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An Overview Quality Design Testing of Insulating Material's Different Parameters Used for the Stator of a Generator

G Mahabei*, M Vijay Karthik**, V. Minnie Florence***
*Bhel R&D Hyderabad
**Dept Of Ece,Cmr Engineering College,
***Dept Of Eee, Sphoorthy Engineering College

ABSTRACT
Rotating machines are the work horses of the industry .The critical part of any electrical equipment is its insulating system. Epoxy resin chemistry plays an integral part of in insulation chemistry. Whether it is primary insulation, consolidation or impregnation, the first choice is epoxy resin. Though other chemistries are in vogue in the field of electrical insulation, epoxies play a greater role in the higher end applications. Epoxies are known for their high mechanical strength, excellent electrical insulating properties, good long term performance, excellent heat resistance and good resistance to moisture.
In high voltage machines, two schemes of insulation are used, namely resin rich and resin poor. In this paper we are studying the testing and recording of various insulating parameters like dielectric strength, tensile strength, viscosity and shelf life of certain resin rich and resin poor insulating materials.
Index Terms—resin rich tapes, resin poor tapes, dielectric strength, tensile strength,viscosity.

I. INTRODUCTION

Recent progress is reviewed on the research and development of electrical insulation applied to modern electric power systems. Insulating materials are backbone of all electrical devices. An effective and well integrated insulation system is basic requirement for implementing any electrical engineering idea in the field. They are a host of basic requirements for good insulating material. To name a few, the most desired are high dielectric strength, tensile strength, viscosity and also the pot life,

However other factors such as ageing, porosity, density, dielectric constant, dielectric loss, ductility, shelf life may also affect the stress at which the insulation can be used. As the systems utilizing higher and higher electrical stresses are desired and are coming into use, different insulating materials as dictated by needs are being discovered and put to use.

From the beginning of manufacture of electrical machines, insulation is considered as an important in deciding the life of the equipment. With the increase in the unit size of machine, the voltage ratings also steadily increased. Higher voltages demand better and more reliable insulation systems.

In initial stages of manufacture, natural fibres like cotton, jute etc were used without any impregnation. Later impregnation with oil and natural resins enriched the quality of insulation. Development of synthetic materials, and resins helped in getting more reliable insulation systems. During this evolution ,it was realized that mica ,a naturally occurring material ,is one of the best insulations for high voltage applications. Even today there is no substitute for mica in high voltage Insulations.

Insulation materials and systems-

Electrical insulating materials are defined as materials, which offer a large resistance to flow of current and for that reason they are used to keep current in its proper path i.e ,along the conductor.

In electrical machines and transformers the insulating materials applied to the conductors are required to be flexible and have high specific (dielectric) strength and ability to withstand unlimited cycles of heating and cooling.

Thermal classification of insulating materials-

The insulating properties of materials change considerably with temperature .As such insulating materials are classified into different classes, depending on the maximum permissible temperature on the material.

Classes of insulating materials-

Y –assigned insulating temperature (degree Celsius) is 90 degrees. Insulating materials included are cotton, paper .They are neither impregnated nor immersed in oil. Material of Y class are unsuitable for electrical machines and apparatus as they deteriorate rapidly and are extremely hygroscopic.

A-assigned temperature is 105 degrees .Materials of class Y impregnated with natural resins, cellulose esters, insulating oils etc.The list also includes laminated wool and varnished paper.
E- synthetic resin enamels cotton and paper laminates with formaldehyde bonding etc. Assigned limiting temperature is upto 120 degrees.
B- mica, glass, fibres, absetos with suitable binding substances built up mica, glass fibre and asbestos laminates. Maximum permissible temperature is 130 degrees.
F- Materials of class B with binding materials of higher thermal stability. Assigned permissible temperature is 155 degrees.
H- glass fibres and asbestos materials and built up mica with silicon resins and temperature is 180 degrees.
C- mica, ceramics, glasses quality without binders with silicon resins of higher thermal stability and Temperature is above 180 degrees.
According to IEEE standards beyond class *H*(180 degrees),*N*(200 degree),class *R* (220 degrees),class *S* (240 degrees),class *S* (240 degrees) and class *C* (over 240 degrees).

Different types of insulation systems-
Thermoplastic insulation system-

Thermoplastic compounds are materials that go soft when heated and harden when cooled . When heat is applied the energy will allow the bonds to separate and the material can flow (melt) and be reformed ,for example-Polyvinyl Chloride – is the most commonly used thermoplastic insulator for cables. It is cheap, durable and widely available. However, the chlorine in PVC (a halogen) causes the production of thick, toxic, black smoke when burnt and can be a health hazard in areas where low smoke and toxicity are required (e.g. confined areas such as tunnels). Normal operating temperatures are typically between 75C and 105C (depending on PVC type). Temperature limit is 160C (<300mm2) and 140C (>300mm2).Another example Polyethylene – is part of a class of polymers called polyolefins.Polyethylene has lower dielectric losses than PVC and is sensitive to moisture under voltage stress (i.e. for high voltages only).

1)Shellac mica folium wrapped system-In the early stages mica folium with shellac binder was used to wrap the straight part of coils and flexible fabric taps with varnish on overhang portions. In this system the joint between the mica folium and the tape is the weakest part. This system is no more used for high voltage machines.It has been used extensively for coils upto 6.6kv operating voltage. The main constituent materials are cellulosic backing paper, mica splittings,shellac varnish,and industrial methylated spirit.

2)Bitumen mica folium wrapped system-
The latter development is the use of bitumen mica film in straight part and mica tape in overheating portion. But the system did not work satisfactorialy without impregnation. It has been used for insulation upto 11kv operating voltages.The constituents are same except that bitumen varnish is used.

3) Bitumen mica taped and pressure impregnation system- As refinement of the process ,vacuum – pressure impregnation of the coils in bitumen was introduced .The system consists of taping the coils with bitumen mica tape with backing and compounding ,the insulation three-four stages with bitumen .The final coils gave satisfactory performance. It was very popular among prior to the introduction of thermosetting system .Till recently this system was in practice in some major industries. These materials have several advantages like cheap, durable and widely available and had has lowest dielectric losses and initial dielectric strength.But these materials have certain limitations for high temperature operations as they become plastic under application of heat. Machines after regular usage for a while developed winding faults due to cracking of insulation caused by the movement of tapes. When the machine is heated up, the main insulation is swelled up and voids are created inside the insulation which result in electrical discharges and in turn damaged the main insulation. These materials also defects like highest dielectric losses and it contains halogens , its not suitable for MV / HV cables. They Highly sensitive to water treeing and Material breaks down at high temperatures.

Thermo setting insulation system-

Thermosetting compounds are polymer resins that are irreversibly cured (e.g. by heat in the vulcanization process) to form a plastic or rubber. Example-
a)Cross-Linked Polyethylene– has different polyethylene chains linked together ("cross-linking") which helps prevent the polymer from melting or separating at elevated temperatures. Therefore XLPE is useful for higher temperature applications. XLPE has higher dielectric losses than PE, but has better ageing characteristics and resistance to water treeing. Normal operating temperatures are typically between 90C and 110C. Temperature limit is 250C.
b)Ethylene Propylene Rubber– is a copolymer of ethylene and propylene, and commonly called an "elastomer". EPR is more flexible than PE and

XLPE, but has higher dielectric losses than both. Normal operating temperatures are typically between 90C and 110C. Temperature limit is 250C.

1)Resin rich system-

The introduction of epoxy resins in the field of insulation changed the systems drastically.Epoxy resin is two component reactive system.In the unactivated state(A stage) the resin remains in liquid/solid form and is not good insulating material.When the hardner /accelerator is added to the resin the system changes to B stage or semicured stage. In this stage the resin is in transition from uncured to cured. This time needed for changing from uncured to cured stage depends on the temperature ,usually known as shelf life of the B stage resin.In the fully cured stage (C- stage) the epoxy resins have good insulating and bonding properties.The resin rich mica paper tape consists of epoxy resin in B stage as bonding material mica paper and glass backing for good tensile strength.
When heated and pressed the resin in the tape melts and hardens to form homogenus mass.As the resin in the tape is more than sufficient for providing homogenus mass,the system is known as resin rich system. Some of the materials used are-
a)calmica flex tape
b)prepreg glass cloth
c) epoxy varnish

2)Resin poor system-

In the resin poor or vacuum impregnation process system ,the tape contains about,8% resin and excessive accelelerator/hardner. After taping ,the coil is impregnated in an epoxy resin having no accelerator. As the tape contains the accelerator,the resin reacts with accelerator and forms a homogenus mass when heated and pressed. In this system the impregnation is done under pressure after removing all gases by creating vacuum .As such insulation will be void free and more compact. The tape used may be either mica paper or mica flake tape. The materials used for 2 pole generators and 4 pole generators.
1*) bar impregnation*
2) form impregnation
3) total impregnation.
Some widely used insulating materials for in different parts above generators are
a) nomex sheet
b) polyster fleece
c) fine mica paper tape.

II. TESTING OF INSULATING MATERIALS-

The resin poor insulating materials are comparatively advantageous than resin rich insulating materials. The samples insulating materials are being tested through various tests evaluating various important insulating properties of the insulating materials. The samples are tested mainly on the following parameters-
1) insulation class
2)tensile strength
3)dielectric strength
3)shelf life
4)total weight age
5)porosity or penetrability
6)viscosity

Testing of tensile strength-the minimum tensile load per unit of the the orginal cross section of body which will cause its rupture under specified conditions of test,expressed in pounds per square inch or kilograms per square millimeters.
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Testing of dielectric strength-the value of voltage which causes the electrical rapture of an insulating material in practical use. The value obtained must be qualified by reference to the type of voltage applied,the method of its application ,the uniformity of the electrical field developed,the thickness of the insulation tested,the temperature and the conditioning treatment to which the material has been exposed before and during the actual test.

Dielectric constant –the ratio of capacitance of a material measured with a given electrode configuration to the capacitance of same electrode configuration and spacing with air as a dielectric.

Dielectric loss-when an ac voltage is applied to an electrical insulating material, heat is generated because of its imperfect dielectric nature.The time rate at which the electrical energy is transformed into heat is designated as the dielectric loss and is expressed as watts/cubic centimeter.

Test of ageing-the change which is observed in one or more properties of material during its normal commercial use.

Test of viscosity-the resistance to flow within a body. The ratio of shearing stress and the rate of strain in shear which is constant in the new to main concept but varies with the shearing stress in most plastic compositions. The time rate of fluid flow under which prescribed conditions of test.

Shelf life-the ability of material to maintain its usability during storage ,expressed in terms of time

under prescribed conditions of temperature,light oxidation and humidity.

Calmica flex tape-
Semicatherm tape is a resin rich mica paper tape with glass backing.The tape contains mica paper,epoxy resin in B stage and glass cloth backing.semicatherm tape is used for main insulation of stator bars.
Its insulation class is class F i.e its permissible temperature is 155 degrees.
The tensile strength of calmica flex tape or resin rich tape is 15kg/cm width.
Dielectric strength is 4kv/mm.
Shelf life evaluated at two different temperature levels-6 months at 20 degrees and 12 months at 5 degrees.

Prepreg glass cloth-
Its main application is for inter halves insulation and winding holders.
Tensile strength is 25kg/meter square of width
Dielectric strength is 10 to 12 kv/mm.
Shelf life is 6 months at 20 degrees and 12 months at 5 degrees.

Epoxy Varnish -
Its main application is stack consolidation of stator bars.
Viscosity at 60 degree Celsius is 110CP.
Shelf life is 6 months at 20 degrees and 12 months at 5 degrees.

Nomex sheet-
To avoid damage of change of over position and to provide extra protection.
Dielectric strength is min 5kv/mm

Polyster fleece-
It is used for sticking purpose.
Tensile strength is min 40N/cm of width.
Shelf life is 6 months at 20 degrees and 12 months at 5 degrees.

III. CONCULSION-

Recently developed insulating materials for high voltage rotating machines offer the distinct advantage over conventional tapes. The impregnation with epoxy resins of higher viscosity is possible.Therefore substantial cost savings are attained as the increased viscosity of the impregnated insulating materials. The viscosity of insulating materials varies considerably as the function of the temperature. The properties of the like better heat transfer, high mechanical strength, reduced corona and improved performance is achieved by these insulating materials. Other advantages like low resin content in the tape as minimum quantity of the resin is used. Very great flexibility of the tape and reduction in the risk of sticking between turns which raises from the absence of resin in meshes of glass cloth. Hence excellent conformability of the above insulating materials for different parts of stator in a generator in terms of time, cost and quality is obtained.

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