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Methods to reduce the risk of wooden pole ignition

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ABSTRACT

A number of reported wooden pole ignition incidences show evidence that the source was located near the pole bolt/pin mounting hardware. This has been observed for environmentally stressed insulators, as well as for larger overhead equipment in situations where the wooden pole has become the dominant part of the leakage conduction path through loss/deterioration of a case ground conductor. In both of these cases, the bolt-to-wood interface is the focal point for the leakage current. A mechanism which can cause pole ignition in these situations is examined with comprehensive details. This paper suggests a novel method to reduce the risk of wooden pole ignition. The mathematical basis of the suggested method is also explained.

1. Introduction

Wooden poles are common all over the world as part of the physical transmission and distribution network. While wooden poles are insulators by nature, the conductance of wooden pole surfaces exposed to the environment can increase based on airborne contaminations. In addition, airborne contamination and weather driven cyclic stresses can deteriorate the porcelain used for the insulation of conduction wires. Medium and high voltage conductors are insulated from the wooden pole by way of pin glass/ceramic insulators. In this situation, the wooden pole is deliberately part of the leakage path, but the insulator is sufficiently specified to prevent significant leakage currents. In addition, utilities design to have a minimum distance of wood between primary and other ground/secondary conductors. This distance concept, as well as the typical construction for overhead pin insulators is shown in Fig. 1.

Overhead equipment with metallic cases, such as reclosers and capacitors, are installed with a physical down-pole wire between the metallic equipment case, secondary neutral, and earth ground. This equipment has insulating devices, between the primary voltages and case, specified to prevent significant leakage current. However, the deterioration of the ground wire over time, theft, or other means of absence, can create a failure condition which allows the wooden pole itself to be the primary conduction path for leakage current, where it normally would not. Missing ground conductor, combined with insulator degradation, can lead to the effect being examined similar to the above pin insulator scenario, conducting through the mounting bolts of the device. In addition, many of these devices have internal components, such as power supplies or other capacitive coupled devices, which can present the full voltage on the case when the ground cable is removed. The mounting bolts and typical installation can be seen in Fig. 2.

With prolonged exposure the insulation integrity of both of these examples can become compromised, and therefore the magnitude of the leakage current would also increase. An IR camera captured the persistent incandescent glow of the bolt caused by the heat produced as result of the leakage current flow in each wood specimen. The threshold value at which the leakage current caused smoldering and glow in wood was measured as 3.2 mA in specimen 1 and 4.1 mA in specimen 2. These observations validated some of the anecdotal evidence which suggests that the ignition of pole fires usually takes place in the junction between the metallic accessories such as king bolts or insulator base-pins and the timber pole (Figs. 3 and 4). This junction forms a hotspot in the wooden structure and is prone to smoldering. The potential mechanisms behind ignition will be explained in the Section 2. Analysis of past wooden pole ignition events suggests that the ignition started at the bolt metal–wood junction. The photographs shown below further support this concept through visual inspection. It is also found to be consistent in laboratory tests that the metal–wood junction is the most susceptible to the pole ignition process [1] contingent to wood smoldering due to localized high temperature. It is worth noting that, in the absence of a valid case ground connection, overhead equipment also poses the risk of accidental electrocution to workers. Lack of ground connections allow stray voltages to be present

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on what otherwise would be grounded surfaces. While most utility workers are trained to always assume that these surfaces are 'hot' when first approaching them, there is still an increased safety risk. Unfortunately, no utilities today are actively monitoring for a valid ground connection to each overhead device, as this would be an expensive proposition.

2. Mechanisms behind ignition

2.1. Smoldering followed by high voltage arc at the bolt–wood junction

Older wooden pole surfaces exposed to harsh weather conditions and seasonal stress can develop enough conductivity from surface contamination often assist pole ignition [1]. Brine precipitation can be built up on the wood surface providing a lower impedance path down the pole. These surface contaminants allow sufficiently large tracking current to develop in the wooden pole. Close to the point of origin, near the wood metal junction, high temperatures are created. This process can begin with a corona discharge that ionizes the dry air in the vicinity of the bolt head. Wind can also intermittently blow ionized air, exposing its high resistivity to the leakage current. Due to high impedance, it can create a high voltage in the bolt–wood junction. It is shown in the subsequent analysis that the leakage current passed through this small area poses a high enough thermal energy density per unit area to ignite the pole. After ignition, this fire is sustained by the dry, due to the subsequent temperature rise, wood surrounding the heated area. At a high enough temperature to smolder the dry wood surface, a subsequent electric arc can lead the dry wood surface (hydrocarbon) to sustain ignition. The intensity of the liberated energy from the arc would be sustained by the magnitude of the leakage current.

The ignition process is strongly aided by the wood-through metal bolt that attaches through the pole. It continually forms the mechanical vulnerable junction with the wooden pole. Metal exposed to open environment is subject to oxidation, which means that metals such as iron loose electrons in the presence of environmental catalyst such as sunlight, temperature, water vapor and airborne impurity such as positive ions. The rate of oxidation of metal surface due to its exposure to varying environmental condition varies from one kind of metal or metal alloy to another kind. Regardless of how long a certain metal or metal alloy may take to show a visible oxidation symptom it is well observed that the reaction starts with loosing electrons to air containing water molecule, acid or salt within short period of time, typically a few weeks. This oxidation process causes the metal to be positively charged and act as cathode in the electrical sparking process [2].

2.2. Voltage surge at the ungrounded pole mounted equipment

Pole top equipment including transformers, reclosers, line charging capacitors or isolators have a grounding contact. However, grounding is deemed optional by most of the electrical regulatory body for the pole mounted equipment more than 8 feet above

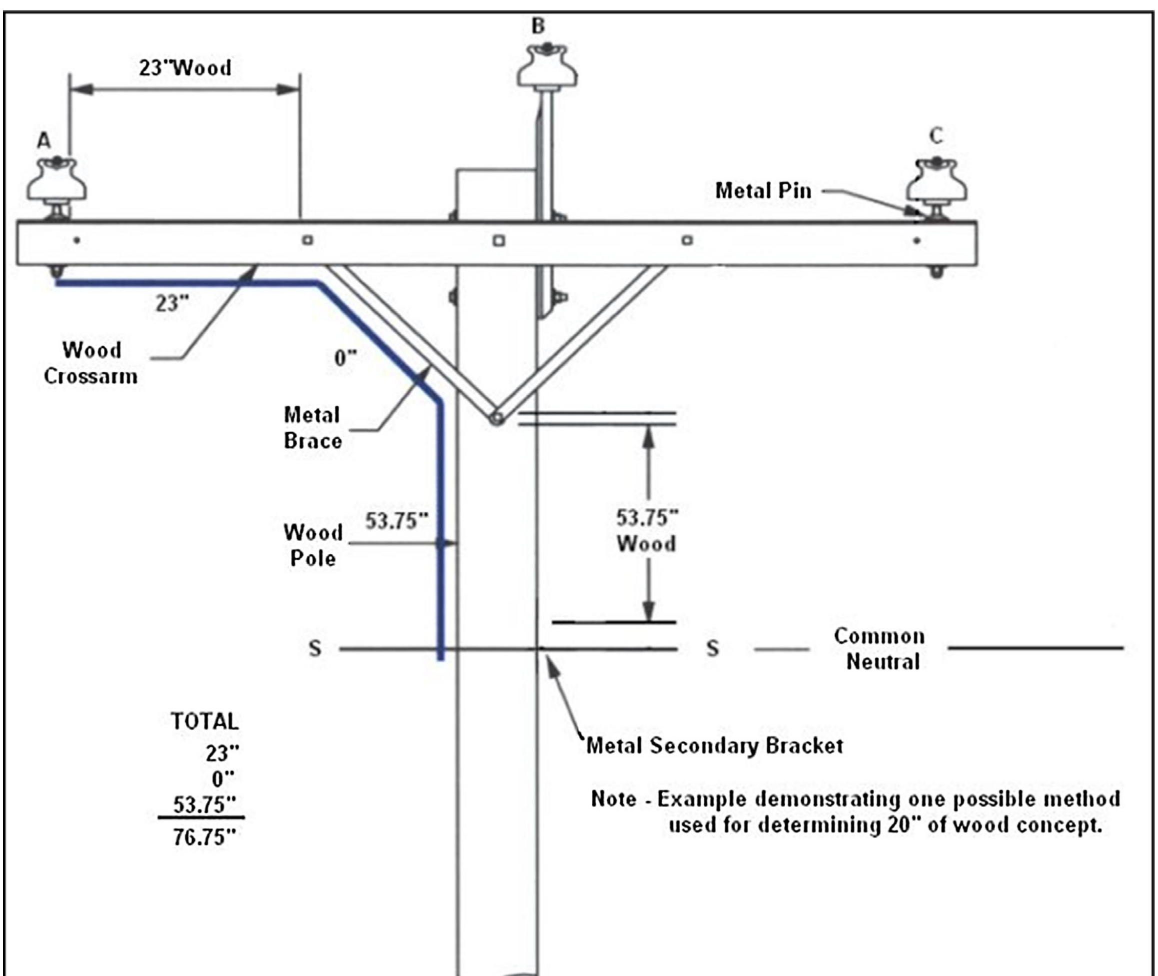

Fig. 1. Typical overhead pin construction, showing leakage path.