What is Your IQ ? (Insulation Quality)

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ABSTRACT

Electrical power systems use insulation as structural members to isolate the energized conductors from the grounded cabinets or structures. Electrical insulation has been of many materials over the years leading to the current polymers, ceramics, bonding cements, fiberglass and epoxy's. Insulation is subjected to fault currents, over-voltages, contamination, structural overload, and over-heating. Electrical insulation is used to isolate energized conductors which may have voltages ranging from 2.4 to over 700kVAC and over 400kVDC for generation, transmission, distribution and through the conversion to another form of power or lower voltages for industrial and residential uses.

Electrical insulation is tested using various techniques to identify defects during R&D, manufacturing, field start-up, sometimes on-line monitoring, and off-line predictive maintenance testing. The defects can be internal or external to the insulation material, the internal defects "growth" can be accelerated by structural loading or electrical over-voltage and the external defects can be accelerated by moisture, freezing weather and chemical contaminants.

The physical condition of insulation during manufacture is defined by quality control to various applicable standards of NEMA, IEEE, UL, military standards, ASNT, and other certifications dependent upon the users' application. The condition of installed insulation is tested on-line using non-destructive inspection (infrared, ultrasound, corona camera) and for specific equipment defined off-line testing procedures are used to perform quantitive energized testing for tan-delta (power factor), dielectric resistance, and surge testing for electric motors.

Keywords: Corona, insulation quality, dielectric breakdown, arcing, grounding, thermography, ultrasound

1. INTRODUCTION

Insulation quality is defined as being non-conductive through the applied voltage range, plus any tolerance for transients or over voltage spikes that may occur. Destructive and non-destructive methods are used to evaluate insulation quality to many standards for various applications. This paper is meant to describe current high voltage insulator types, the causes of breakdown of modern insulators, elaborate on non-destructive testing, the tools and the reasons for its use. The conference presentation will include pictures to elaborate on defects observed and testing methods.

2. TESTING INSULATION QUALITY

Insulation quality is tested in several ways, the means to test insulation depends upon its shape or configuration. Flat material insulation as might be found in switch gear as cabinet bus spacers typically is tested for dielectric breakdown with a dielectric tester. Electric motor winding insulation is tested for withstand to ground or enclosure with a dielectric tester, then tested for turn-to-turn dielectric strength or inter-turn shorts with a surge tester which is applied in both directions to stress the end turns. Other types of insulators, suspension insulators used on outdoor poles and transmission lines are tested using dielectric and magnetic field testers, these insulators may have about 35kV across each one. These insulator strings have higher voltages present on each insulator at the end of the insulator string, and the redundancy allows some in the string to be failed without causing an outage. Another type

of insulator is called a post type insulator used for mounting substation open-air switches, these insulators may have 120kV or more across each insulator. The non-ceramic type insulator will have the full rated voltage applied across its length with a fiberglass rod in the center as the structural member and is encased in a ribbed molded cover from connector to connector. The biggest detriment to the non-ceramic insulators is the designer that doesn't put corona rings on above 160 kV. Flash-over damage and the freeze thaw cycles once the cover is penetrated can create arcing paths which will lead to failure.

3. DETRIMENTAL TRANSIENTS

Lightening voltages can create an intense electric field which can make air "sizzle" and can also deliver tremendous fault currents through utility distribution and transmission lines. The next most powerful transients are from capacitor switching, generator synchronizing or accidental faults such as tree branches falling across lines, summer construction severing lines, etc. These transients are coupled from line to parallel line and if high enough voltages and electric fields are involved even to lines running at 90 degrees or by raising the ground plane potential to couple these transients into control signal and analog transducer wiring. The longer the run the higher the potential for induced voltages. Parallel lines that are insulated and become contaminated become capacitors which can discharge creating corona or arcing. Winter icing can create many unintended energized circuits including the fencing surrounding substations.

4. RESOURCES FOR MAINTENANCE

Reliability is locating defective components and preventing the faults that exist from creating an outage. Random outages are also being reduced by squirrel, bird and snake guards. Construction and home-owner safety around distribution voltage electricity education is active in many areas of the country. Predictive maintenance to identify those defective components that will cause an outage uses several types of test equipment including infrared, ultrasound, acoustic, radio frequency, night vision, ultraviolet low-light and daylight multi-spectral corona sensing cameras. Each technology contributes to the knowledge about the condition of the electrical system (motor/generator, MCC, switch gear, distribution system, substation, and transmission line). The technician's knowledge about the limitations of each technology are also important, the following table is meant to provide basic guidelines, there are variables with different sensors for each technology. The basic device being sensed is a defective pin and cap type insulator as pictured.

5. DEFINING CORONA INDICATIONS

Equipment energized with high voltage has the potential to create ionization of the surrounding air or corona discharge, corona does require energy to produce this chemical reaction. When corona occurs sound is produced from audible through ultrasound, nitric acid is produced when moisture is present, ultraviolet light is emitted,

Because corona itself can be intermittent the sound can be difficult to detect if moving the sensor too quickly. Corona in enclosed switch gear can be detected when the nitric acid white or gray powder can be found as a witness to the corona activity. The line-of-sight ultraviolet corona cameras are used to view corona discharge on high voltage electric motor and generator windings, switch gear and substation bus, terminals, linkage, insulators of all types and the daylight corona cameras are especially easy to interpret indications if you remember:

1) Corona is an indicator of conductivity, corona can indicate punctured insulators if present on the insulator cement.

2) Corona can indicate insulator contamination, random, flitting about along the length of the insulator barrel or on the bell.

3) Corona can identify hardware that may suffer from acid attack.

4) Corona can waste power; corona points equals 1 kW per James Booker.

5) Corona can eat the re-enforcing steel cable out of an ACSR cable.

Ultrasound may tell you there is corona present but visibly seeing the exact location and type of corona can identify exactly what the cause and future action should be.

6. DEFINING FLASH-OVER INDICATIONS

At very high voltages flashover can leap across great distances like a stone skipping in a pond and be very deadly. High voltage uses the circumstances offered by partially conductive areas and air that is ionized to bridge gaps that are too long for the applied voltage under a static condition.

7. DEFINING ARCING INDICATIONS

Arcing comes in multiple shapes from arcs across a small gap (a few thousandths) with only a few volts present in electric arc welding to tiny gaps at 220kV producing random arcing, too small to produce heat in the connector's mass, or at 35kV with a loose aluminum wire in a clamp. The ultrasound unless held up to some of these source would not detect them, the corona camera can see a very short arc across the road or a mile away dependent upon the KVA present in the arc which determines the light emitted.

8. DEFINING PARTIAL DISCHARGE

This is the combination of arcing within voids in an insulating material and potential corona discharge in the air over the insulating material. Partial discharge uses a hardwire voltage and current detection method thus it cannot readily discern discharge within a material from airborne corona discharge.

9. SUMMARY TABLES

The following tabulations summarize the comparative performance parameters of various technologies in terms of specifications, distance performance and suggested applications in detecting and evaluating insulation breakdown corona indications. These technologies are:

Infrared

Ultrasound

Accoustic

Radio Frequency

AM / FM / SW

Night Vision

Ultraviolet

Low-light Viewer or Camera

Daylight

Dual Spectrum Camera

Technology	**Infrared**	**Ultrasound**	**Accoustic**	**Radio Frequency** **AM / FM / SW**	**Night Vision**	**Ultraviolet** **Low-light Viewer or Camera**	**Daylight** **Dual Spectrum Camera**
Sampled Medium	Radiated and reflected heat from source(s)	Air for sound waves radiated by source(s)	Solids for sound waves radiated by source(s)	Airborne magnetic sine waves radiated by a source(s)	Ambient light in the near infrared from source(s)	Ultraviolet light after sunset, or indoors from source(s)	Solar-blind wavelengths from source(s), Daylight or Darkness
Sample Rate	15 to 20,000 fps	Analog	Analog	Analog	Analog	Analog output of 30 fps	60 fps UV/ 30 fps visible digital, NTSC
Sensor	Wavelength dependent MW: 3 to 5 Micron LW: 7 to 14 Micron	40 kHz typical	40 kHz, some 150 kHz	AM 455 to 1650kHZ FM 88 to 107MHz SW	NIR 0.75 to 1.1 Micron	300 to 400 nm	240-280 nm UV & visible 0.4 to 0.75 Micron
Sensing Distance							
Minimum:	About 6" Lens dependent	About 6 inches, dependent upon signal strength	Varies with signal strength,	Varies with signal strength, strong signal larger minimum radius	Typically 10 feet	18 inches	24 inches
Maximum:	Lens dependent 50mm 100mm	About 60 to 100 feet dependent upon sensor and reflector configuration	Varies with signal strength,	Source strength dependent, can be re-radiated, source must be found by isolation, turning power lines off	Source strength dependent, signal decreases rapidly with distance from source	Source strength dependent, signal decreases rapidly with distance from source	4,000 feet plus, source dependent for corona, arcing can be further

Technology	**Infrared**	**Ultrasound**	**Accoustic**	**Radio Frequency** **AM / FM / SW**	**Night Vision**	**Ultraviolet** **Low-light Viewer or Camera**	**Daylight** **Dual Spectrum Camera**
Applications:							
Corona, Indoors	Close to failure? May be 1 to 3 F rise.	Usually, may also sense reflected sound and sound through	Coupled by oil or solids, transformers, etc Airborne, No	No	Yes, darkness only, lights cause shutdown	Yes, Line of sight, Best for getting image for reporting	Yes, Line of sight, Best for getting image for reporting
Corona, TSM Line & Substation	No	Continuous - Yes, Random - Maybe	Coupled by oil or solids, transformers, etc Airborne, No	No	Yes, darkness only, lights cause shutdown	Yes, Low-light to darkness, no shutdown due to lighting.	Yes, best if 60 Hz to increase sensitivity, weight, ergonomics
Corona, TSM Line Helo	No	No	No	No	No	No	Yes, best if 60 Hz UV frame rate, light weight
Arcing, Indoors	Continuous - Yes, Random - Maybe	Continuous - Yes, Random - Maybe	Coupled by oil or solids, transformers, etc Airborne, No	Yes, antennas may be hazardous around high voltage	Yes, darkness only, lights cause shutdown	Yes, Low-light to darkness, no shutdown due to lighting.	Yes, can "see" at over 1 mile line-of sight, power dependent
Arcing, TSM Line & Substation	Continuous - Yes, Random - Maybe	Continuous - Yes, Random - Maybe	Coupled by oil or solids, transformers, etc Airborne, No	Yes, antennas may be hazardous around high voltage	Yes, darkness only, lights cause shutdown	Yes, Low-light to darkness, no shutdown due to lighting.	Yes, best if 60 Hz to increase sensitivity, weight, ergonomics
Arcing, TSM Line Helo	Continuous - Yes Random - Maybe	Interference sources	No	Yes, antennas may be hazardous around high voltage, high winds,	No	No	Yes, best if 60 Hz to increase sensitivity, weight, ergonomics