Power Disturbance Analysis

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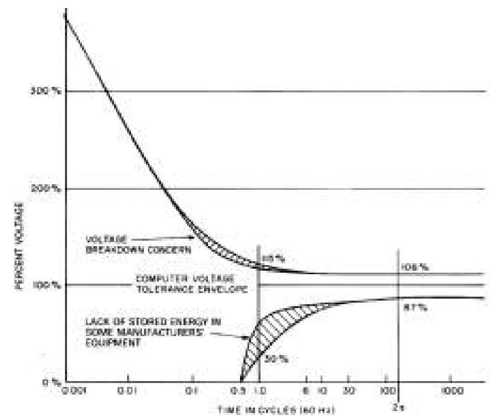
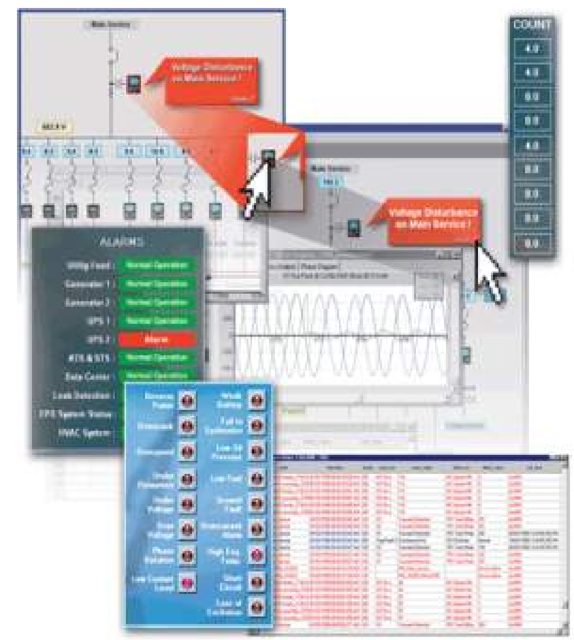
Schneider Electric

Why worry about disturbance analysis?

- There are many ways to analyze power disturbances
  - Common methods include magnitude and duration
  - For example, ITIC and CBEMA
  - These help determine the potential impact of the disturbance
- Another analysis is finding the location and cause of the disturbance
- The benefits include:
  - Determining the source of power quality events more accurately
  - Minimizing repetitive events by quickly locating disturbance sources
  - Increasing production uptime by improving facility power quality levels





Determining disturbance location

- This presentation contains two approaches to disturbance location using power quality meters, in lieu of traditional fault location devices
  - Hydro-Québec system - Voltage Drop-based Fault Location (VDFL) technique [1]
  - Schneider Electric – Disturbance Direction Detection (DDD) [2]
- The Hydro-Québec system focuses on voltage drop, and is well suited for utility overhead radial distribution systems
- The Schneider Electric approach utilizes voltage and current analysis, and is mainly intended for demand side applications

Hydro-Québec system - Voltage Drop-based Fault Location (VDFL) technique

- Intermittent voltage disturbances are often related to maintenance issues such as tree limbs, defective insulators, etc.
- Hydro-Québec determined that if they could accurately locate the source of these disturbances, a maintenance program could be developed to address the problems before they get worse
- Traditional line impedance systems are limited by unknown parameters such as fault impedance, line complexity, unbalanced loads and the difficulty of building an accurate line model
- This system utilizes multiple power quality meters on the distribution network for voltage drop data, and provides the additional benefit of system performance data, such as voltage unbalance, harmonic content, etc.

Hydro Québec

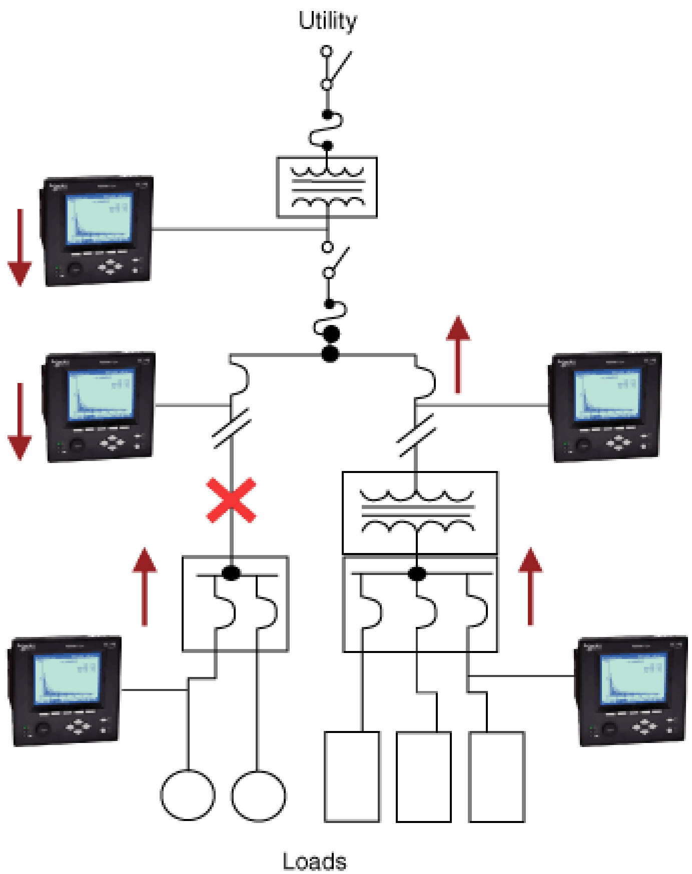
Voltage Drop-based Fault Location technique

- This technique includes the following steps:
  - Voltage drop measurement from at least 3 devices
  - Automated grouping of the measurements
  - Modeling of the distribution line
  - Calculation of the fault distance using Hydro-Québec's algorithm
- While time stamping helps with the grouping of the measurements, voltage-drop waveform characteristics are also analyzed to aid in the grouping accuracy
- A line model is created to determine the most likely locations
- The more complex the feeder topology, the more potential locations will be determined – but the number of locations is much smaller than if a centralized measurement system was used

Voltage Drop-based Fault Location technique

- Pilot Project
  - Initial development was done on two distribution feeders from 2002 to 2006
  - The pilot project was for 2 years with 2 more distribution feeders
  - The result included 26 confirmed fault locations for the total of 4 monitored feeders.
  - With the exception of 1 fault, all were calculated to less than 332 meters from the actual locations. The exception was 619 meters.
  - Based on the average distance to end of line of 23 km, the average error was 0.8%, or 2.7% in the worse case, based on accuracy of the numerical assessment, database errors, and actual distance evaluation inaccuracies
- Example use case – the failing insulator
  - 253 km distribution feeder in rural southwest Montreal with 2074 customers
  - Customers complained about multiple faults
  - PQ devices were deployed to capture the data
  - A fault was captured, resulting in 2 possible locations being calculated
  - Also a 1.3 kV fault amplitude was deduced by the system indicating tree contact or a defective insulator
  - Site inspection discovered the failing insulator and a damaged fuse which would have failed under the next winter load rise. Both problems were corrected.

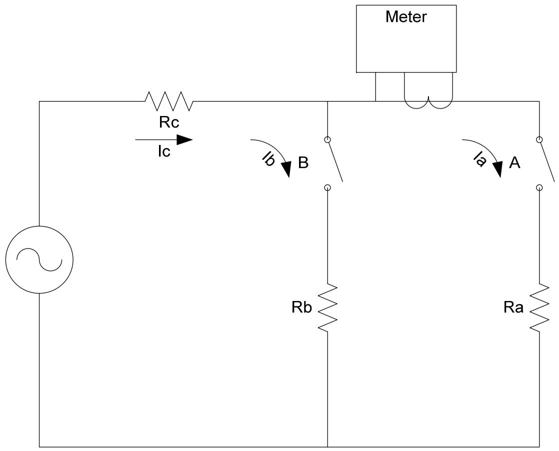
Schneider Electric - Disturbance Direction Detection

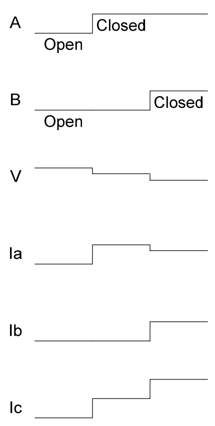


- Determine the location of a disturbance relative to the meter.
- Analyzing disturbance direction detection information from multiple meters in a power monitoring system enables the location of the cause of the disturbance to be determined more quickly and accurately.
- The ION Disturbance Direction Detection module was created for this application and launched in v350 firmware for ION7x50 meters in 2008

DDD – Theory of Operation

- Disturbance Direction Detection is an application of Ohm's Law.
- When switches A and B are open, all currents are 0 and the meter voltage reading is that of the source.
- When switch A is closed, Ia and Ic increase and the meter voltage reading will decrease due to the voltage drop across Rc. Current increase with voltage decrease is the signature of a downstream event.
- When switch B is closed, Ib and Ic increase. The voltage drop across Rc increases so the voltage measured by the meter decreases. Ia also decreases because the voltage driving it decreased. Current decrease with voltage decrease is the signature of an upstream event.





Disturbance Direction Detection – how?

- When the disturbance is captured, the change in voltage and current are compared with 2 cycles prior to the event
- To increase accuracy, 3 comparisons are made of the event vs. the circuit prior to the event
  - The uncertainty comes in the inability to detect a small magnitude event in a variable "noisy" waveform
  - The 3 comparisons include a point-by-point time scale; a window-by-window (fraction of a cycle) time scale; and a cycle-by-cycle time scale
  - Each comparison evaluates the change in voltage and current to determine direction
  - The magnitude of the event is also compared to the pre-event “noise.”
  - The combination of these comparisons results in the confidence level of the DDD calculation

Disturbance direction detection – case study

- A large industrial user experienced a disturbance early one morning, causing equipment to trip offline.
- No cause could be found in the facility.
- Fortunately the user had a Schneider meter installed on the main and checked the event log. It indicated a high confidence of the event occurring upstream from the metering point (i.e., the utility)
- Further investigation revealed a single phase fault had occurred from the utility
- Three months later, during a thunderstorm, the facility experienced major disturbance, that involved blowing all 3 fuses in the switchgear. This time the meter indicated the event occurred downstream (i.e., in the customer's facility)
- The investigation found the cause to be a piece of gasket material lying against the bus bar in the switchgear

Questions?

References

1. “Accurate Fault-Location Technique Based on Distributed Power-Quality Measurements” CIRED2007 Paper 0615
2. Disturbance direction detection in a power monitoring system by Larry E. Curtis, US Patent number: 7138924