Finding Fault Location Accurately with Traveling-Wave Fault Location

In our Tech Talk, **Finding Fault Location Accurately with Traveling-Wave Fault Location,** we discussed how to use the traveling-wave fault location (TWFL) technique to determine fault location, with excellent accuracy rates. This technique is well-proven under a variety of circumstances including high and low impedances, and varying line lengths (as much as thousands of kilometers) with and without reactive compensation.

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QUESTION	ANSWER
What are the differences between single-ended and double-ended TWFL? What are the limitations to implementing single-ended TWFL solutions?	Single-ended TWFL solutions have been around for a while and pose some challenges when using only one end of the line. It is difficult for the IED at one end of a line to distinguish or interpret the traveling-wave reflections from taps and neighboring terminals. The double-ended TW-based method is simpler because this method has more information about the power system. Essentially, the double-ended method depends on the identification of the first fault-induced incident TW arrival times at both the local and remote terminal ends; this information is gathered via a communications channel. Reflections and wave distortion are not an issue in the double-ended method. This method requires a communications channel and satellite time at both ends. This equipment is readily attainable, the communications channel is reliable, and the costs today are small compared to the benefit of the application. Of course, problems can occur with the double-ended method because of communications channel loss or a GPS clock failure. There is interest in the single-ended TWFL method because it does not require any communications link or time-stamping devices. The principle behind single-ended TW-based algorithms depends on the correct detection of the delay between the first incident wave and the successive reflections from the fault. Lately, single-ended TWFL methods use extensive mathematical modeling and fault-pattern learning to make a reasonably accurate solution. Some techniques distinguish the fault reflected wavefront from other surges on the grid by comparing it to similar shapes presented by fault-induced incidents and reflected surges.
I've been thinking about using traveling-wave protection (TWP) on transmission lines. (TWP is different from TWFL.) Is this a good idea?	Consider very carefully whether to employ TWP on transmission lines. Some of the limitations of TWP are the following: • Exhibits questionable performance • Not standard/universal • Requires specialized test equipment and knowledge • TWP incremental speed not worth the risk—no appreciable benefit over good distance or line-differential protection It's important to weigh the potential impact on dependability and security so that you are comfortable with the decision.
Is there any impact on the fault-location distance calculation detection on a double circuit tower due to mutual induction? How do travelling waves compensate for mutual coupling?	TWFL is not affected by mutual impedance. The fault wavefront travels quickly down the line; the wavefront speed is not affected by inductive reactance. As covered in the webinar, the fault-location equation does not have reactance/impedance in the calculation.

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Can we use fault locator and distance protection at the same time?	Yes, the RPV311/RA333 fault-location solution can be added to both D60 distance and L90 line differential protection schemes.
Is the RPV311 a single contingency device? Can it perform if an internal fault is preceded by an external fault? How many consecutive faults can the TW system handle?	The TW record is a COMTRADE file with three cycles prior to the trigger plus one cycle after the trigger; this is approximately 67 ms at 60 Hz and 80 ms at 50 Hz. The RPV311 takes about 30 seconds to create a record and it can create as many as four records at the same time. When four records are being created simultaneously, new triggers will not create a record and the "BUSY" LED in the RA333 illuminates. After the record from the first trigger is finished, the RA333 captures the next trigger. Trigger events that occur within a time window of one cycle create a single TW record file. If another trigger happens after one cycle from the first trigger of the event, then the RPV311 creates another TW record file. This capturing of triggers and recording TW records is more than adequate for real-world transmission-line fault events, including evolving faults and switch-on-to-fault operations.
How many lines can you monitor with the RPV311/RA333 system?	If the voltage is sourced from a bus VT you need only one RA333 module to capture traveling waves from all the lines connected to that bus. For other configurations you can connect as many as four RA333 modules to one RPV311 processing unit—which gives you two double-ended lines.

QUESTION	ANSWER
What about switch-on-to-fault (SOTF) situations?	When a short circuit occurs right after the circuit breaker closes, the behavior of the traveling waves is different from regular faults. The circuit breaker itself can create traveling waves that can be misinterpreted as traveling waves from the fault. This makes the fault location calculation more difficult. To avoid this problem, the DR Manager software analyzes both the COMTRADE waveform from the fault and the TW COMTRADE records to identify that a switch-on-to-fault event occurred. Then, the software applies a special fault-location algorithm. Special conditions need to be met for switch-on-to-fault (SOTF) events to be located automatically: • The fault must be at least 6 km (3.6 miles) away from both line terminals • The maximum length for a transmission line is 2,000 km (1,200 miles) (this is very long!) • Fault location for SOTF events will not work for mixed (hybrid) lines • There needs to be a corresponding waveform recording for each event SOTF events are rare. The DR Manager software indicates in its reporting window when an event is characterized as a SOTF event to alert caution and instigate double-checking the recordings.
How about close-in faults? How close can the TW system detect traveling waves?	Our TWFL method is double-ended and doesn't require identifying any reflections, as opposed to the single-ended method. There is no limitation on close-in the faults, the method can locate these from 0 to the total line length without impact on the accuracy. This is one of the benefits of using the double ended TWFL solution—it does not rely on identifying reflections that can be more easily distorted and attenuated. Also, it can cover many more use cases than the single-ended method, such as close-in faults, short lines, long lines, high-impedance faults, hybrid lines, tapped lines, and railways/ traction.
Does the TWFL theory work for all voltage levels?	There is no limitation on the voltage level or type of system, as long as the fault is sufficiently fast and/or powerful to generate the traveling wave. GE Vernova has practical experience with lines from 69 kV to 725 kV.

QUESTION	ANSWER
What is the back-up method adopted for fault calculation in case of a communications channel failure?	The GE Vernova TWFL method relies on traveling-wave records captured and generated in the RPV311. These records are non-volatile. Therefore, even if there is a communications channel failure, it does not impact the fault location—it just delays the eventual calculation. Once the channel is restored, the information from both sides is available and the DR Manager software performs the fault location calculation. If an immediate fault location is needed during a communications channel failure, the impedance-based fault location method is available in the RPV311.
Can traveling waves be used to diagnose equipment issues on a transmission line?	There are several studies that explore the use of traveling wave technology to identify non-critical failures before these evolve to a fault. Any electromagnetic transient can generate the traveling wave as long as it is sufficiently fast and powerful. Therefore, it is possible to use TWFL to identify (and locate) partial discharges that are generated by polluted or broken insulators, transformers, or other partially broken components in the transmission system. Although the technology provides this capability, we don't offer any "off the shelf" solution because each case can be very specific. However, we'd love to partner with you for any advanced project in this area!

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