APPARATUS AND METHOD FOR UTILIZING ELECTROMAGNETIC ACOUSTIC TRANSDUCERS TO NON-DESTRUCTIVELY ANALYZE IN-SERVICE CONDUCTIVE MATERIALS

BRIEF DESCRIPTION OF THE INVENTION

This invention relates generally to the non-destructive analysis of conductive materials, such as conductive materials utilized in electric power transmission and distribution infrastructure. More particularly, this invention relates to a technique of using electro-magnetic acoustic transducers to non-destructively analyze in-service conductive materials.

BACKGROUND OF THE INVENTION

Diagnostic methods are widely used throughout industry. Often times, diagnostic evaluation is performed by life cycle, or stress testing. For instance, automobile manufacturers test the safety of their car designs by crashing cars under conditions that simulate an accident on the road. Manufacturers of bicycle frames test their designs by cycling loads until failure results. This type of testing is not useful in many instances. The expense of this type of destructive testing is too great for products, such as bridges or buildings. Infrastructure, such as power lines or phone lines, also requires testing that does not destroy or introduce service disruption.

The power industry contains an enormous amount of infrastructure. This infrastructure includes a vast network of transmission lines, distribution lines, and supporting equipment. There is an acute need for devices that can easily provide information regarding the integrity of electrical conductivity and mechanical connectivity of electric power transmission and distribution infrastructure, referred to herein as electric power delivery infrastructure. In particular, it is important to assess information, such as: the integrity of ground connections, the degree of oxidation in conductors, corroded or broken strands in conductors, and discontinuity and damage within shoes or marker balls of transmission lines.

Electric power delivery infrastructure is commonly difficult to access. For example, electric power distribution equipment commonly includes a buried ground mat that is connected to the equipment through a riser that extends from the ground mat to the equipment. Present techniques to analyze a riser requires that the riser be dug out from the ground for examination. For overhead power line conductors, the conductor suspension assembly must be disassembled to inspect the conductor within the assembly. Thus, this prior art technique is very tedious, labor intensive, and costly. In almost all cases, the equipment or transmission line cannot be energized during this manual inspection process. In other words, in-service inspection is not possible. Thus, at the present time, it is very costly to assess the integrity of any type of conductor within the electric power delivery infrastructure.

In view of the foregoing, it would be highly desirable to provide an improved technique for analyzing conductors within the electric power delivery infrastructure. Ideally, the technique would be operative on equipment in its installed, in-service state. In other words, the technique would be nondestructive to the conductor being analyzed during normal operation.

SUMMARY OF THE INVENTION

The method of the invention identifies damage to an in-service conductor associated with the delivery (transmission or distribution) of electric power. Electro-magnetic acoustic energy is generated in an in-service conductor associated with the delivery of electric power. Corresponding return electro-magnetic acoustic energy is then measured. Features are then extracted from the return electro-magnetic acoustic energy to characterize damage to the in-service conductor. The features may be extracted through a feature analyzer, such as a wavelet analyzer or other signal analyzer. The extracted features may be classified using a neural network or fuzzy logic.

The apparatus of the invention identifies damage to an in-service conductor associated with the delivery of electric power. The apparatus includes a transmitting electro-magnetic acoustic transducer configured for engagement with the in-service conductor through an electro-magnetic coupling. The transmitting electro-magnetic acoustic transducer applies a transmitted signal to the conductor. A receiving electro-magnetic acoustic transducer configured for engagement with the conductor receives a return signal from the in-service conductor that corresponds to the transmitted signal. A feature extraction module identifies selected attributes of the return signal. The feature extraction module may include such advanced signal processing techniques as a neural network module and/or a fuzzy logic module to facilitate the feature extraction process.

The invention provides a non-destructive probing sensor that can be used with an in-service conductor used to deliver electric power. Thus, the non-destructive probing sensor can be used without disconnecting or excavating conductors.

The transducers of the invention do not require a couplant with the conductor under test. The absence of a couplant eliminates errors caused by couplant variations, and increases the accuracy of the instrumentation. In addition to its electro-magnetic coupling, the sensors of the invention work at high temperatures and pass through various coatings while scanning at high speeds. Because there is no incidence angle or crystal selection required, the transducers of the invention are less prone to operator error and produce more repeatable results.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention, reference should be made to the following detailed description taken in conjunction with the accompanying drawings, where:

FIG. **1** illustrates an Electro-Magnetic Acoustic Transducer (EMAT) system for non-destructive evaluation of a conductor in accordance with an embodiment of the invention.

FIG. **2** illustrates an EMAT transducer utilized in accordance with an embodiment of the invention.

FIG. **3** is a side cross-sectional view of the EMAT transducer taken along the line **3**—**3** of FIG. **2**.

FIG. **4** illustrates forces and torques created in accordance with an EMAT transducer of the invention.

FIG. **5** illustrates a basis wavelet for EMAT data processed in accordance with an embodiment of the invention.

FIG. **6** illustrates a wavelet transform for a conductor flaw processed in accordance with an embodiment of the invention.

FIG. **7** illustrates packet data processed in accordance with an embodiment of the invention.

FIG. **8** illustrates packet ratio distributions processed in accordance with an embodiment of the invention.

FIG. **9** illustrates an alternate embodiment of the system of FIG. **1**.