HIGH-IMPEDANCE FAULTS

Detection of High Impedance Faults (HIFs) on distribution networks is a long-standing problem for Electrical Engineers. It remains a great challenge to identify an arcing, downed conductor. Detecting and removing power from fallen wires is very important for safety of property and human life. Recent events of High Impedance faults have spurred the effort to protect against the destruction caused by this situation. The challenge is that a downed conductor exhibits an intermittent, high-impedance, low-current signal that is difficult to sense for conventional relay protection elements.

DEFINITION AND CAUSES OF HIGH-IMPEDANCE FAULTS

A high-impedance fault (HIF) occurs when a primary conductor makes unwanted electrical contact with a tree, pole, structure or with the ground, and there is a large impedance restricting the flow of electrical current. The fault current can be at a few milliamps to few amps of primary current, much smaller than the current that standard overcurrent elements can detect. Even in cases where the instantaneous fault current exceeds standard overcurrent thresholds, the duration of this transient event is so short that standard fuses and overcurrent elements will not clear or pick up. There is little threat of damage to power-system equipment from these transient events, but these events are a safety and fire hazard. Line crews responding to a downed or broken conductor event seldom document these as such on trouble reports. It is quite challenging to detect HIFs; it requires special methods, combining multiple techniques.

Downed and broken conductors are the causes of high impedance faults. The conductor touching the ground might be intact, or, it could be broken. If the conductor touches the ground or other surface, and remains intact feeding a load, then we call this a “downed conductor”. This can be caused by support failure, heavy-loading sag, or an object (tree) on the distribution line. Weather, nature, and faulty equipment can cause this problem. Icing and tree limbs leaning on distribution circuits cause lines to sag and to conduct current intermittently to ground. If a utility does not do an adequate job of clearing vegetation around distribution lines, then tree limbs touch the line irregularly, causing arcing on intact conductors.

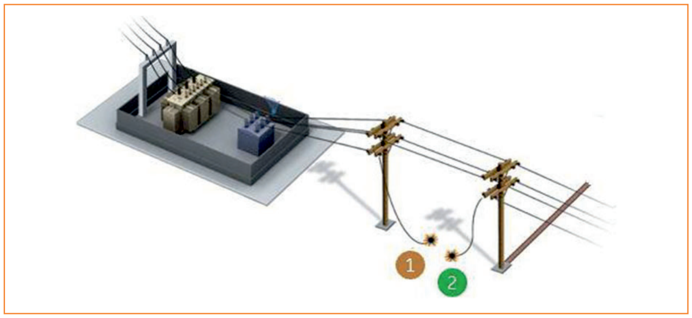
Contaminated and failing equipment, such as disconnects, fuses, and dirty insulators can cause high impedance faults in the distribution system.

High impedance faults are generally not detected by conventional protection functions like overcurrent, ground fault, distance, differential etc. because of the magnitude of impedance involved in the fault path and the nature and characteristic of the fault current are special and different than the conventional fault current profiles. Each type of high impedance fault is unique in terms of magnitude of fault current, nature, characteristic and waveshape. Majority of the high impedance faults are single phase to ground faults but this can involve phase to phase elements as well. Because of the inability of the conventional protection functions to detect high impedance faults especially high impedance phase to ground faults, the electrical conductor remains live under such condition and as can be imagined, poses a huge and significant risk to wild life and more importantly human life. Atmospheric and geographical conditions have a significant role to play in highimpedance phase to ground faults since they have a direct impact on the magnitude and characteristic of the fault current.

Protection from the High impedance fault (HIF) has been one of the biggest challenges in the power distribution network. Among the disturbances that may occur on distribution systems, high impedance fault (HIF) is considered one of the most distressing. A HIF occurs due to the contact between a primary energised conductor and a highly resistive surface as soil, sand, asphalt or even tree branches. The main characteristic of HIF is the amplitude of the fault current, which is usually insufficient to sensitise a conventional protective system. As a result, HIF is neither detected nor eliminated, affecting the reliability of the electrical system and bringing danger to living beings through the possibility of electric shock and fire hazard due to the presence of the electric arc. HIF typically occurs when the conductors in distribution network break and touch the ground surface; or lean and touch a tree branch. This fault, with current magnitude close to the load current level, is not detectable by over-current relays.Therefore, HIF occurrence is a major challenge for distribution networks.

Causes of HIF Faults

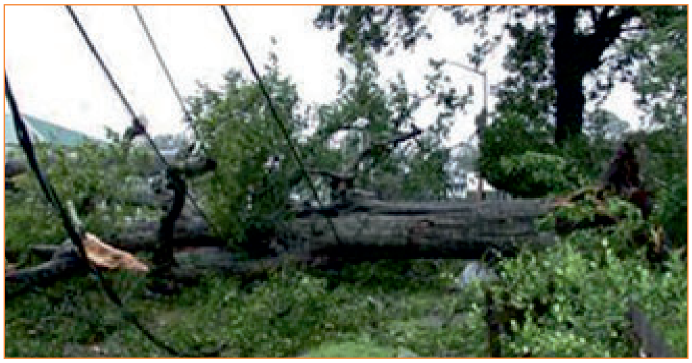
A) Broken Conductor on Ground (Downed Conductor)



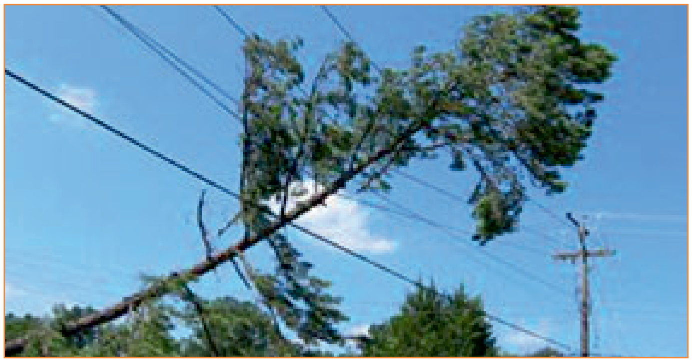
On Grass Surface

On Concrete Surface

B) Broken Pole Allowing Conductor to Ground or Conducting Surface contact



C.) Broken Pole, Tree Limb or Ice Allowing Conductor Sag



D) Intermittent Contact with Tree Limbs or Other Objects

E) Contaminated or Failing Equipment eg. Insulators, transformers, disconnects, fuses etc.

Primary equipment such as insulators, transformers, disconnectors, breakers, fuses etc. might be contaminated in a harsh environment or start to fail causing very intermittent failures with very low fault current.

Complications due to HIF:

- Undetected and isolated, live Downed Conductors can be fatal to public and line crewmen.
- HiZ faults often arc and can be a fire hazard.
- Inability to detect HiZ faults can cost utilities liabilities/service issues.
- HiZ performance must be verified under normal conditions.
  (noisy feeders, arc furnaces, arc welders, capacitor switching, line switching and load tap changing)

Misconceptions about HiZ faults:

1. **Misconception:** Properly set, 50/51/50SG (Sensitive Ground Instantaneous Over Current) detect, trip and clear all faults on distribution feeder.

   Reality: HiZ faults can be low current (mA –amps), lower than loads, hence 50/51/50SG unable to detect lots of HiZ faults.

2. **Misconception:** 50SG used to detect low ground current, will detect and clear HiZ faults

   Reality: Unbalanced loads limit sensitivity of 50SG. HiZ may result in more balanced loading and reduced In; mislead 50SG not to operate.

3. **Misconception:** Over time, fault current increase and 50/51 operate.

   Reality: Fault current decreases as conductor burns, moisture evaporates, sand fuses, etc. 50/51 seldom operates after first minute.

4. **Misconception:** Faults always clear on my system.

   Reality: Engineering staffs believe HiZ rate is low, line crews report many downed conductors still hot when arrive on scene.

5. **Misconception:** HiZ detection available solve all HiZ problems.

   Reality: Available HiZ will detect many faults, 50/51/50SG cannot, no known HiZ detection can detect 100% of all HiZ.

References:

1. Paper on High-Impedance Faults: Comparing Algorithms.
2. High-Impedance Faults:Comparing Algorithms by Daniel Ransom, PE, GE Grid Solutions
3. High-Impedance Fault Diagnosis: AReview by Abdulaziz Aljohani and Ibrahim Habiballah
4. Tutorial on High Impedance Fault Detection: JC Theron, Abraham Varghese, Amit Pal, GE Grid Solutions in 71thTexas A&M Conference for Protective Relay Engineers 2018.

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