non-magnetic stainless steel spider arms while support insulator caps can be made of bronze or stainless steel. Another large source of loss is due to eddy currents in the winding conductor. By utilizing individually insulated, stranded wire, Trench has reduced eddy current losses to approximately 2-3% of the total reactor losses.

Vibration and Noise

Large MVA reactors and their high field strength can result in significant steady state, 120Hz forces on the components. These forces can be a problem if any of the coil components have a natural frequency near 120Hz (ie. at resonance, the effect of the forcing function can be magnified several times). As a result of the studies performed on the 18 MVA reactor, all parts of the shunt reactor, including the spiders and encapsulated windings, are designed such that their natural frequency was, at least, a factor of square root 2 displaced from the 120Hz electromagnetic forcing functions that are applied in service. Accelerometers and integrating circuits have verified that coil components do not produce vibrations that could damage the structural integrity of the unit.

Temperature rise tests, at full power rating, have confirmed that Trench shunt reactors do not produce excessive sound pressure levels and in fact are extremely quiet.

Typically, Trench shunt reactors produce sound levels in the range of 55-60dBA, while the largest reactors may produce up to 70dBA. This dictates that these reactors can be installed in populated areas with no impact on the local noise spectrum.

Mounting

As with all Trench reactors, the mounting of shunt reactors is flexible within certain limits. In order for efficient connective cooling of the parallel windings to take place, approximately six feet of free air space is required under units in the 50 MVA class. Less space is required for smaller MVA ratings. This space can be made up of the appropriate insulator and non-magnetic extension brackets.

Trench manufactures several mounting pedestals which are designed to withstand the high loads imposed by large reactors, while providing proper magnetic clearances below the reactor. These pedestals can also be utilized to elevate the shunt reactor for purposes of personnel protection. Additional information on reactor support pedestals is included in other sections of this catalogue.
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