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Generic Directional Overcurrent Relay Model for the Western Electricity Coordinating Council

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WECC Modeling SPS and Relays Ad-Hoc Task Force (MSRATF)

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1 Introduction

In May of 2012, the Federal Energy Regulatory Commission (FERC) and North American Electric Reliability Corporation (NERC) issued a joint report on the September 8, 2011 Southwest Blackout Event calling, among other things, for improved planning. It recommended that entities throughout WECC identify and plan for external contingencies that could impact their systems and internal contingencies that could impact their neighbors' systems, and expand entities' external visibility in their models through, for example, more complete data sharing.

To achieve WECC wide visibility of contingencies in planning and operating the Modeling SPS and Relays Ad-Hoc Task Force (MSRATF) was created by TSS to develop and/or implement models for Remedial Action Scheme (RAS), relays and contingency definitions in WECC base cases, in BCCS, and in cases that are consistent with the West-Wide System Model (WSM). This task force will also coordinate with the RAS and Protective Systems Modeling Oversight Task Force (RPSOTF).

It is envisioned that transmission planning engineers will begin to more completely model automatic actions in their simulations. This will include an emphasis on modeling relays and remedial action schemes within the modeling software environment.

2 Purpose and Scope of Specifications

This document is intended to serve as a specification for the directional and load enchroachment aspects to be added to the time inverse overcurrent relays to be used by WECC as described in [1]. This is to be implemented by software developers and approved by the WECC MVWG for use in dynamic simulations in accordance with various NERC standards. Additionally, these requirements describe how these models should be interpreted and implemented in the power flow simulation environment.

Future requirements for improved directional overcurrent relay models are outside the scope of this document and shall be addressed via the formal MVWG modeling development process, as an example, the added functionality of monitoring the sum of multiple elements with the same relay.

3 Purpose and Scope of Model

Existing or newly approved models available in the GE, PTI, and PowerWorld software's adequately model the traditional user specified curve associated with overcurrent relays (**LOCTI**, **TIOCR1**) or equation based curve associated with overcurrent relays (**TIOCRS**).

This document describes two "new" modules to interface with the existing curve-based (**LOCTI**, **TIOCR1**) and equations based **(TIOCRS)** models which is to add the directional and load encroachment elements to these models. This gives the models the ability to trip according to the direction and to be able to compensate for load current that can enter the characteristic of the directional element of the relay model.

The models described in this document are additional functionality to existing or new models in the various planning software used by WECC. This document describes the basic features and functions of these models.

3.1 Model Function and Software Requirements

It is well known that system faults cause notable changes in various electrical quantities that are calculated in both the power flow and transient stability tools. One of the most common fault indicators is a sudden, and generally significant, increase in the current; subsequently, overcurrent protection (i.e. relays) may be widely used.

Accordingly, the WECC MSRATF has developed a series of functional requirements for use within the various study software used by WECC members. For more information on the two types of time inverse overcurrent relays (curve-based and equation-based), see Reference [1]. For the additional functionality, additional requirements are listed below (in no particular order):

- Requirement: Add a directional element which is defined by a characteristic angle and will be covered more in detail later in this document.
- Requirement: Add a load encroachment module which enables the relay to ignore load characteristics that might enter the zone characteristic of the directional element.
- Requirement: Modify the existing **LOCTI**, **TIOCR1**, and **TIOCRS** models to accept the output of the directional element and the load encroachment function.

- Requirement: The directional overcurrent relay behavior should be imported from the transient stability environment and enabled in a meaningful way within the power flow environment.
    - Directional overcurrent relays may not operate during stressed system conditions until after a many-second time delay. Thus modeling the relays in power flow based contingency analysis is important. Typical transient stability practice in WECC has simulation times that seldom exceed 30 seconds for a faulted condition. A run time of up to 60 seconds appears to be the maximum simulation time modeled and is only used to determine case adequacy for a "no-bump" or "flat-line" simulation.

3.2 Modeling of Relays in Steady State Contingency Analysis

The new models will be active in both the transient stability software environment as well as the power flow environment. We expect that the dynamics data can be parsed by the power flow software and the appropriate <If/Then> detection of the overcurrent relay and subsequent action be modeled in the power flow contingency tool. It is important to note that this represents a paradigm shift of the merging of power flow data and transient stability data. Presumably the future trend will be that, someday, there exists a single unifying electric system model that stores both power flow data and transient stability data in a single data structure or file.

4 Specification of Directional Time Inverse Overcurrent Relay – Curve Based and Equation Based

The new relay models will be called **DIRECLEN** which is the directional element for the overcurrent relay **LOADEN** is the same load encroachment element that was described in the Generic Distance Relay specification.

4.1 Prerequisite

DIRECLEN will be called with **LOCTI, TIOCR1,** or **TIOCRS**. **LOADEN** will be called by **DIRECLEN** if load encroachment function is specified.

4.2 Block Diagrams

The following is the logic block diagram of this set of models that will build upon the work that was done for the **LOCTI**, **TIOCR1**, and **TIOCRS**.

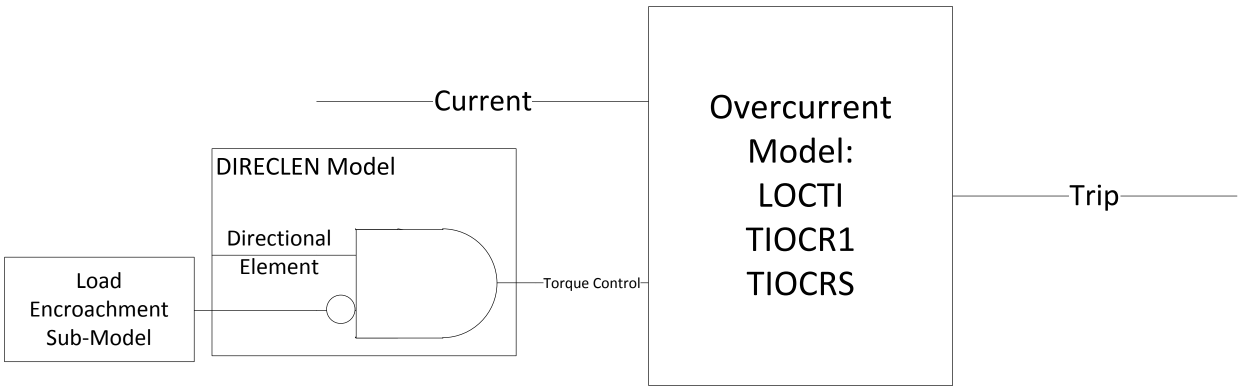

Figure 3-1: Logic Diagram of the Directional Overcurrent Relay

4.3 Directional Element Implementation

The directional element is defined by its characteristic angle which is shown in the following mho characteristic as shown in Figure 4-1.

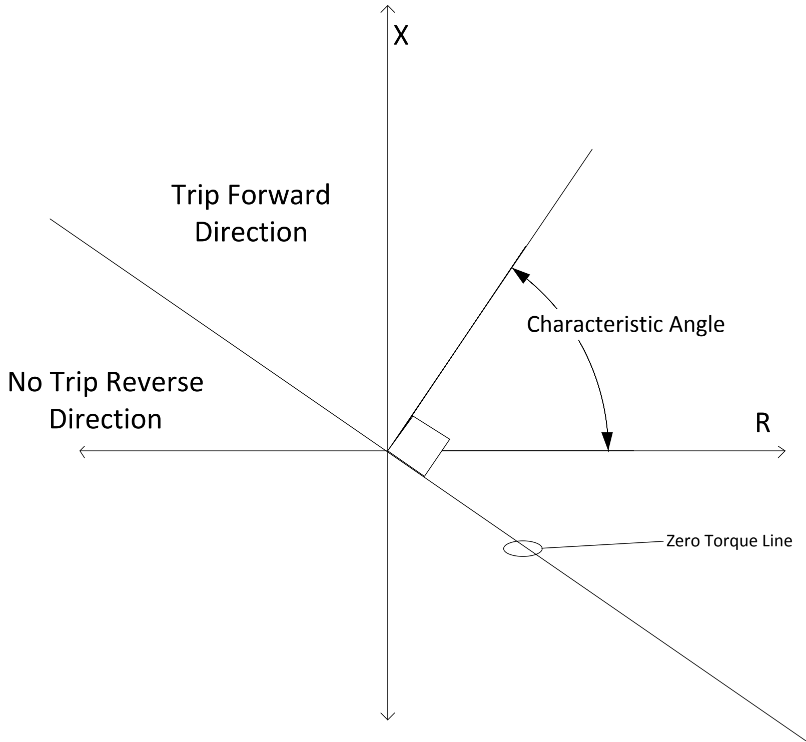

Figure 4-2: Directional Element mho characteristic

This is the essence of giving the time-inverse overcurrent model the directionality.

To represent the angle of maximum torque on the R-X diagram for electromechanical relays or other relays that specify voltage and current relationships, determine the angle between voltage and current at unity power factor for the relay connection used. Next determine the angle that the current must shift to achieve maximum torque (refer to relay instruction book for maximum torque angle), normally this angle will be lagging the unity power factor condition. The angular shift in a lagging direction from unity power factor to maximum torque is the angle of maximum torque on the R-X diagram.

4.4 Load Encroachment Function

The load encroachment function is deployed due to load getting near or at the same current levels as a fault along the line. Relay manufacturers would let the Protection Engineers to "notch out" the zone shape so that when loading of the line reaches that portion of the directional element characteristic then the load encroachment would block the relay so it does not false trip.

The load encroachment function has the following parameters **FREACH** (forward impedance) **RREACH** (reverse impedance), **PLAF** (positive forward load angle in degrees), **PLAR** (positive reverse load angle in degrees)**, NLAR** (negative reverse load angle in degrees)**,** and **NLAF** (negative forward load angle in degrees)**.** Of note, some relay models just have REACH and the same angle for **PLAF, PLAR, NLAR,** and **NLAF**. Figure 4-2 describes each of these parameters.

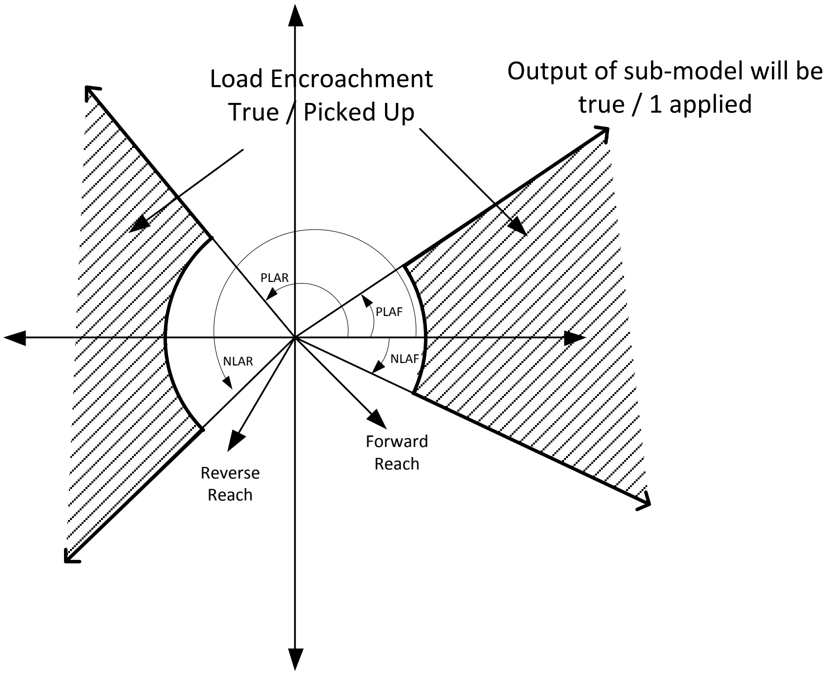

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Figure 4-3: Load Encroachment characteristic

4.5 Torque Control Function

Torque control is a throwback to when relays have a disk that enables the relay to function in the forward direction. In modern relays this term is still valid and its function is to activate the overcurrent relay's tripping function including the timer function after the direction and load encroachment have been evaluated. So a slight modification to the existing time inverse overcurrent models will need to be done to add this function as described in this document.

4.6 Input Parameters

The basic functionality for specifying when the relay will cause devices to trip should be based on the input parameters shown in the following table.

Directional Component (**DIRECLEN**)

Parameter	Type	Description
Nf		The bus where the relay is located.
Nt		The bus at the other end of the line the relay is located on.
Ckt#		Circuit number of line
CharAng	Float	Characteristic Angle

Load Encroachment Sub-Model (**LOADEN**)

PARAMETER	**TYPE**	**DESCRIPTION**
Nf		The bus where the relay is located.
Nt		The bus at the other end of the line the relay is located on.
Ckt#		Circuit number of line
Func		This sub-model is used for distance and overcurrent relay: 1. Distance Relay 2. Overcurrent Relay (directional / non-directional) 3. All relays in the line
FReach	Float	Forward Load Impedance (in Primary Ohms)
Rreach	Float	Reverse Load Impedance (in Primary Ohms)
PLAF	Float	positive forward load angle in degrees
PLAR	Float	positive reverse load angle in degrees
NLAR	Float	negative reverse load angle in degrees
NLAF	Float	negative forward load angle in degrees

5 Dynamic Data Conversion to Steady State Contingency Analysis

Overcurrent relay models may not operate when performing typical dynamic simulations due to expected trip times often in excess of standard transient stability simulation times (i.e. usually no more than 30 seconds). A number of OC relays tripped during the September 8, 2011 event in about 35 seconds to- 3½ minutes.

It is important to determine whether the modeled current would exceed the relay threshold (pickup) value, which indicates an eventual trip. In such a case there is an issue requiring further investigation. This motivates the requirement that we include the modeling of overcurrent relays in the power flow based contingency analysis processing.

Steady State Contingency Analysis tools should interpret the dynamic model data for use in the contingency analysis processing. The steady state contingency analysis processor should pick up by the trip characteristic of the directional element and then trip the line for any current above the Threshold current (overcurrent element). A report would be generated to show the direction and threshold current has been exceeded based on the load flow (not fault current). In a situation where multiple relays exceed their threshold in the steady state simultaneously, then the contingency processor should choose only those relays that would trip first based on their respective *Time To Close* calculation. If multiple relays have the same *time to close*, then they should trip together. This list of “first to trip” relays should cause devices to trip, after which the steady state power flow should be resolved and remaining relays should be re-evaluated to see if they may also trip. The contingency processor should continue re-evaluating relays iteratively until no new relays operate.

6 Summary

This model specification is to represent the behavior of the directional and load encroachment aspect of the overcurrent relay. This is to simulate for the purposes of operations/planning studies, which is not the same level of detail as needed for protection system modeling of a relay.

7 References

[1] Generic Overcurrent Relay Model for Western Electric Coordinating Council
[2] Generic Distance Relay Model for Western Electric Coordinating Council