Incipient Conditions on Electric Power Circuits

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Incipient*: adjective; beginning to develop or exist; beginning to come into being or to become apparent.* (source: Merriam-Webster online)

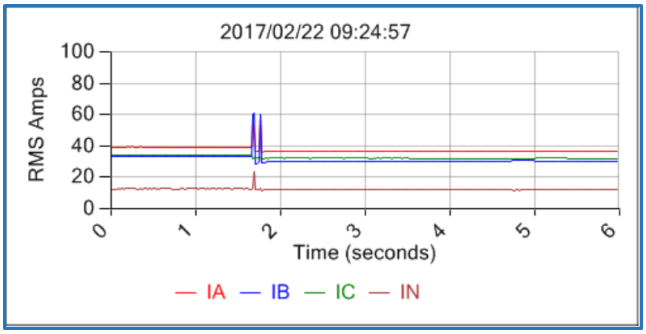
A practical definition of an incipient condition on an electric power circuit is anything likely to cause a fault, outage, or other negative event in the future. A common misconception holds that incipient conditions manifest themselves only as low-amplitude electrical events, and conversely that high-amplitude electrical events do not represent incipient conditions. More than a decade of Distribution Fault Anticipation (DFA) field investigations demonstrates that this often is not true. Incipient conditions can manifest themselves as high-amplitude electrical events, although often in ways that conventional systems and processes fail to recognize as predictors of future events. Field experience demonstrates that an incipient condition may have any combination of the following characteristics:

- It may or may not have caused past customer complaint(s).
- It may or may not have caused past high-amplitude electrical event(s).
- It may or may not have caused past conventional protection operation(s).
- It may or may not have caused past outage(s).

It is the potential to cause negative future events, not the amplitude of past events, that makes a condition incipient. Incipient conditions are predictive of consequential events that may occur in the future. Documented examples of incipient conditions include the following:

- Fault-induced conductor slap (FICS) – FICS events draw substantial current and often cause circuit-level momentary interruptions or sustained outages. FICS events represent incipient conditions, because a span that has experienced FICS once is prone to experiencing it again. FICS conditions are difficult to diagnose with conventional tools and practices, and therefore often are not diagnosed properly or corrected. FICS events tend to occur repeatedly in a given location. Future consequences of this type of incipient condition can include additional faults, interruptions, outages, equipment stress, progressive conductor damage, and possibly broken conductors.
- Cracked bushings – A cracked bushing may result in a high-amplitude flashover fault, often when rain or dew wets the surface of the bushing. Momentary trip/close operations can clear individual flashover incidents but leave the underlying incipient failure condition undiagnosed. Future high-moisture events can result in additional flashover faults and trip/closes. Potential consequences of this type of incipient condition include additional faults, system stresses, damaged conductors, catastrophic equipment failures, outages, and possibly broken conductors.
- "Hot spots" in clamps and switches – A failing in-line clamp or switch can develop a "hot spot," which can cause progressive erosion both of the clamp and of the conductor. Over time such a condition can cause intermittent power quality issues, mysterious fuse operations, eroded conductors, and possibly broken conductors.

- Failing capacitor switches – Switched capacitor banks experience a high incidence of failures, including failures of their switches. Vacuum and oil switches can develop incipient failures that produce electrical transients that are not detected by conventional systems, including sophisticated capacitor controls. These incipient failures can evolve and cause substantial power quality problems and catastrophic switch failures.



The foregoing list is not intended to be exhaustive but rather to demonstrate that incipient conditions take many forms and cause both high-amplitude and low-amplitude electrical events. Of the examples listed, early-stage "hot spots" and capacitor failures may cause only low-amplitude electrical activity, but FICS and cracked bushings can cause high-amplitude events and interruptions. Personnel often are unaware of incipient conditions, even those that cause intermittent, high-amplitude events, and their lack of awareness limits their ability to diagnose the problems and take appropriate corrective action.

Distribution Fault Anticipation (DFA) Technology and Incipient Faults

DFA technology, developed collaboratively by Texas A&M Engineering and the Electric Power Research Institute, Inc. (EPRI), is a multi-function, data-driven technology that provides utility companies with awareness of circuit conditions that conventional monitoring and protection systems do not provide. DFA technology detects and helps locate existing problems. DFA technology also detects and helps locate incipient conditions. It does this by continuously monitoring circuit current and voltage waveforms, in high fidelity, from substation CTs and PTs, and applying sophisticated digital signal processing, pattern matching, and other software techniques that report ongoing and developing circuit events and conditions.

- DFA technology can detect the unique electrical signature caused by FICS and provide information to target a search for its location.
- DFA reports intermittent flashover faults, caused by such things as cracked bushings, and provides information to help locate the underlying, incipient problem. It does this even when fault episodes are separated in time by weeks of inactivity.
- DFA reports in-line clamp and switch "hot spots" as they evolve, often intermittently over periods of days to weeks, so that a utility company can make informed responses to vague, hard-to-diagnose symptoms such as mysterious fuse operations and intermittently flickering lights.
- DFA reports multiple specific types of capacitor bank failures and incipient failures, including those not detected by advanced capacitor controls, so that the utility company can take corrective action.

With conventional systems and processes, utilities often remain unaware of such conditions and therefore unable to correct them. A DFA incipient fault report can be the first or only notice they receive. It is this awareness that enables them to act upon these incipient conditions.

DFA technology does not purport to detect all negative circuit conditions or prevent all problems, incipient or otherwise, but it has demonstrated the ability to alert utility companies to numerous existing and incipient conditions that are not found by conventional means. Improved awareness enables the utility to be more proactive in addressing some incipient conditions, thereby preventing some negative future events and outages, and to respond with faster, more targeted responses to outages and other trouble.