APPLICATION NOTE

ERL PHASE Power Technologies Ltd

L-PRO Line Protection Relay

Using a Distance Relay as a “Mini-DFR” for Small Transmission Substations

Introduction

Disturbance fault recorders (DFRs) provide data that helps analyze the operation of the transmission system after local transient events (such as short circuits), and after wide area disturbances (such as dynamic power swings). The rise of microprocessor-based DFRs have made them much less expensive to install, operate, and maintain, thereby increasing the number of fault recorders used on a typical system. However, in many small transmission substations (especially ones at voltage levels below 345kV), DFRs are still too costly to justify. Microprocessor relays can provide fault recording capabilities for these substations, although they do have some recording limitations in comparison with full-fledged.

DFRs:

- Relays are typically limited by a sampling rate too slow to accurately record some phenomena, such as CT saturation
- Relays typically only record the filtered data used in protection processing, and not the raw power system data desired in fault records
- • Relays are designed only to accept enough current and voltage inputs to perform a specific protection application, not to provide data for an entire substation.

Every transmission line would need a microprocessor relay for adequate recording for a single substation.

- Synchronizing records between multiple relays is performed manually, a step which is very inefficient and time consuming
- Retrofitting an existing substation for recording on all transmission lines, by adding microprocessor relays, is also very costly and time-consuming, and is often more costly and time consuming than installing an actual DFR

The L-PRO Line Protection Relay from ERLPhase, a complete microprocessor-based distance protection relay, can provide adequate fault recording for a small transmission substation. The L-PRO includes 18 analog input channels: 4 three-phase current inputs, and 2 three-phase voltage inputs. These analog input channels are usable both for protection functions, and for recording functions. The L-PRO, like all ERLPhase protective relays, records unfiltered system data at 96 samples per cycle, providing the resolution necessary to capture CT saturation, voltage sags, and other short duration power system phenomena. Fault records may be triggered by any protection function, by over-current conditions on any of the additional current inputs, or by external contact triggers. Fault recording captures waveforms on all 18 analog input channels, so the effect of a fault on the entire substation is easily seen and analyzed. Like regular DFRs, the L-PRO provides fault records with user-adjustable length, stored in non-volatile memory. In addition to transient fault records, the L-PRO also includes power swing recording, to capture information on wide area disturbances, as well as the impact of routine switching of transmission lines and generation. This application note describes a typical installation of the L-PRO Line Protection Relay operating as a “mini-DFR” in a small transmission.

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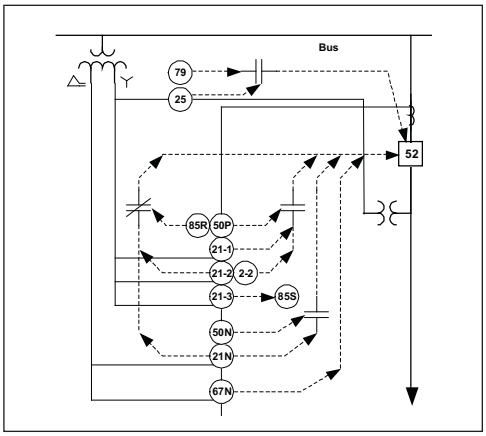
Existing Protection Scheme

For a typical application of the L-PRO as a “Mini-DFR”, consider a small 161 kV transmission substation, with 4 single breaker transmission lines. The station also includes a 161 kV-13.8 kV distribution transformer and several distribution circuits. The small size of the station means it’s not cost effective to install a separate DFR. 161 kV stations are also generally not critical enough to justify installing a DFR.

The protection system on all 4 transmission lines is identical, and employs electro-mechanical relays. The protection scheme is a Directional Comparison Blocking (DCB) pilot protection scheme, using power line carrier for the blocking signal. Each line uses 2 three-phase distance relays to provide forward-reaching Zone 1 and Zone 2 protection, and a reverse looking three-phase distance relay for carrier start. Ground fault protection is provided by both a carrier ground distance relay, and a directional overcurrent relay. All lines include synchronism check for automatic reclosing.

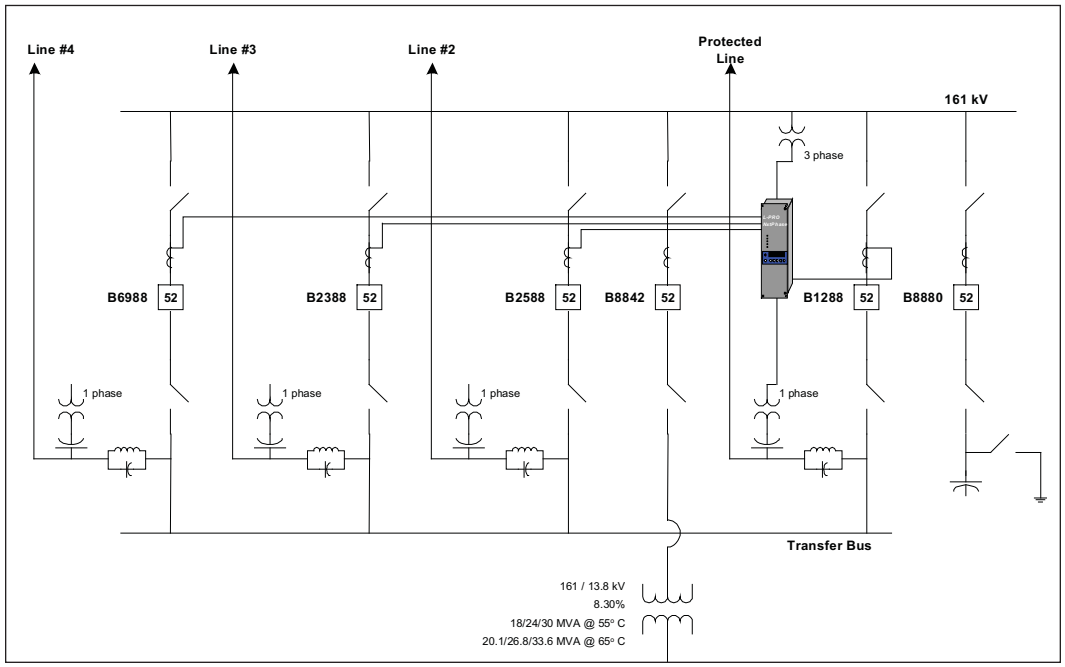


Line protection scheme

Currents for all protection functions come from a set of bushing CTs located on the line circuit breaker. Voltages for all protection functions are provided by a three-phase set of VTs located on the 161 kV bus. These VTs have dual secondaries, with 1 set wye-connected to provide 3 single-phase voltages for protection functions, and 1 set connected broken-delta to provide a 3V0 polarizing voltage for the electro-mechanical ground relays.

Reclosing on these transmission lines uses 1 reclosing attempt, on ground faults only. Reclosing also checks synchronism conditions, between the bus voltage, and a single-phase CCVT connected to A-phase of the protected transmission line. Reclosing is permitted when synchronism conditions are met, or when Hot Bus-Dead Line conditions are met.

L-PRO Protection Application



L-PRO as “mini-DFR”: one line diagram

Replacing the protection scheme of one of the transmission lines allows the L-PRO to be a “mini-DFR” for the substation. The L-PRO is configured to replicate the existing protection of the 161 kV line exactly. The L-PRO pilot protection scheme is set to “DCB”. For both the phase and ground distance elements, Zone 1 and Zone 2 operate in a forward direction, with Zone 4 reversed for carrier start. Carrier set signals are sent and received via contact input. Additional ground protection is provided by a forward directional ground overcurrent element. Automatic reclosing is configured to provide 1 reclosing attempt, with a 5 second reclosing interval, supervised by the internal synchronism check element. Reclosing is allowed on both synchronism conditions, and on Hot Bus – Dead Line conditions.

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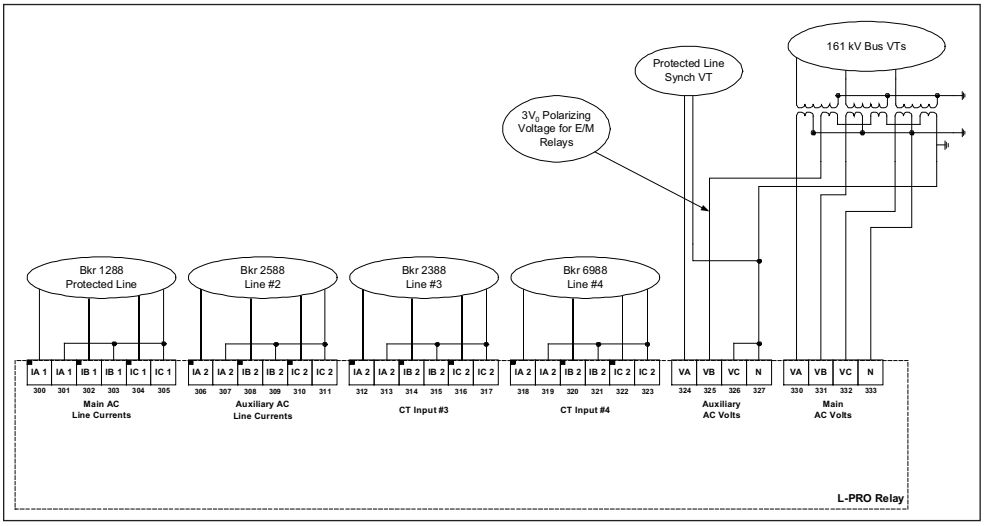
Connections

For the primary protection application, the line currents must be connected to the Main AC Line Current inputs (terminals 300-305), and the bus VTs must be connected to the Main AC Volts inputs (terminals 330-333). As described, the synchronism voltage source comes from a CCVT located on A phase of the protected line. The output of this VT must be connected to the Phase A Auxiliary AC Volts input (terminal 324) of the L-PRO. The protection functions, therefore, use 7 of the available 18 analog input channels.



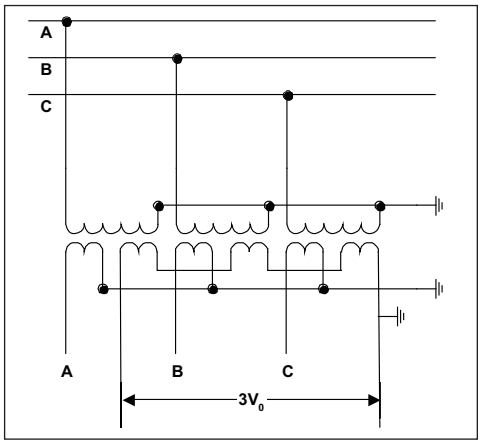
Analog channel input connections

L-PRO Recording Application

When applied on a single breaker transmission line, as in this application, the L-PRO has 3 remaining sets of three-phase current inputs for use as a “mini-DFR”. These inputs are used to capture waveforms on the other 3 transmission lines in this substation for a fault event on any of the lines. Line CTs from the other lines are directly connected to the L-PRO via: Auxiliary AC Line Current inputs (terminals 306-311), CT Input #3 (terminals 312- 317), and CT Input #4 (terminals 318-323).

Since all 4 transmission lines use voltages from the same set of bus VTs for protection functions, the L-PRO provides voltage and current measurements, which are useful for analysis of a fault on any of the lines and can determine the actual tripping impedance for the line.

The bus VTs used in this application are dual winding VTs. The second set of windings is connected in a broken-delta configuration to provide a polarizing voltage to the electro-mechanical ground relays. This voltage may be connected to one of the Auxiliary Voltage inputs for recording purposes. There will only be 3V0 voltage when an unbalanced fault exists, so there will be no interference with the synchronizing voltage, or the synchronism check function.



Dual winding VTs

Configuring the L-PRO for use as a “Mini-DFR”

The L-PRO lends itself well to application as a “Mini-DFR”, not just due to its functional capabilities, but from a configuration standpoint as well. The basic steps for configuring the L-PRO for use as a “Mini-DFR” are the same as a regular DFR:

- Describe the inputs (analog and digital)
- Set up recording
- Configure the trigger events

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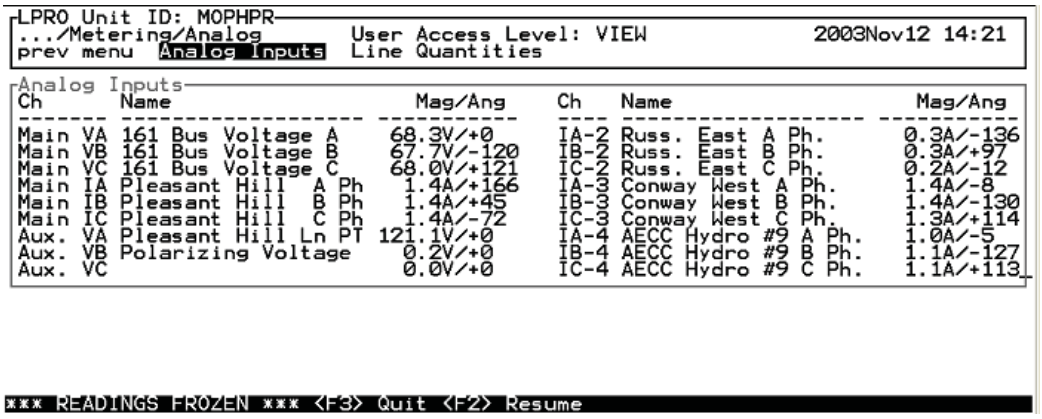
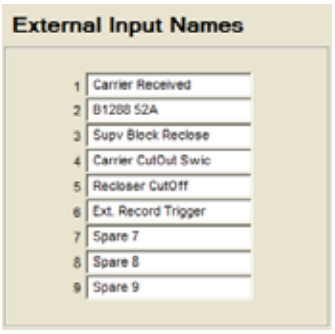
Describe the inputs

The L-PRO supports user defined names for all analog input channels, and all external inputs. The user-defined names appear in all metering displays, and in the waveform capture data.



Analog metering display

Analog input channel names

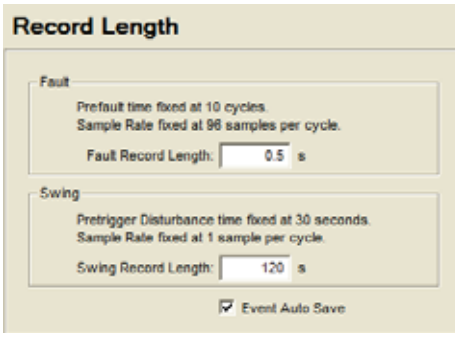


External input channel names

Set up recording

The L-PRO provides both high speed and low speed recording. High speed recording is traditional fault recording at 96 samples per cycle, with a configurable record length of 0.2 to 2.0 seconds. Low speed recording is swing recording, capturing current and voltage phasors once per cycle, with a configurable record length of 60 to 120 seconds. Records are stored in a first-in, first-out buffer in non-volatile memory, with a maximum of 15 records.

Both recording types include a unique feature: the ability to auto-extend the record length for sequential triggers. The L-PRO automatically extends a record as required to capture consecutive triggers that are close together. If a trigger occurs while a recording is in progress, the record is stretched to include the full post-trigger time of subsequent triggers, up to a maximum length—2.0 seconds for transient records, 180 seconds for swing records. If a trigger occurs before the end of a record caused by a previous trigger, but too late to allow sufficient post-trigger time in a maximum extended record, a new overlapping record is created.



Record length setup

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Configure the trigger events

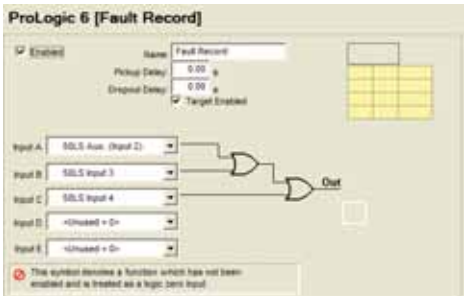
Configuring the trigger events is a two-step process in the L-PRO. The first step is to set conditions for the trigger, and the second is to assign the trigger to initiate recording in the Output Matrix. Like any DFR, the trigger events may be analog input levels, or external contact trigger events.

For this L-PRO application, there are 3 trigger events: protection elements on the protected line, analog overcurrent triggers for the other 3 lines, and external contact triggers for other events. All of these elements are configured to initiate a recording in the Output Matrix, so that any protection function becomes an analog trigger event.

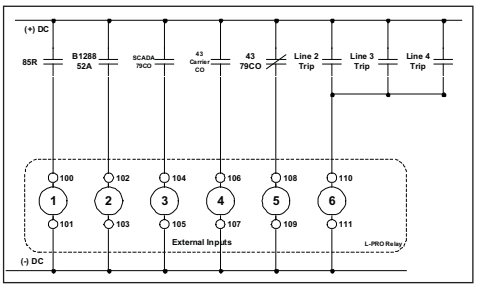
The L-PRO includes definite time overcurrent functions (the 50LS elements), specifically to trigger fault recording on the analog current channels. There is one 50LS element each for the Main AC Line Currents, the Auxiliary AC Line Currents, CT Input #3, and CT Input #4 current inputs. The settings for these elements should be approximately the fault detector settings for the transmission line. The 50LS elements for CT Input #3 and CT Input #4 are not directly configurable in the Output Matrix. It's necessary to create a ProLogic equation, and then assign this ProLogic equation to initiate recording in the Output Matrix.

It may be desirable to include contact triggers from the other lines to trigger fault recording. Contact triggers could be trip contacts from protection relays, received signals from carrier sets, or any other device that can provide a contact to the L-PRO. Including these contact triggers ensures a fault record is created, even if the fault current in the line isn't enough to operate the 50LS elements. Wire these contacts to an external input of the L-PRO, then configure this input initiate recording in the Output Matrix.

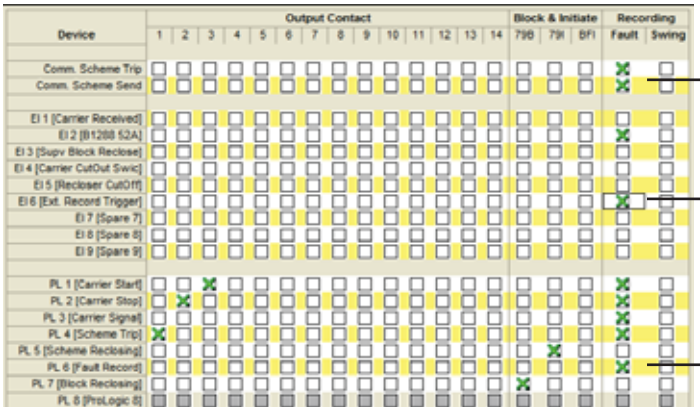
50LS element trigger settings



Recording trigger ProLogic equation



Contact trigger DC schematic



Protection function triggers

External input trigger

50LS element triggers

Output Matrix configured for fault recording

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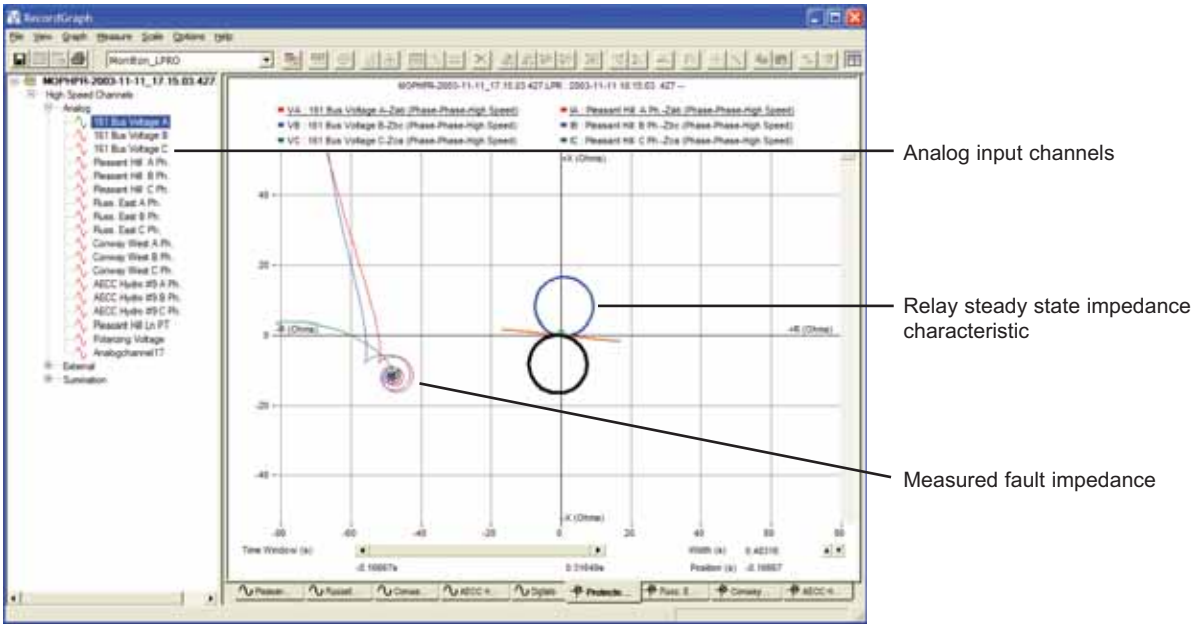
Analyzing the Data



RecordBase View impedance analysis view

All ERLPhase relays come with a copy of the RecordBase View fault analysis software. This is the same software package included with the ERLPhase TESLA Disturbance Fault Recorder, and includes features not typically found in protective relay fault analysis software. Obviously, RecordBase View will display the data from all analog channels and external channels in time domain displays. RecordBase View also has the ability to display harmonic content and symmetrical component content, but most importantly, RecordBase View can display impedance, calculated from the data recorded in the analog channels. The impedance display can show both phase-phase and phase-ground impedances.RecordBase View also includes the ability to display the steady state characteristic of the impedance zones of the L-PRO in conjunction with the measured impedance.

Since the impedance shown in a view is calculated from the current and voltage recorded in the analog channels, RecordBase View can show the impedance from any of the 4 lines by combining the bus voltages with the appropriate line current.

It's also possible to display a representation of the zone steady state characteristic for any distance relay on any of the lines. The fault record stores the protection settings of the L-PRO for the protected line. From an impedance view in RecordGraph, launch L-PRO Offliner, and change the line angle settings in Line Parameters, and the reach impedance in the 21P and 21N settings, to match those of the protected line and relay. This will change the zone diagram in the impedance display but won't save the changes to the fault record.

Other Possible Applications

The use of the L-PRO as a "mini-DFR" for fault recording on all the lines in a small transmission substation is one possible application. The additional current inputs can be used for fault recording for any device, such as transformers and shunt reactive equipment. Additionally, if the Auxiliary AC Volts inputs aren't used for synchronism voltages, they can be used for recording purposes, triggering on under- or over-voltage conditions.

It's also possible to extend the application described in this note to larger substations through cross-triggering. Just like regular DFRs, a trigger event on one L-PRO can be used as a digital input to another L-PRO to produce synchronized records.

Conclusion

This Application Note describes the use of an ERLPhase L-PRO Line Protection Relay as a "mini-DFR" in a small transmission substation. Retrofitting an L-PRO onto one of the transmission lines improves the reliability of the protection system by reducing the number of devices, and simplifying the wiring. The additional analog current channels can be used for fault recording on additional transmission lines and equipment. This configuration provides solid justification for adding recording to a small substation: substation waveform capture, for the cost of a reasonably priced distance relay.

References

[1] L-PRO Line Protection Relay User Manual Version 3.3 Revision 2, ERLPhase Power Technologies Ltd., 2003

[2] RecordBase View User Manual Version 1.5 Revision 2, ERLPhase Power Technologies, 2003