Reactor: A Vital Part of Electrical System
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Abstract:
Reactor is very important part of electrical system and has many applications in generating, distributing and even controlling electricity. Reactors can improve the system stability and efficiency. Reactors are also known as inductors or chokes, depending on their function in the electrical circuit. The basic inductor is a simple wound conductor in which current flows. It is a passive component and their main functions are to give reluctance to changes in current or to modify the phase shifts between voltage and current. This paper explains the importance of reactor also according to its application. This also includes the types of reactor according to IS and IEC standards. Also the testing of different type of reactors according to IS standards are listed.

Keywords: reactor, application, testing, IS 5553, IEC 60076-6

I. INTRODUCTION

During power generation using any of the generating schemes it is very important to maintain the voltage and frequency at the receiving side. Therefore, it becomes moral role at generating side to maintain these factors at suitable level for continuous and smooth flow of power at the receiving side. Now for controlling the voltage, reactors are used in series or parallel with the grid. These reactors are also used for harmonics compression and current limiting reasons. System voltages and frequency are the main parameters of system which normally indicate that the system is healthy or not. Also they indicate the level of generated active and reactive power against the load power requirement. In a healthy system, Voltage and frequency are maintained to the rated system values. Increase in active and reactive power load results in decrease of the system frequency and voltage levels respectively. Therefore, it becomes necessary to generate or control an additional active and reactive power. In order to safeguard MVA capability of Generators and control stator thermal limit it is preferred to have reactive load support from other sources of reactive power such as fixed Capacitor banks or other FACTS devices and reactors. Also in transmission lines due to ferranti effect there is increase in the receiving end side voltage which can be eliminated by reactors. When a network becomes larger, sometimes the short-circuit current on transmission line exceeds the short-circuit rating of the equipment. To control the capacitive effect of the transmission line and to regulate the voltage and reactive power of the power system, reactors are connected either at line terminals or at the middle, by this means improving the voltage profile of transmission line. A shunt reactor is connected in parallel with a transmission line or other load. A series reactor is connected between a load and source.

II. REACTOR

The reactor is a coil of low resistance and high inductance that introduces reactance into a circuit.

A device for introducing an inductive reactance into a circuit. Inductive reactance \( x \) is a function of the product of frequency \( f \) and inductance \( L \); thus,
\[
x = 2\pi fL
\]
For this reason, a reactor is also known as inductor. With increase in frequency of applied currents voltage drop across a reactor increases, a reactor is sometimes also called as a choke. All three terms describe a coil of insulated wire. According to their construction, reactors can be divided into two types, those utilize iron core and those where no magnetic material is used within the winding. The first type consists of winding or coil surrounding magnetic material or iron which usually contains an air gap or series of air gap. The air gap is used to ease the saturation effect in the core. The second type is called air-core reactor, which consist of circular coil wound around a nonmagnetic material for greater mechanical strength. Both iron-core and air-core reactors may be of the air-cooled dry type or immersed in oil or a similar cooling fluid. [2]

III. TYPES OF REACTOR

A. Types of reactor according to IS 5553 [3]

1) **Shunt reactor**: Reactor planned or used for shunt connection in a system to compensate capacitive current.
2) **Current limiting reactor**: Reactor planned or used for series connection in a system for limiting the current under system fault conditions.
3) **Neutral earthing reactor**: Single-phase reactor used for connection between the neutral of a system and earth for limiting the line-to-earth current under earth fault conditions of system.
4) **Damping reactor**: Reactor planned or used for series connection with capacitors for limiting the inrush current during switching.
5) **Tuning or filter reactor**: Reactor planned or used for series or parallel connection for instance with
capacitors for reducing or blocking harmonics and/or communication frequencies (reactors line-traps).

6) **Earthing transformer (neutral coupler):** Three-phase transformer or reactor planned or used for parallel connection in a system to provide a neutral.

7) **Arc-suppression reactor:** Single-phase reactor planned or used for connection between the neutral of a system and earth for compensating the capacitive line-to-earth current due to a single-phase earth-fault.

8) **Smoothing reactor:** Reactor planned or used to reduce the flow of harmonic currents and transient current in dc systems.

**B. Types of reactor according to IEC 60076-6[4]**

1) **Shunt Reactor:** Reactor connected between phase to earth, phase to neutral or between phases in a power system to compensate for capacitive current.

2) **Current limiting reactor:** Reactor connected in series to limit the current under system fault conditions in a power system.

3) **Neutral-earthing reactor:** Reactor connected between earth and the neutral of a power system to limit the line to earth current under system earth fault condition to a desired value.

4) **Power flow control reactor:** Reactor used to control the power flow and connected in series in a power system.

5) **Motor starting reactor:** Reactor used to limit the inrush current during the motor starting operation and connected in series with a motor.

6) **Arc-furnace series reactor:** Reactor used to increase the efficiency of the metal melting operation and reduce voltage variation on the power system and connected in series with an arc-furnace.

7) **Damping reactor:** Reactor used to limit the inrush current when the capacitor is energized, limit the outrush current during close-in faults or adjacent capacitor switching and/or to detune capacitor bank in order to avoid resonance with the power system and connected in series with shunt capacitor.

8) **Filter reactor:** Reactor used to reduce or block harmonics or control signals (ripple signals) with frequencies up to 10 kHz and connected in series or in parallel with capacitors.

9) **Discharge reactor:** Reactor used to limit the current under fault conditions and used in the bypass or discharge circuit of high voltage power system series capacitor bank application.

10) **Earthing transformer (neutral coupler):** Three-phase transformer or reactor connected to provide a neutral connection for earthing either directly or via an impedance which is connected in a power system.

11) **Arc-suppression reactor:** Reactor used to compensate for the capacitive line-to-earth current due to a single-phase earth-fault (resonant-earthed system) and connected between the neutral of a power system and earth.

12) **Smoothing reactor:** Reactor used to reduce the flow of alternating current and transient overcurrent which is connected in series in a d.c. system.

**IV. APPLICATIONS OF REACTOR**

There are different applications in the electrical field where reactors improve the performance of a system or play a role to protecting it. The major application is where there found in systems with presence of harmonics, but not only for those. [1]

Some applications are listed hereafter. [5]

1) **Current limiting reactor**

This reactor is connected in series to the transmission line or to the feeder for limiting the current under system fault conditions to level which is compatible with the protection system or equipment. This is a very cost-effective solution, as it eliminates the need for upgrading the entire switching and protection system when the short-circuit power of the system is increased. This reactor is designed to withstand the rated and fault (short-time) currents during a specified period of time and to give specified impedance value.

![Figure 1. Current Limiting Reactor](image1.png)

2) **Neutral-earthing**

This single-phase reactor is designed and used to ground the neutral point of three-phase circuit or networks to limit the current in the fault condition between phase and ground. If the circuit or network is perfectly balanced, the resulting current flow through the reactor will be zero and there will be no losses.

![Figure 2. Neutral-earthing reactor](image2.png)

3) **Smoothing**

Smoothing reactors are designed and used to reduce the transient overcurrent in the DC system and harmonic currents. They are used in industrial applications such as rectifiers, traction systems, etc. and also HVDC link.

![Figure 3. Smoothing Reactor](image3.png)
4) **Harmonic filtering**

Due to operation of power electronics devices, large inductive machines, etc. the distortions introduced to the network which is known as harmonic current. These harmonic currents also create several network problems, such as:

- High neutral currents
- Malfunctioning control systems
- Greater losses
- Interference with computers
- Interference with telecommunications Equipment.

5) **Shunt**

These reactors are used in a parallel connection to reduce and optimize the capacitive currents of long transmission lines or cables. As a result, it allows the flow of more active energy through the system. During low-load situation, shunt reactors may be used to reduce the voltage rise due to capacitance of the transmission line or ferranti effect and, in so doing, reduce corona losses.

6) **Damping reactor**

Damping reactor connected in series with one or more capacitor banks to limit the inrush currents which occur during their switching operation. This reactor is designed to offer a specified impedance and to withstand the rated current and the fault current during a short-circuit associated with a high frequency discharge current of the capacitor bank.

7) **Discharge reactor**

In this application reactor is connected for series compensation systems which use capacitor banks which are series connected to the transmission lines. These improve voltage regulation, system transient stability, increase transmission line capacity, reduce electrical losses and save costs.

8) **Arc-furnace series reactor**

The arc-furnace series reactor is connected in series with the electrodes of an arc-furnace used to smelt metals (iron, steel, aluminum, etc.). It provides the necessary required power factor correction and limits the unstable arc-furnace current and voltage (flicker), especially during the melting process. Its winding has a high mechanical strength to resist the forces caused by the fast switching operations of the electrical arc and the high harmonic currents which are intrinsic to the electrical arc.

9) **Power flow control**

Power factor control reactors are connected in series in a power system (which is usually a transmission line) to optimize the power flow by modification of the transfer impedance. They change the line impedance characteristic such that the load flow can be controlled, ensuring maximum power transfer over adjacent transmission lines.

10) **Motor starting**

The motor starting reactor is connected in series with a motor to limit the inrush current during the motor starting operation. After motor is started, the reactor is typically by-passed to limit losses in continuous operation.

V. TESTING OF REACTOR

For confirm the specifications or rating and performances of a reactor it has to go through numbers of testing procedures. Some tests are done at manufacturer location before delivering the reactors. Mainly two types of reactor testing are done at manufacturer location i.e type test and routine test. Also some tests are also carried out at the consumer site before commissioning and also periodically in regular & emergency basis throughout its service life.

Types of tests:-

A. **Type test** –

Test carried out to prove quality with the specifications. These tests are intended to prove general qualities & design of a given type of manufactured item. Type testing used to determine whether a product or system complies with the requirements of a specification, contract or regulation. Testing is often either logical testing or physical testing. The test procedures may involve other criteria from mathematical testing or chemical testing.

B. **Routine test** –

Test carried out on each part or item manufactured to check parameters which are likely to vary during production is termed
as routine test. In case of mass production, there will be some of the test items that need to be implemented in order to make sure that the quality matches with the engineer samples. It is conducted on each product manufactured to confirm proper manufacturing of each and every unit. This test is essential to be performed on each unit before dispatching the product to site. These tests are intended to check the quality of the individual test unit. These tests are done to ensure the reliability of test object and consistency of the material used in their manufacture.

C. Special test –
A test other than a type test or a routine test, agreed by the manufacturer and the purchaser. Some of the tests of different types of reactor are listed below. [3]

1) Shunt Reactors

A. Type Test
- Measurement of winding resistance
- Measurement of insulation resistance
- Measurement of reactance
- Measurement of loss
- Dielectric test
- Measurement of voltage ratio and short circuit impedance on shunt reactor as with additional loadable winding
- Temperature test

B. Routine Test
- Measurement of winding resistance
- Measurement of insulation resistance
- Measurement of impedance of continuous current
- Measurement of loss, if applicable
- Separate source voltage withstand test
- Induced overvoltage withstand test
- Measurement to insulation resistance
- Temperature rise test at rated continuous current
- Lightning impulse test

C. Special Test
- Short-time current test and measurement of impedance at short-time current
- Measurement of acoustic sound level

2) Current limiting reactors and Neutral earthing reactors

2.1) Current limiting reactors

A. Type Test
- Measurement of winding resistance
- Measurement of insulation resistance

2.2) Neutral earthing reactors

A. Type Test
- Measurement of winding resistance
- Measurement of insulation resistance
- Measurement of inductance
- Induced overvoltage withstand test
- Separate source voltage withstand test
- Inter-turn overvoltage withstand test

B. Routine Test
- Measurement of winding resistance
- Measurement of insulation resistance
- Measurement of inductance
- Separate-source voltage withstand test
- Inter-turn overvoltage withstand test

C. Special Test
- Inrush current withstand test
- Q-factor measurement

4) Tuning Reactor

A. Type Test
- Measurement of winding resistance
- Measurement of insulation resistance
- Measurement of inductance
- Induced overvoltage withstand test
- Separate source voltage withstand test
- Measurement of Q-factor
- Measurement of losses
- Temperature rise test
- Lightning impulse test
B. Routine Test
- Measurement of winding resistance
- Measurement of insulation resistance
- Measurement of inductance
- Induced overvoltage withstand test
- Separate source voltage withstand test
- Measurement of Q-factor
- Measurement of losses

5) Earthing Reactors

A. Type Test
- Measurement of winding resistance
- Measurement of insulation resistance
- Measurement of zero sequence impedance
- Measurement of no-load loss and no-load current
- Dielectric test; in case of earthing transformers with a secondary winding
- Measurement of voltage ratio and check of voltage vector relationship
- Measurement of impedance voltage, short-circuit impedance and load loss
- Measurement of insulation resistance
- Dielectric test
- Temperature-rise test

B. Routine Test
- Measurement of winding resistance
- Measurement of insulation resistance
- Measurement of current at all adjustments
- Measurement of voltage ratio between main winding and auxiliary and secondary windings, where appropriate
- Dielectric test
- Operation test of tapping or core air gap mechanism, where appropriate

C. Special Test
- Measurement of winding resistance
- Measurement of current at all adjustments
- Measurement of voltage ratio between main winding and auxiliary and secondary windings, where appropriate
- Dielectric test
- Operation test of tapping or core air gap mechanism, where appropriate
- Temperature-rise test
- Loss measurement
- Measurement of linearity up to 1.1 times rated voltage

7) Smoothing Reactor For Indoor installation, voltage not higher than 10 kV

A. Type Test
- Measurement of winding dc resistance
- Measurement of insulation resistance
- Measurement of inductance
- Separate-source voltage withstand test with ac and ac voltages where applicable

B. Routine Test
- Measurement of winding dc resistance
- Measurement of insulation resistance
- Measurement of inductance
- Separate-source voltage withstand test with ac and ac voltages where applicable
- Dielectric test
- Operation test of tapping or core air gap mechanism, where appropriate

C. Special Test
- Short-time current withstand test
- Measurement of acoustic sound level
- Measurement of vibration
- Measurement of high-frequency impedance
- Loss measurement
- Temperature-rise test

For Outdoor installation, voltage 50kV or higher

A. Type Test
- Measurement of winding dc resistance
- Measurement of insulation resistance
- Measurement of inductance
- Dc voltage withstand test

B. Routine Test
- Measurement of winding resistance
- Measurement of insulation resistance
• Lightning impulse test
• Switching impulse test

B. Routine Test
• Measurement of winding dc resistance
• Measurement of insulation resistance
• Measurement of inductance
• Dc voltage withstand test
• Lightning impulse test
• Switching impulse test

C. Special Test
• Short-time current withstand test
• Measurement of acoustic sound level
• Measurement of vibration
• Measurement of high-frequency impedance
• Loss measurement
• Temperature-rise test

For both
• Temperature rise test

VI. CONCLUSION

From the review we conclude that reactor has very significant role in electrical system and their types in standards are according to their applications. Example by using reactor we can limit the current and also control the power flow and quality, by which the stability and efficiency of the system can be improved. Basically three types of tests should be performed on reactor according to IS standards which are type test, routine test and special test. It had been observed that most of the test in type test and routine test were common.

VII. REFERANCE

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