Application Note

Substation Automation and Protection Division

Sensitive and Selective Ground-Fault Protection in Ungrounded MV Networks Using the DPU-2000R with the Directional-Sensitive-Earth Fault Feature

Introduction

The Distribution Protection Unit, DPU-2000R, is designed to provide flexible protective and control elements. Along with these is the ability to create logical control schemes using the internal programmable logic functions. When combined, these two capabilities provide a vast number of possible configurations to suit a particular function not normally associated with a distribution relay. One such function that is possible with the DPU-2000R is sensitive and selective ground fault protection for ungrounded medium-voltage networks. This application note deals in detail with this function.

Application

In the Medium Voltage networks with isolated i.e., ungrounded neutral, or a delta source without a neutral, the currents of single phase to ground faults depend mostly on the capacitance of the lines. This equivalent capacitance depends on the types and lengths of the lines connected in same part of the galvanically connected network.

Neutral or zero-sequence voltage is dependent on earth fault current and equivalent capacitance. In the ideal case, when fault resistance is zero, this voltage is equal to the nominal voltage (phase-neutral) of the network. Both zero-sequence voltage and current during the fault are inversely proportional to the fault resistance.

Selective tripping for ungrounded MV networks may be achieved using the directional sensitive earth fault protective element available as an optional feature in the DPU-2000R, catalog number series: **587E or 687Ey…-…..,** where digit "y" is 4, 5, or 6. In MV networks with isolated neutral the phase shift between the ground fault current of the faulty line and the current at the sound lines is about 180 degrees. Hence the selectivity is based on the on a directional measurement principle, using the zero sequence voltage as the reference and the zero sequence current as the operate quantity. (See Figure 1 for the relationship of the currents on the faulted and unfaulted feeders)

Typical Connections

For the Sensitive-Earth-Fault model of the DPU-2000R, a separate ground current input is provided at sensor 5 (terminals no.45-46). This input may be connected to residually-connected line current transformers or it may be connected to a separate core-balance (window type) current transformer. (See Figure 2)

Zero-sequence voltage will be automatically derived by the DPU-2000R from the three bus voltage transformers (VT) whenever the VT connection is set to 69Wye or 120Wye in the Configuration settings (Unit must have firmware V4.10 and greater). The derivation of the zero-sequence voltage is accomplished inside the relay by the vector summation of the three phase-to-neutral voltages.

If it is desired that the zero sequence voltage polarization be provided via a separate set of three phase VT's connected in broken-delta, choose the appropriate VT connection configuration setting of "69Wye-3Vo Input", "120Wye-3Vo Input". The separate voltage input is at Sensor 10 (terminals no 35-36). Figure 2 shows this arrangement.

If there are only two open-delta connected VT's to terminals 31-32-33, then the configuration setting would be "69 Delta" or "120 Delta", and the external broken-delta source connected to terminals 35-36 will be required as the zero-sequence voltage polarization source.

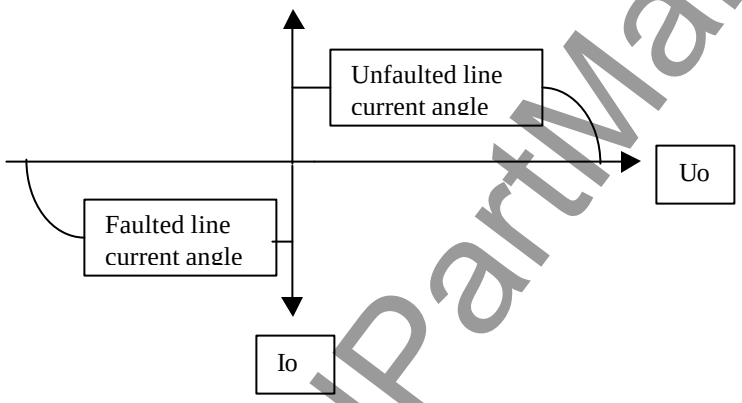

Figure 1 – Phasor diagram of ground fault currents on unfaulted and faulted feeders in ungrounded Medium Voltage networks

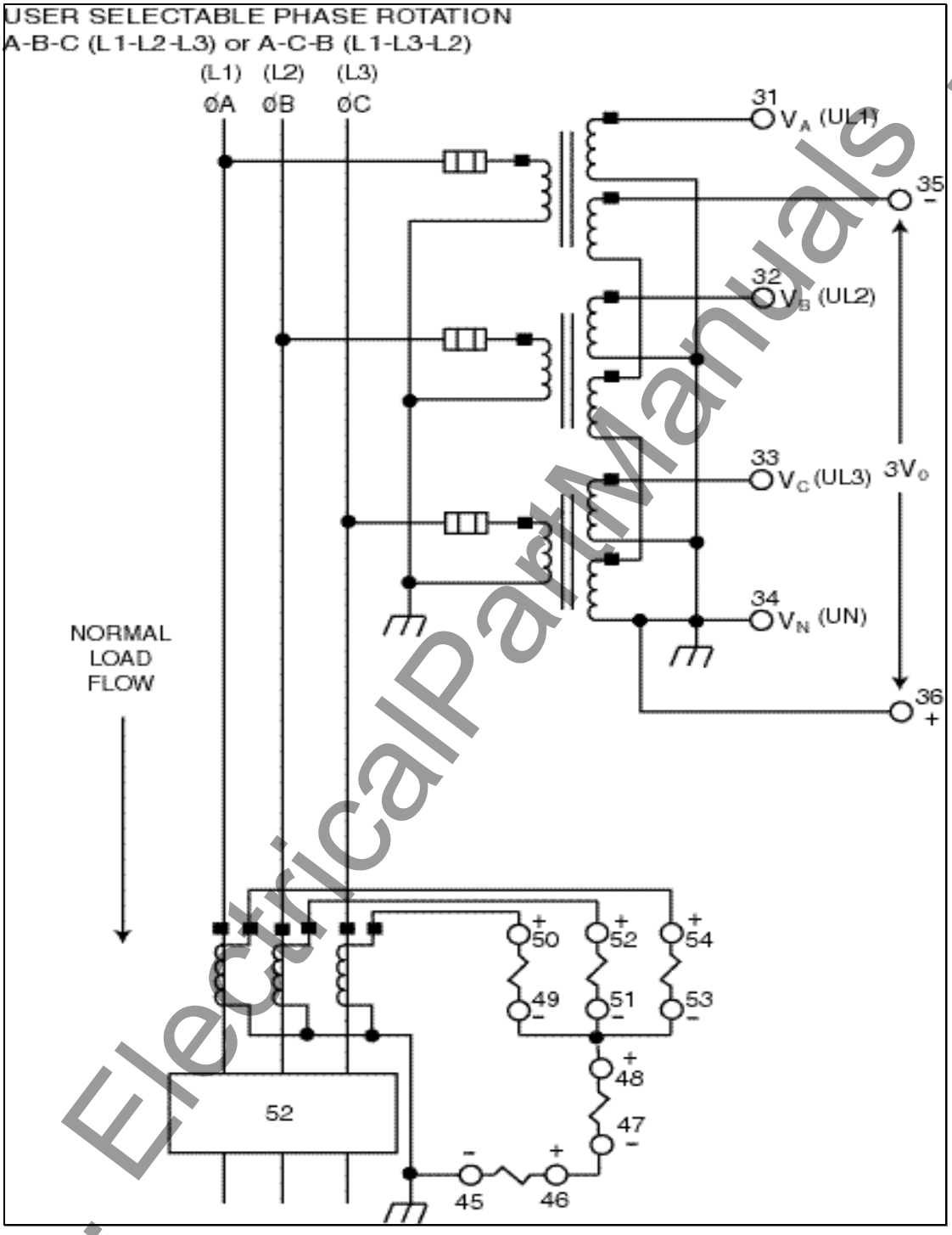

Figure 2 – Typical VT and CT Connections for Directional Sensitive Earth Fault Units

Relay Settings

Figure 3 outlines the Boolean logic associated with this application. In the following example the DPU-2000R SEF (Io), is used to determine sensitive earth fault condition (both seal-in and non-sealed-in outputs may be used). The overvoltage element, 59G is used for supervision of the whole tripping logic. BFUA is used to determine Blown Fuse Alarm.

The DPU-2000R contains User Logical Input (ULI) and User Logical Output (ULO) functions. A ULI is undefined logical input seen in the relay input map. A ULO is an undefined logical output seen in the relay output map. A ULI in the input map is soft connected to the corresponding ULO in the output map. A setting can break this soft connection in the DPU-2000R. In summary, ULO can be explained as a method of feeding an input signal to the output mapping.

The reverse is true for elements called "feedback terms". These feedback terms (FBs) are a method of feeding a logical output signal back to the input map. They are also soft connected but this soft connection can not be broken.

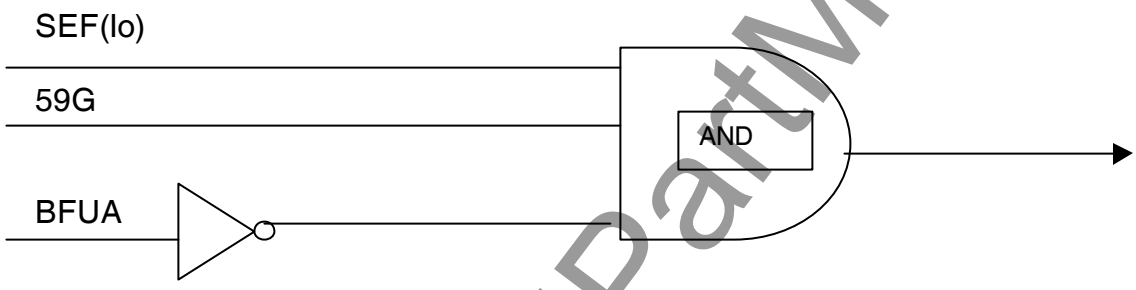

Figure 3 –Directional Sensitive Earth Fault Logic Diagram

For Io the pickup setting range varies between 5-200 mA, with a definite time delay setting between 0.5-180sec. The current threshold value must be chosen according to the smallest expected capacitive current flow of the medium voltage network during a ground fault.

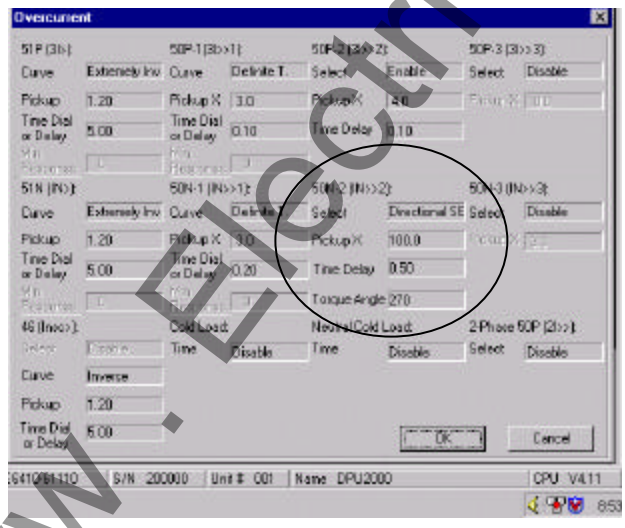

Figure 4 – Setting window for Io

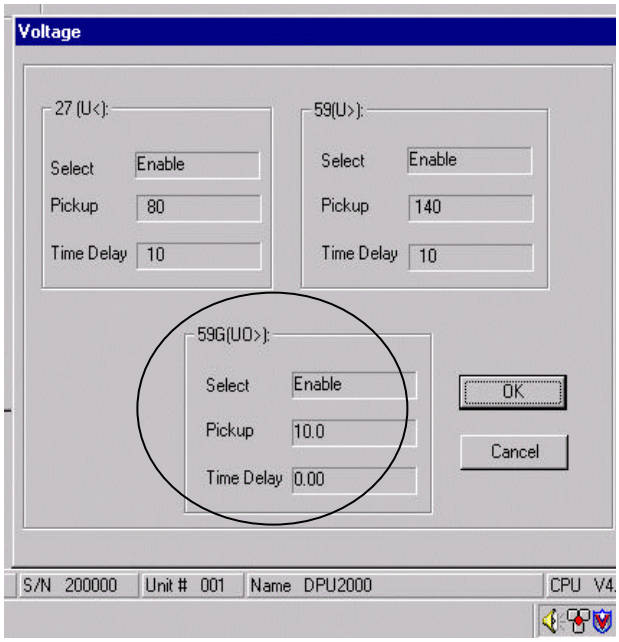

Figure 5 – Setting window for Uo

Recommended setting for 59G(Uo) is about 30-40V with time delay of 3-10sec. (Figure 5). The logical output from 59G(Uo) may be mapped to physical output for signalization purposes.

Figures 6a and 6b show the output map required for this application. On the top of the map screen are the physical outputs and FBO, the timers associate with physical outputs, and the logical AND/OR selection. To the left are logical outputs.

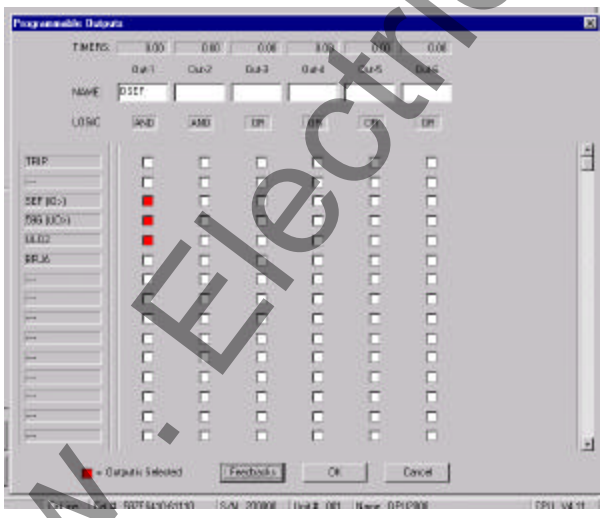

Figure 6a – Output Mapping

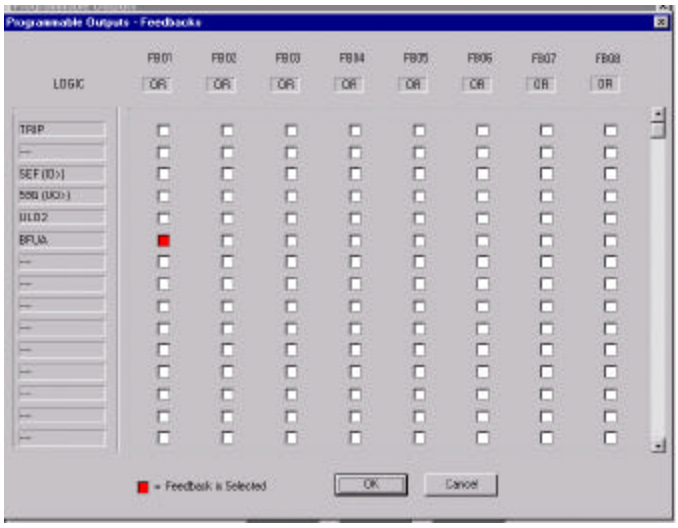

Figure 6b – Feedback Output Mapping

Figure 7 shows the input map required for this application. On the top of the map screen are the FB inputs. The ULI2 is used for blown fuse detection.

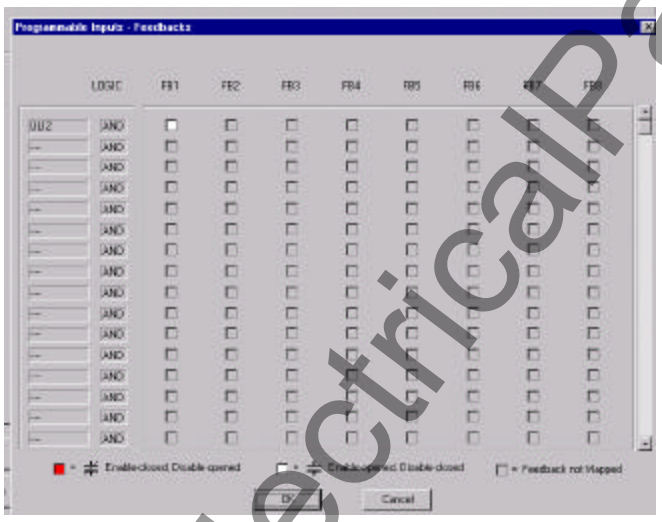

Figure 7 – Input Mapping

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