APPLICATION NOTES:

SINGLE BUSBAR BLOCKING SCHEMES,

MiCOM P140 FEEDER MANAGEMENT

RELAYS

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Section 1. INTRODUCTION

Faults on power system busbars pose risks of equipment damage and danger to personnel if left uncleared. Dedicated "instantaneous" busbar protection is regarded as essential for higher system voltages. Traditionally, however, distribution system busbar faults have been cleared by time delayed protection upstream. Numerical technology now allows proven schemes to be applied to protect distribution system busbars. The busbar protection is achieved by simple interconnection of the MiCOM relays which are already specified for their primary task of feeder protection. The advantages offered by such a Busbar Blocking Scheme are:

- Faster busbar fault clearance compared to tripping initiated by upstream feeder protection.
- Busbar protection at minimal additional cost - the blocking scheme uses overcurrent elements already provided in the feeder protection relays.
- Fault and disturbance records stored for busbar faults, allowing fault analysis.
- Blocking schemes can be easily modified to suit substation extension.

Blocking schemes give fault clearance after a small inherent time delay and so are not appropriate where instantaneous tripping for busbar faults is required. Therefore, for transmission systems differential protection or frame leakage protection is recommended (types MCAG34, MFAC34, MBCZ or MCAG12). Figure 1 gives an indication of where MiCOM Busbar Blocking Schemes may be appropriate.

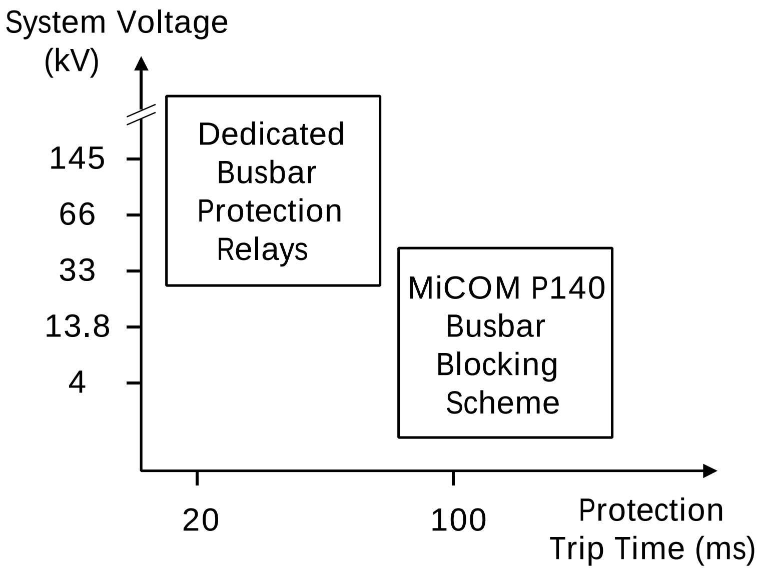

Figure 1. Application of Busbar Protection

Fast clearance of a busbar fault may be desirable in terms of limiting fault damage within metal-clad switchgear and it would also be necessary where required to limit the duration of supply voltage depressions. Such considerations often arise in relation to switchgear used to supply an industrial site; especially where a costly continuous manufacturing process is involved. MiCOM schemes offer a simple and effective solution.

The purpose of this document is to detail how a MiCOM P140 scheme can be configured to protect a single busbar substation.

The Busbar Blocking Schemes are configured using P140 numerical relays. Reference publications are available, as below:

- **Technical Guide TG8612 - MiCOM P140 Series Feeder Management Relays.**
- **Application Guidelines R4013 - Overcurrent and Earth Fault Protection.**
- **Network Protection and Application Guide - NPAG.**

Section 2. PROTECTION OF A SINGLE BUS WITH ONE INCOMING FEEDER - GENERAL PRINCIPLE

Figure 2 shows a typical substation layout, where one incoming feeder ("incomer") supplies a number of outgoing radial feeders from an unsectioned busbar. Three phase overcurrent and earth fault relays, from the P140 series, are already provided for conventional time-graded protection as shown. A Busbar Blocking Scheme needs to be configured which will give fast tripping of the incomer for the busbar fault shown at "A" whilst remaining stable for the feeder fault at "B". The feeder fault would be cleared by overcurrent protection tripping only the relevant outgoing feeder breaker.

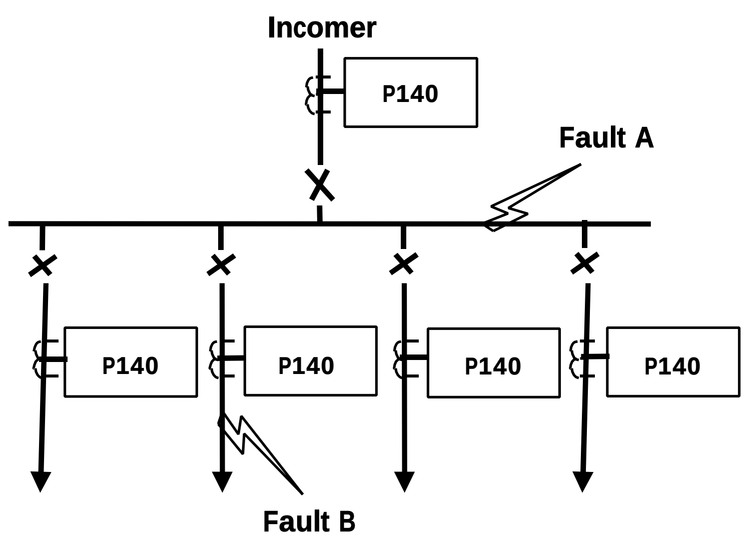

Figure 2. Single Busbar with One Incoming Feeder

Traditionally, incoming feeder protection would not be able to distinguish between a busbar fault at A, and a close-up feeder fault at B. Busbar protection would be provided by an incoming feeder IDMT relay, which had been set to time grade with all outgoing feeder protection. Hence, clearance of the fault at A could have been slow. The P140 relays now provide a means to detect whether a fault is within the protected busbar zone (eg, at A), or is external to the zone (eg, at B). This allows the incoming feeder relay to determine whether to trip, or leave outgoing feeder protection to clear the fault, respectively. The means by which the scheme is configured is described in the fault scenarios below:

2.1 Fault External to the Busbar Zone (Fault B)

The fault at B would typically cause operation of IDMT phase fault or earth fault elements of the feeder's P140 protection relay. These elements are designated I>1 and IN>1 respectively, and trip the relay output contact assigned. Each of these elements have instantaneous start output contacts for I>1 and IN>1 available, which although not used for tripping can be used to indicate that the fault is on a feeder, and hence external to the busbar. In Busbar Blocking Schemes, these start output contacts are used to block (prevent) tripping of the incoming feeder relay I>3 element, which is nominally set to provide busbar protection. The principle is shown in Figure 3.

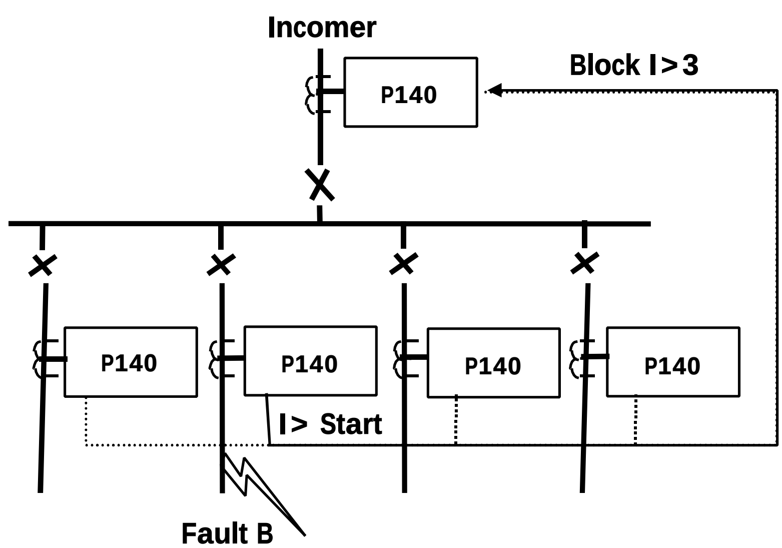

Figure 3. Blocking of I>3 Busbar Protection for External Faults

2.2 Fault on the Busbar (Fault A)

Rather than wait for the incoming feeder IDMT protection elements (I>1 and IN>1) to clear the fault, its I>3 and IN>3 elements are used. These third stage elements will trip on detecting fault current above setting, provided that a block signal has not been received from outgoing feeder I>1 or IN>1 start contacts. Because the connection of blocking signals between relays is hardwired (blocking buswires in a marshalling cable), the third stage elements must allow sufficient time for any start to be issued by an outgoing feeder relay, and then to recognise that the block opto input has been energised, allowing the block to be applied. For the busbar fault at A, no block would be received and incoming feeder tripping would be subject to the short time delay set for I>3 and IN>3.

Figure 4 shows the principle of the blocking scheme, where the bold arrows indicate hard-wired interconnections. Note: As the earth fault elements ("Earth Fault 1") of the incomer and outgoing feeder relays are generally driven from residually-connected phase CTs, it is necessary to consider possible transient operation of earth fault elements with transient CT spill current, which may arise for a through fault if CTs saturate asymmetrically. For an outgoing feeder phase fault there is a remote possiblity that the incomer I_N>3 element could operate transiently from CT spill current, whereas the I_N>1 element on the faulted feeder may not. To avoid unwanted tripping of the incomer I_N>3 element in this case, it is necessary to arrange for the outgoing feeder I_N>1 elements **and** I>1 elements to block the incomer I_N>3 elements. The outgoing feeder I>1 elements should pick up in the event of a feeder phase fault, and block incomer tripping. Best practice is to block incomer I>3 and IN>3 tripping from any outgoing feeder start.

To enhance the scheme, the circuit breaker fail protection in the outgoing feeder relays can also be wired to backtrip the incoming feeder circuit breaker. The scheme design would become as shown in Figure 4. However, it is standard practice to backtrip all of the circuit breakers connected to a section of busbar in the event of one breaker failing. To avoid placing an excessive burden on the set of contacts assigned for breaker fail protection, the contacts can be configured to energise backtrip buswires. The buswires would energise an opto input on each of the relays to be backtripped (including reinforcing the trip for the failed breaker). Any “Bus Zone Trip” command received via this opto input is routed directly to the relay’s trip output contact. Generally, opto input L6 “External Trip” with a slight modification to the P140’s default Programmable Scheme Logic is used for this purpose. Thus, each relay trips only one circuit breaker.

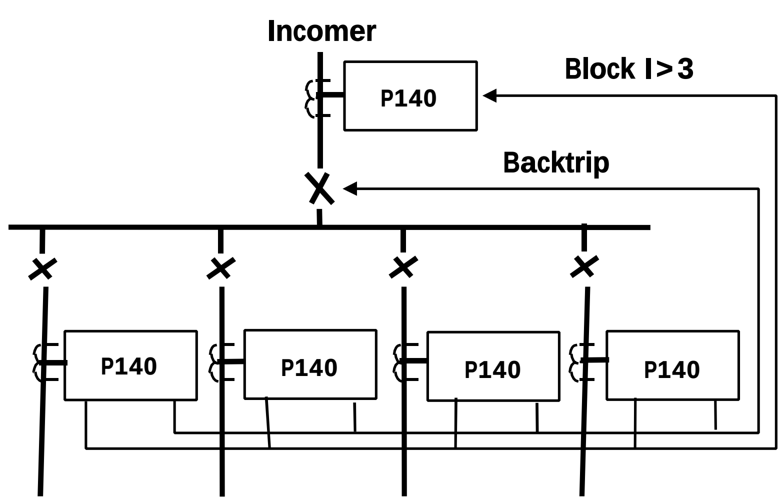

Figure 4. Busbar Blocking Scheme (simplified)

Section 3. PROTECTION OF A SINGLE BUS WITH ONE INCOMING FEEDER - RELAY SETTINGS

Figure 5 below shows the method by which time discrimination between the incoming feeder and outgoing feeder protection is maintained. Firstly, all relays have I>1 and IN>1 overcurrent and earth fault IDMT elements set. For all fault currents up to the maximum busbar fault level, the incoming feeder curve should be slower than the outgoing feeder curve by a suitable grading margin. This is marked “IDMT Margin” in the Figure, with 0.4 seconds being typical. Secondly, the I>3 and IN>3 time delays for the incomer must be sufficient to allow for correct receipt and application of blocking signals.

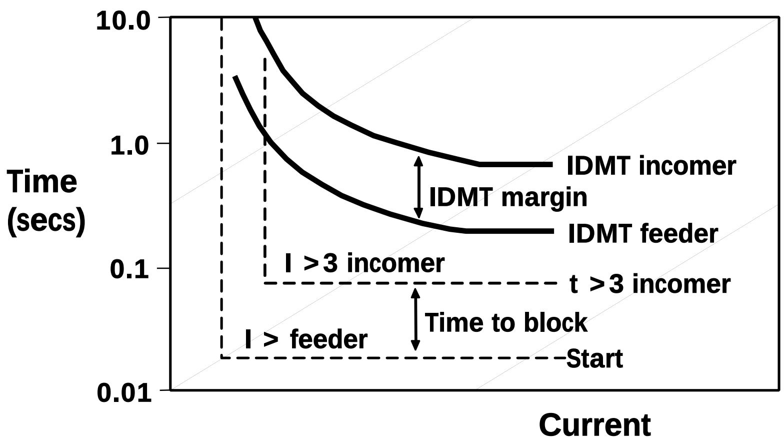

Figure 5. Selection of Relay Current and Time Delay Settings

A flowchart to assist in calculating MiCOM P140 relay settings for Busbar Blocking Schemes is shown in Figure 6, with detailed guidance following in Sections 3.1 to 3.8 below.

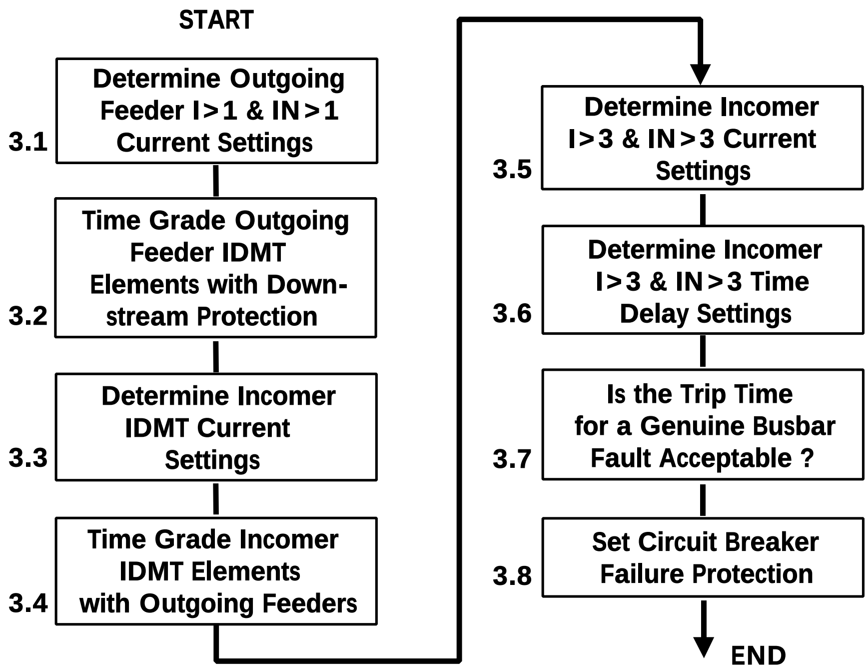

Figure 6. Flowchart for Setting Blocking Scheme - Single Incomer Substation

3.1 Outgoing Feeder I>1 and IN>1 Current Settings

The primary I>1 phase fault pickup setting must be set higher than maximum load current, and higher than the primary current setting of downstream protection. Typically, settings would be the higher of:

I >1 $\geq$ (Full Load Current) x (100% + Transient overload) / Relay reset ratio

$\geq$ FLC x 110% / 0.95

$\geq$ Typically 120% FLC (Higher where motor starting current is significant).

And:

I >1 $\geq$ Downstream Relay pickup x 110%

Or:

I >1 = 3 to 4 times Downstream Fuse rating (In practice).

In a similar way, the IN>1 earth fault element pick-up must discriminate with the maximum single phase loading imbalance, and with any downstream earth fault protection. Publication R4013 (Application Guidelines - Overcurrent and Earth Fault Protection) gives details, if required.

3.2 Grading Outgoing Feeder I>1 / IN>1 Elements with Downstream Protection

Here, conventional time grading principles are used, as in Publication R4013.

3.3 Incomer I>1 and IN>1 Current Settings

Conventional current pickup and time grading principles are used, as in Publication R4013. The IDMT elements are still required for back-up protection, as in traditional applications.

3.4 Grading Incomer I>1 / IN>1 Elements with Outgoing Feeders

As previous section 3.3 and R4013.

3.5 Incomer I>3 and IN>3 Current Settings

The I>3 setting for bus zone protection must exceed the maximum transient load current, in a similar way to section 3.1. The primary I>3 setting for the incomer protection should also exceed the highest primary I>1 setting of an outgoing feeder relay by at least 25% in order to ensure full co-ordination of the busbar protection scheme. This setting recommendation is based on the assumption that there are no interconnecting paths between remote ends of the outgoing feeders (ie. all outgoing feeders are radials, none are parallelled, and none form part of a ring main). Those cases would have to be carefully considered in order to determine a suitably safe margin between the primary I>3 overcurrent setting for the incomer and the primary I>1 setting for the outgoing feeders.

In this application, earth fault elements are included in the busbar protection scheme to provide tripping even for a low level of busbar earth fault current. The incomer primary $I_N>3$ setting should exceed the highest feeder $I_N>1$ setting by at least 25%. Also, the incomer $I_N>3$ setting should ideally be less than 30% of the minimum bus earth fault level, to ensure fast fault clearance.

3.6 Incomer I>3 and IN>3 Time Delay Settings

Time delay settings for the incoming feeder relay can be chosen from the following Table, with both time delays set to the same value. In Table 1, X/R is the primary system reactance/resistance ratio, and the minimum fault current for an outgoing feeder fault should also be estimated (as a multiple of the I>1 and IN>1 feeder protection settings) as follows:

- Phase fault ratio = Minimum feeder phase fault current / (I>1 setting)
- Earth fault ratio = Minimum feeder earth fault current / (IN>1 setting)

If the ratio (Incomer I>3 setting / Outgoing feeder I>1 setting) is higher, this figure can be used instead. The same is true for (Incomer IN>3 setting / Outgoing feeder IN>1 setting).

Minimum Fault Current Ratio	X/R Ratio			
	£ **10**	£ **15**	≤ 20	≤ 25
≥ 2	70	**80**	100	110
≥ 5	60	70	70	80

Table 1. Typical Minimum Incomer I>3 and IN>3 Delay Settings (ms) (50Hz)

Typical X/R ratios for distribution systems are shown in bold in Table 1 (ie. 5 to 15). Thus, it can be seen that 80ms is a typical universal setting. Note: When using CTs sized to ALSTOM recommendations, the maximum system fault current level expressed as a multiple of the smallest CT rating used in the scheme (ie: a “times In” figure) must not exceed 50In, otherwise the stated times may be insufficient. Time delays sometimes much less than those shown can be determined by system-specific stability testing.

3.7 Check on Trip Time for Genuine Busbar Faults

Protection trip times for a genuine busbar fault will be approx. 20ms slower than the set I>3 / IN>3 delay. Thus, 100ms is a typical operating time. It should be remembered that where induction motors are connected to the system, regeneration (dissipating energy stored as rotational momentum of the motor(s)) can transiently backfeed a busbar fault for 100ms or so. If the backfeed from any outgoing feeder circuit can be in excess of the I>1 setting for the feeder, it is possible that the incomer I>3 elements could be blocked transiently. This would result in a busbar fault clearance time slightly slower than expected. Directionalising outgoing feeder protection in the forward direction would help in this case.

3.8 Breaker Failure Protection Settings

The principle of operation is described in Technical Guide TG8612, Chapter 2, Section 2.17. A typical tBF time delay would be 200ms where vacuum circuit breakers (VCBs) are used, possibly slower for oil-filled switchgear (OCBs). Typical I< and IN< undercurrent settings are 20% of In, or half of the respective phase and earth fault overcurrent settings, if lower.

Section 4. PROTECTION OF A SINGLE BUS WITH ONE INCOMING FEEDER - RELAY CONFIGURATION

4.1 Relay Input/Output Assignments – Incoming Feeder

The busbar blocking scheme can be achieved using just the default opto input and output contact assignments as supplied. The relevant connections used in scheme are:

Logic Inputs		**Output Relays**	
L3	**Blocking Bus (Block IN>3&4)**	RL3	**Trip Circuit Breaker**
L4	**Blocking Bus (Block I>3&4)**	RL5	**Backtrip Bus Zone (Breaker Fail)**
L6 #	**Bus Zone Trip (for Breaker Fail)**		

Table 2. Incoming Feeder Input/Output Assignment

Note #: Any "Bus Zone Trip" command received via this opto input is routed directly to the relay's trip output contact, RL3. This requires a slight modification to the P140's default Programmable Scheme Logic.

4.2 Relay Input/Output Assignments - Outgoing Feeder

Logic Inputs		Output Relays	
L6 #	**Bus Zone Trip (for Breaker Fail)**	RL1	**Earth Fault Start (IN>)**
		RL2	**Phase Fault Start (I>)**
		RL3	**Trip Circuit Breaker**
		RL5	**Backtrip Bus Zone (Breaker Fail)**

Table 3. Outgoing Feeder Input/Output Assignment

Note #: Any “Bus Zone Trip” command received via this opto input is routed directly to the relay’s trip output contact, RL3. This requires a slight modification to the P140’s default Programmable Scheme Logic.

4.3 Relay Settings - Incoming Feeder

Settings specific to the busbar scheme are listed below, other elements may be enabled if required. Please refer to Chapter 2 Application Notes in Technical Guide TG8612 for guidance. Settings which require a change from the factory defaults are shown in **bold** type.

SYSTEM DATA

Frequency	50 or **60Hz** as appropriate

CONFIGURATION

Overcurrent	Enabled
Earth Fault 1 #	Enabled
CB Fail	**Enabled**

Note #: - Earth Fault 1 elements are driven from the C11-C12 “IN” current input for 1A relays, C10-C11 for 5A relays. This input is usually connected as a residual current measurement from the line CTs.

CT & VT RATIOS

Main VT Primary	**All as appropriate….**
Main VT Secondary	
Phase CT Primary	
Phase CT Secondary	
E/F CT Primary	**Same as Phase CT when using the residual connection.**
E/F CT Secondary	

GROUP 1 OVERCURRENT

I>1 Function	**Curve type from Section 3.3**
I>1 Direction	Non-Directional
I>1 Current Set	**From Section 3.3**
I>1 TMS	**From Section 3.4**
I>3 Status	**Enabled**
I>3 Direction	Non-Directional
I>3 Current Set	**From Section 3.5**
I>3 Time Delay	**From Section 3.6**

GROUP 1 EARTH FAULT 1

IN1>1 Function	**Curve type from Section 3.3**
IN1>1 Direction	Non-Directional
IN1>1 Current Set	**From Section 3.3**
IN1>1 TMS	**From Section 3.4**
IN1>3 Status	**Enabled**
IN1>3 Direction	Non-Directional
IN1>3 Current Set	**From Section 3.5**

IN1>3 Time Delay	**From Section 3.6**

GROUP1 CB FAIL & I<

CB Fail 1 Status	Enabled
CB Fail 1 Timer	**From Section 3.8**
I< Current Set	**From Section 3.8**
IN< Current Set	**From Section 3.8**

4.4 Relay Settings - Outgoing Feeder

Settings specific to the busbar scheme are listed below, other elements may be enabled if required. Please refer to Chapter 2 Application Notes in Technical Guide TG8612 for guidance. Settings which require a change from the factory defaults are shown in **bold** type.

SYSTEM DATA

Frequency	50 or **60Hz** as appropriate

CONFIGURATION

Overcurrent	Enabled
Earth Fault 1 #	Enabled
CB Fail	**Enabled**

Note #: - Earth Fault 1 elements are driven from the C11-C12 "IN" current input for 1A relays, C10-C11 for 5A relays. This input is usually connected as a residual current measurement from the line CTs.

CT & VT RATIOS

Main VT Primary	**All as appropriate….**
Main VT Secondary	

Phase CT Primary	
Phase CT Secondary	
E/F CT Primary	**Same as Phase CT when using the residual connection.**
E/F CT Secondary	

GROUP 1 OVERCURRENT

I>1 Function	**Curve type from Section 3.2**
I>1 Direction	Non-Directional
I>1 Current Set	**From Section 3.1**
I>1 TMS	**From Section 3.2**

GROUP 1 EARTH FAULT 1

IN1>1 Function	**Curve type from Section 3.2**
IN1>1 Direction	Non-Directional
IN1>1 Current Set	**From Section 3.1**
IN1>1 TMS	**From Section 3.2**

GROUP1 CB FAIL & I<

CB Fail 1 Status	Enabled
CB Fail 1 Timer	**From Section 3.8**
I< Current Set	**From Section 3.8**
IN< Current Set	**From Section 3.8**

4.5 Programmable Scheme Logic – All Relays

Just one change needs to be made to the default PSL files loaded in the P140 relays. In order that a backtrip applied to opto input L6 is routed to the relay trip output contact RL3, a signal “L6 External Trip” needs to be added to page 2 of the PSL. In the new location on page 2, this signal is then connected to the OR gate which drives RL3. The new configuration of the affected logic is shown in Figure 7.

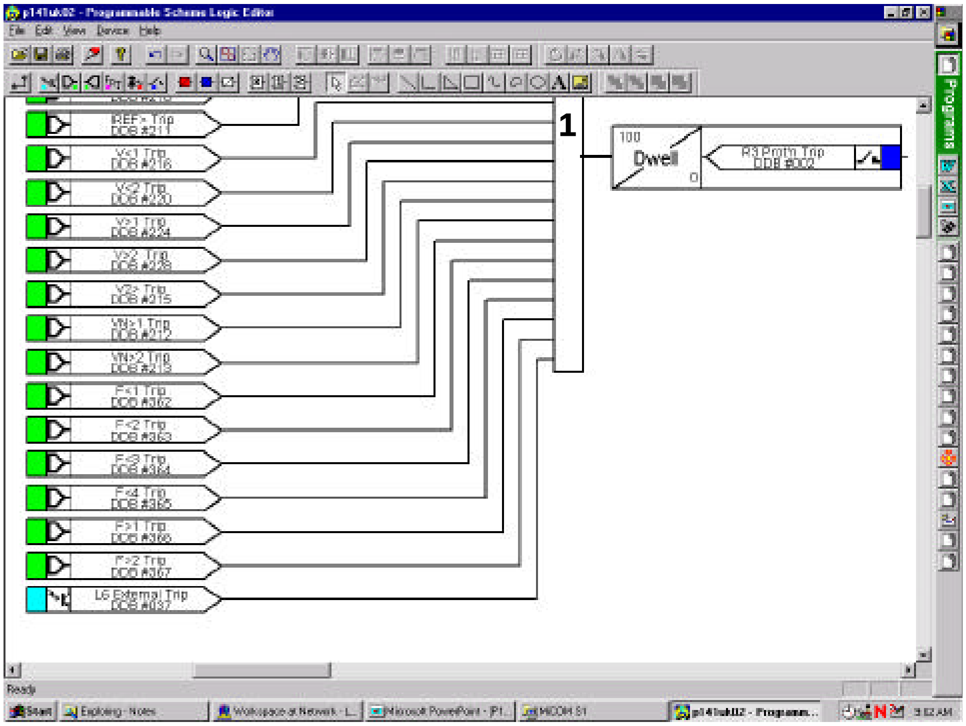

Figure 7. Modification Required to Programmable Scheme Logic

Optionally, customers may decide to map the incoming feeder I>3 and IN1>3 trip signals used for the busbar protection to additionally close output contact RL5. These signals are DDB#189 and 201, and would need to be ORed together with the Bfail1 signal already driving RL5. This causes all outgoing feeders to be tripped too, in the event of a busbar fault, giving a clearer indication of the exact nature of the fault. However, it should be ensured that the voltage depression on the trip battery is not too severe during this mass trip operation.

4.6 Interconnecting Wiring

Figure 8 shows the hard-wired interconnections between MiCOM P140 series relays required to configure the blocking scheme. All relays make connections to three buswires, namely the +48V Field Supply Buswire, the Blocking Buswire, and the Bus Zone Trip Buswire. There is no need to run –48V buswires as the cathodes (negative terminal) of all opto inputs are commoned together at each relay, and then connected to the negative terminal of the field voltage supply. Only one outgoing feeder relay is shown, connections to other outgoing feeder relays will be similar. All three buswires extend along the length of the switchgear, marshalling the scheme I/O for all feeders. Figure 9 shows how buswires may run within marshalling cables (rear/back of panel mounted), giving the benefits of easy interconnection, and allowing standardisation within racks of feeder protection.

NOTES: As for simple overcurrent protection, **RL3 is assigned as the Trip output contact**, tripping the relevant feeder circuit breaker. Also, when using the P143 relay, terminals H1, H2 … H12 are used instead of E1, E2 … E12; and terminals J8 and J9 are used instead of F8 and F9.

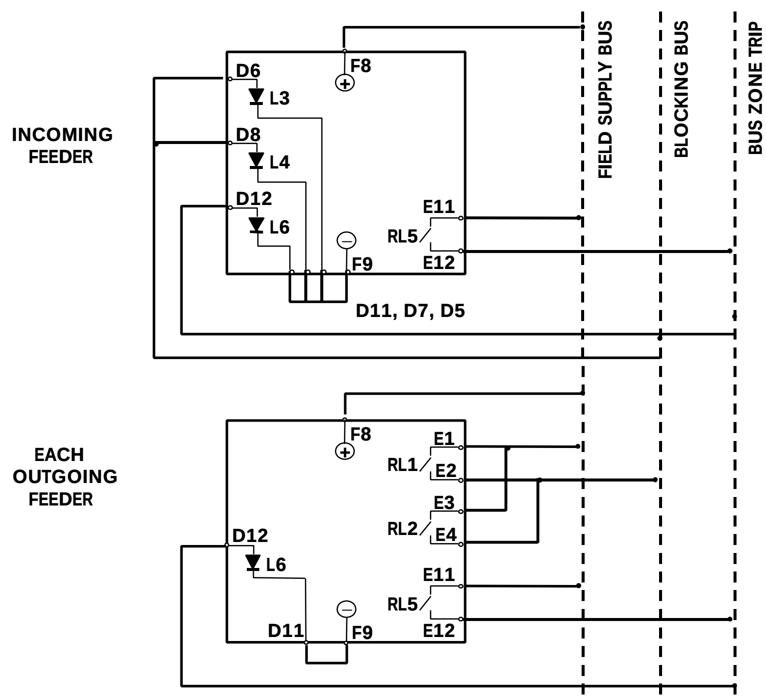

Figure 8. Relay Interconnections (P141 or P142) Showing the Three Buswires Required

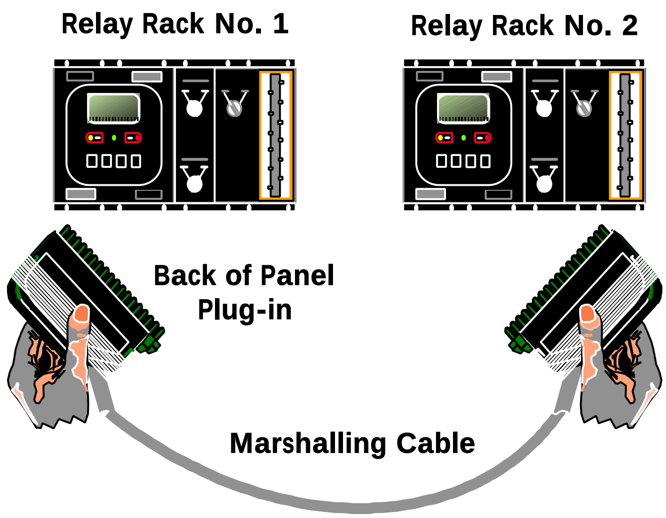

Figure 9. Use of Prewired Marshalling Cables for Blocking Scheme Configuration

Section 5. PROTECTION OF A SECTIONALISED BUSBAR WITH TWO INCOMING FEEDERS - GENERAL PRINCIPLE

Figure 10 shows a typical substation layout, where two incoming feeders supply a number of outgoing radial feeders from a sectionalised busbar. Incoming feeders are given arbitrary designations F1 and F2 (for the purpose of scheme description); the bus section breaker is designated “BS”; and the outgoing feeders 1A, 1B, 2A and 2B. Because fault current may flow in either direction at the incomers and the bus section, those overcurrent relays must be directional, eg. From the MiCOM P140 Series. Outgoing feeders could use non-directional relays if all feeders are radial, however directional relays can be used when voltage, real power and VAr measurement functions are required, or merely for standardisation. These notes assume that P140 Series relays will be used throughout, making connections to the voltage transformers already required to directionalise the incomer and bus section relays. The use of P140 relays throughout would also allow Busbar Blocking Scheme application where outgoing feeds are non-radial (eg. parallelled or forming part of a ring main), however fault current division would need to be considered.

Note that the following conventions have been observed:

- The Blocking Scheme will provide two distinct zones of busbar protection, Zone 1 for the left hand side of the busbar, and Zone 2 for the right.
- The forward direction for incoming feeder relays is away from the busbar, similarly for outgoing feeders.
- The benefits of standardisation can be gained by choosing the forward direction for the bus section relay to be for current flow from Zone 1 of the busbar into Zone 2. Typically this equates to current flow from left to right on-site.

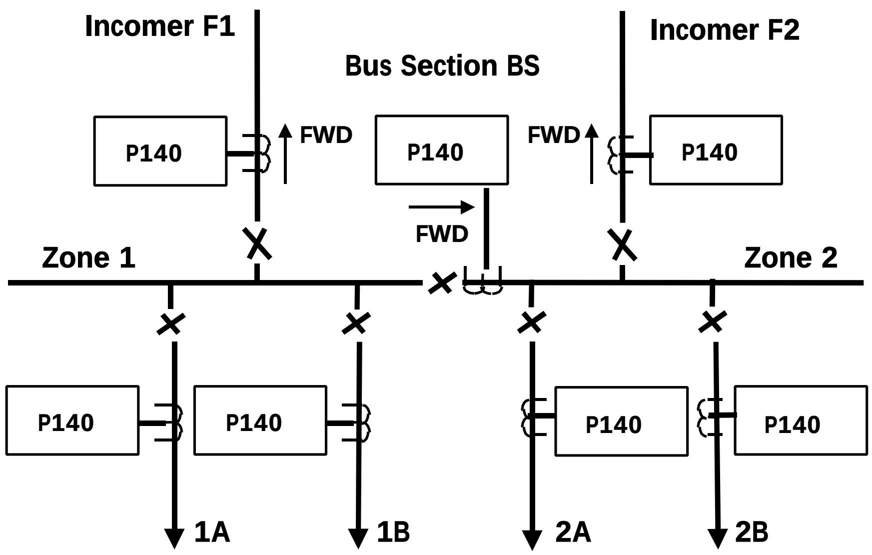

Figure 10. Busbar Blocking Scheme – Sectionalised Busbar

The positions of the current transformers define the boundaries of each of the zones of busbar protection, so ideally all the relays are positioned on the line side of their circuit breakers. It does not matter if the bus section relay is on the left hand side of the circuit breaker provided that its forward direction is left to right, as shown. The relays are split up into two zones, so that a fault on one side of the busbar does not cause isolation of the whole substation. The benefit of using MiCOM P140 relays throughout means that all are interchangeable, thus limiting the number of spare relays required, as a feeder relay can be used on an incomer and vice versa.

At this point it is recommended that the reader familiarises him/herself with the general principle of a Busbar Blocking Scheme applied to a simple busbar layout, as described in Section 2. The extension of the scheme to cover a sectionalised busbar with two incomers, whose operation is discussed below, can then be read.

<u>5.1 Zone 1 Bus Zone Protection - Tripping Elements</u>

The Busbar Protection for Zone 1 is configured using the P140 relays already required for feeder and bus section protection. If a fault occurs in busbar Zone 1, a bus zone trip will result, after a small inherent time delay. To standardise, all relays connected to Bus Zone 1 use third stage I>3 and IN>3 elements for busbar protection trips. In the relay menu, both of these elements are set reverse directional. This makes the elements sensitive to current flow towards the busbar. Correct settings ensure that a busbar fault would lead to current above the I>3 or IN>3 third stage pickup for any infeed into Zone 1. Depending on which of the breakers are closed at the time of the fault, this would cause I>3 or IN>3 tripping of incoming feeder relay F1, and/or the bus section in order to interrupt all fault current infeeds. (Should there be any infeed such as local generation on feeders 1A or 1B, this too would trip, assuming that the third stage elements are set following the same practice).

As fault current may flow via F1 or the bus section to an out of zone fault, I>3 and IN>3 tripping must be subject to blocking logic, similar to that shown in Figure 4. The criteria for blocking are now discussed in Section 5.2.

5.2 Zone 1 Bus Zone Protection - Blocking Elements

Any fault external to the bus zone must be detected by the relevant P140 relay, which must close its directional start output contacts (I>1 /IN>1 Start) as appropriate to block (prevent) bus zone tripping for Zone 1. The starts are forward directionalised, for fault current away from the busbar. Fault scenarios are shown in Table 4.

Location of Fault on System	**Block Issued by Relay**	**Start Contacts for Blocking**	**Effect on Bus Zone 1 Protection**
Feeder 1A	1A	I>1/IN>1 (FWD)	Stable
Feeder 1B	1B	I>1/IN>1 (FWD)	Stable
Feeder 2A	Bus Section, BS	I>1/IN>1 (FWD)	Stable
Feeder 2B	Bus Section, BS	I>1/IN>1 (FWD)	Stable
Busbar Zone 1	(No Block)		Bus Zone Trip
Busbar Zone 2	Bus Section, BS	I>1/IN>1 (FWD)	Stable
Incoming Feeder F1	F1	I>1/IN>1 (FWD)	Stable
Incoming Feeder F2	Bus Section, BS	I>1/IN>1 (FWD)	Stable

Table 4. Effect of System Faults on Bus Zone 1 Protection (see Figure 10)

Note that it is the job of the Bus Section relay to stabilise the scheme for any fault on the right hand side of the power system.

5.3 Zone 2 Bus Zone Protection - Tripping Elements

All relays except the bus section use third stage I>3 and IN>3 elements for busbar protection trips, as in 5.1. Because the bus section third stage is already being used to configure Zone 1 protection, the I>4 / IN>4 fourth stage is used for Zone 2 bus zone tripping at the bus section. This element is directionalised Forward.

5.4 Zone 2 Bus Zone Protection - Blocking Elements

The Busbar Protection for Zone 2 is configured in a similar way, except that reverse start contacts for the bus section relay are used in the blocking scheme. These starts are obtained from reverse directionalised I>2 and IN>2 elements. Fault scenarios are shown in Table 5.

Location of Fault on System	**Block Issued by Relay**	**Start Contacts for Blocking**	**Effect on Bus Zone 2 Protection**
Feeder 1A	Bus Section, BS	I>2/IN>2 (REV)	Stable
Feeder 1B	Bus Section, BS	I>2/IN>2 (REV)	Stable
Feeder 2A	2A	I>1/IN>1 (FWD)	Stable
Feeder 2B	2B	I>1/IN>1 (FWD)	Stable
Busbar Zone 1	Bus Section, BS	I>2/IN>2 (REV)	Stable
Busbar Zone 2	(No Block)		Bus Zone Trip
Incoming Feeder F1	Bus Section, BS	I>2/IN>2 (REV)	Stable
Incoming Feeder F2	F2	I>1/IN>1 (FWD)	Stable

Table 5. Effect of System Faults on Bus Zone 2 Protection (see Figure 10)

Note that it is the job of the Bus Section relay to stabilise the scheme for any fault on the left hand side of the power system.

5.5 Improvements to Traditional Blocking Schemes

Several improvements compared to traditional schemes enhance scheme security:

- Directionalising I>3 and IN>3 tripping elements in reverse makes their operation dependent on suitable polarising voltages being present. This means that should polarising be unavailable, even though I>1 and IN>1 FWD blocking elements cannot operate, bus zone tripping elements too are inoperative, giving scheme stability. (Similarly, the I>4 and IN>4 elements at the bus section are made to be dependent on polarising voltages by being set forward directional.)

- It is recommended that phase fault bus zone trip elements use 2 out of 3 (2/3) logic to ensure that correct element directionality is maintained, even during evolving faults. During fault evolution, there is the slight possibility that one phase element may transiently make an incorrect directional decision. Making the output from phase elements subject to the agreement of two or more phases maintains optimum directionality. Note: Detection of single phase to earth busbar faults is then the sole responsibility of IN>3 earth fault elements (IN>4 for Zone 2 at the bus section).

5.6 Bus Zone Tripping and Breaker Failure Protection

It is standard practice to trip all of the circuit breakers connected to a section of busbar in the event of a busbar fault, even though current infeeds may only be via Feeder 1, Feeder 2 or the Bus Section. This is achieved using a parallel connection of output contacts to energise Bus Zone Trip buswires between relays. In the event of I>3 or IN>3 elements operating for a fault in busbar Zone 1, output contact(s) RL5 are configured to energise backtrip buswires. The buswires would energise an opto input on each of the P140 series relays at the zone boundary (ie. F1, 1A, 1B and BS). Any “Bus Zone Trip” command received via this opto input is routed to the relay’s trip output contact, in a similar way to that shown in Figure 7. To enhance the scheme, the circuit breaker fail protection in all Zone 1 boundary relays can be wired to energise the same buswires, and also backtrip the entire zone in the event of any individual failure to trip. Note - it should be ensured that the voltage depression on the trip battery is not too severe during this mass trip operation.

A second set of buswires interconnects all Zone 2 relays. Busbar trip elements I>3 and IN>3 for F2, 2A and 2B operate RL5 output contacts to energise these buswires. Busbar trip elements I>4 and IN>4 are used in the bus section relay, assigned to output contacts RL4, and connected in parallel with those for the feeder relays. Similar to Zone 1, energising the Bus Zone 2 Trip buswires initiates all Zone 2 breakers to trip for full isolation of a busbar fault, or a breaker fail backtrip.

Note that including breaker fail protection in the scheme is extremely beneficial, particularly at the bus section. As can be seen in Figure 10, the location of the BS current transformers means that a small section of the right hand side of the busbar appears within Zone 1. Should a busbar fault occur within this section, Zone 1 protection will initiate isolation of the left hand side of the busbar. However, the breaker failure protection in the bus section relay will detect that fault current still flows through its CTs, and will initiate a breaker fail backtrip for both sides of the busbar, after the set delay. This ensures an eventual trip for Zone 2, as required to clear the fault. (In the event that adding the breaker fail timer setting onto the usual scheme trip time for a busbar fault results in too slow a clearance time, two bus section relays can be fed from separate CTs. A set of CTs would be situated on each side of the bus section breaker, with the relays connected such as to provide two overlapping zones of protection.)

The scheme design would become as shown in Figure 11. NOTE: As for simple overcurrent protection, **RL3 is assigned as the Trip output contact**, tripping the relevant feeder or bus section circuit breaker.

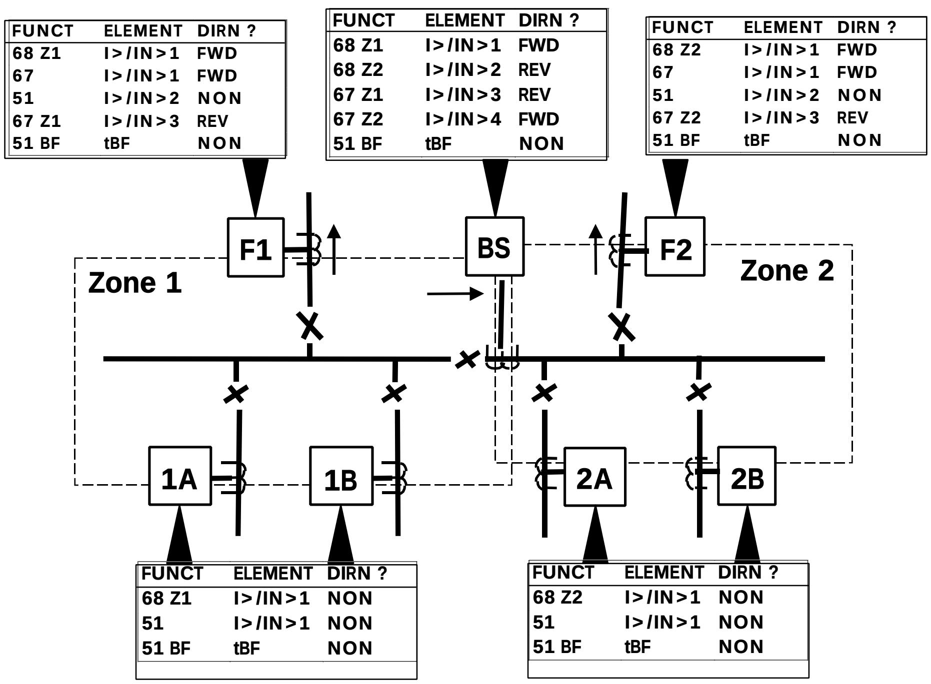

Figure 11. Sectionalised Busbar Blocking Scheme

KEY:

OUTGOING FEEDERS (Example F1)

- 68 Z1 Blocking element for Zone 1 Bus Zone Protection;
- 51 IDMT overcurrent protection for the feeder (or could be directionalised);
- 51 BF Breaker fail protection (backtrips entire zone).

INCOMING FEEDERS (Example 1A)

- 68 Z1 Blocking element for Zone 1 Bus Zone Protection;
- 51 IDMT non-directional incomer overcurrent protection;
- 67 Fast IDMT overcurrent protection looking back upstream;
- 67 Z1 Tripping element for Zone 1 Bus Zone Protection (backtrips entire zone);
- 51 BF Breaker fail protection (backtrips entire zone).

BUS SECTION

- 68 Z1 Blocking element for Zone 1 Bus Zone Protection;
- 68 Z2 Blocking element for Zone 2 Bus Zone Protection;
- 67 Z2 Tripping element for Zone 2 Bus Zone Protection (backtrips entire zone);
- 67 Z1 Tripping element for Zone 1 Bus Zone Protection (backtrips entire zone);
- 51 BF Breaker fail protection (backtrips both Bus Zones).

Note that the element function designations are taken from ANSI/IEEE standard C37.2. Publication R4013 (Application Guidelines - Overcurrent and Earth Fault Protection) gives details for setting the directional and non-directional overcurrent elements not forming part of the busbar scheme. Outgoing feeders could be directionalised, and configured to match incoming feeders for non-radial systems, or where transient backfeed is expected (as described in section 3.7).

Section 6. PROTECTION OF A SECTIONALISED BUSBAR WITH TWO INCOMING FEEDERS - RELAY SETTINGS

Figure 12 below shows the method by which time discrimination between the incoming feeder and outgoing feeder protection is maintained. Firstly, all relays have I>1 and IN>1 overcurrent and earth fault IDMT elements set. The incoming feeders also have non-directional I>2 and IN>2 elements to provide backup protection for downstream busbar or outgoing feeder faults. For all fault currents up to the maximum busbar fault level, these incoming feeder curves should be slower than the outgoing feeder curves by a suitable grading margin. This is marked “IDMT Margin” in the Figure, with 0.4 seconds being typical. Note that the busbar fault level considered is that for just one incoming feeder in service, where all fault current would flow via one incoming feeder, rather than via the two incomers in parallel. This is the worst case condition for grading, allowing for switched feeding arrangements.

Secondly, the I>3 and IN>3 time delays for the incomer must be sufficient to allow for correct receipt and application of blocking signals.

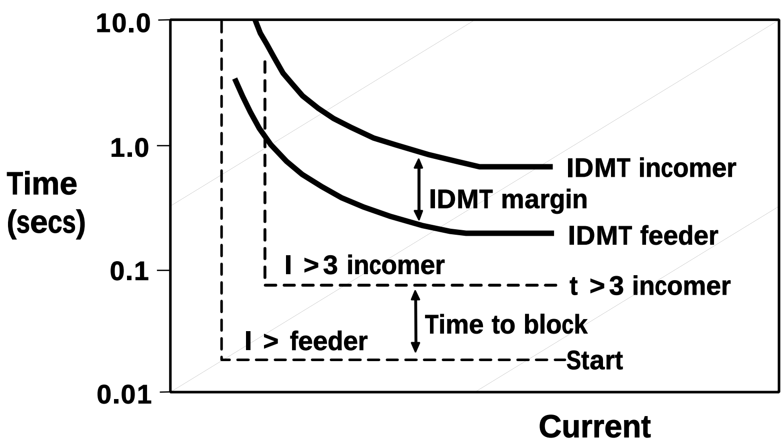

Figure 12. Selection of Relay Current and Time Delay Settings

Note that the settings of the bus section relay are omitted from the diagram, for clarity. In practice, the I>1 / IN>1 and I>2 / IN>2 current pickup settings of the bus section relay will be set the same as I>2 / IN>2 respectively for the incoming feeders, to give equal sensitivity of Start output contacts. To configure the two zones of busbar protection, I>3 / IN>3 and I>4 / IN>4 for the bus section will be set the same as I>3 / IN>3 for the incoming feeders. The time delays for these elements at the bus section are set equal to the I>3 / IN>3 bus zone delay for the incomers.

If the I>1 and IN>1 elements at the incoming feeders are forward directionalised, they look in the opposite direction to load current. Then, their current settings do not need to discriminate with load. They can be set sensitive and fast - giving fast fault clearance for a fault on an incoming feeder. Typical settings would be I>1 = 50% In, Standard Inverse Curve and TMS = 0.10. Using an IDMT element effectively biases the directionalised trip decision to the phase(s) carrying the greater amount of fault current, as the IDMT curve will time out quickest for this phase. Practical experience has shown that this phase(s) has the most reliable directionality during evolving faults.

Note: (1) All incoming and outgoing feeders have IDMT overcurrent protection; also (2) The busbar has bus zone protection; and (3) Backup protection is provided by incoming feeder I>2 / IN>2 elements, there is usually no requirement for IDMT protection at the bus section relay. The I>1 / IN>1 and I>2 / IN>2 elements at the bus section are thus required to give forward and reverse start outputs, but usually not a trip. In order to effectively disable the IDMT tripping function the Time Multiplier Settings for these elements can be set high, at say TMS = 1, or alternatively remove the trip mappings to RL3 in the Programmable Scheme Logic.

A flowchart to assist in calculating P140 relay settings for Busbar Blocking Schemes is shown in Figure 13, with detailed guidance following in Sections 6.1 to 6.9.

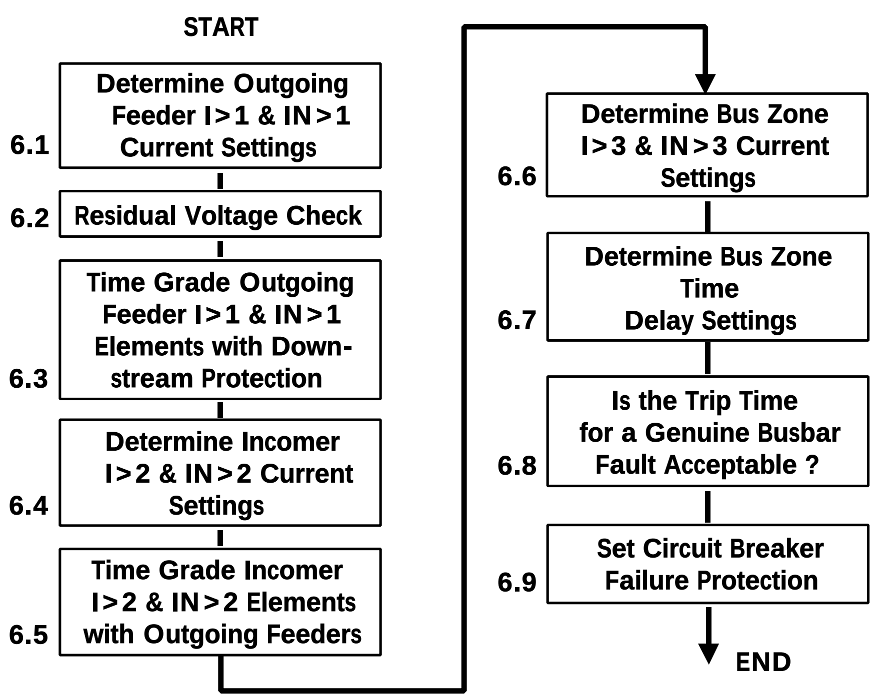

Figure 13. Flowchart for Setting Blocking Scheme - Sectionalised Busbar

6.1 Outgoing Feeder I>1 and IN>1 Current Settings

The primary I>1 phase fault pickup setting must be set higher than maximum load current, and higher than the primary current setting of downstream protection. Typically, settings would be the higher of:

I >1	≥	(Full Load Current) x (100% + Transient overload) / Relay reset ratio	
	≥	FLC x 110% / 0.95	
	≥	Typically 120% FLC	(Higher where motor starting current is significant).

And:

I >1	≥	Downstream Relay pickup x 110%	

Or:

I >1	=	3 to 4 times Downstream Fuse rating	(In practice).

In a similar way, the IN>1 earth fault element pick-up must discriminate with the maximum single phase loading imbalance, and with any downstream earth fault protection. Publication R4013 (Application Guidelines - Overcurrent and Earth Fault Protection) gives details, if required.

6.2 Residual Voltage Check

As bus zone tripping elements use 2 out of 3 (2/3) logic for correct element directionality, these overcurrent elements will not trip for a single phase to earth fault. It is therefore essential that earth fault protection will detect all busbar. All relays in the bus zone scheme are directionalised, and so sufficient residual voltage will need to be generated in order to achieve earth fault element trips.

All earth fault protection has been made directional, and thus dependent on residual voltage above the P140’s VN>pol. setting being generated. The VN>pol. setting is calculated to be above the standing VT error, and might typically be set at 3% of phase-neutral voltage, as described in the Technical Guide TG8612 Chapter 2 Application Notes. For a 100-120V secondary VT, this would give VN>pol. = 2.0V. Voltage checks need to be made to ascertain whether:

- (1) Sufficient residual voltage is generated for a downstream distant earth fault, where the IN>1 outgoing feeder protection setting is just exceeded, and is expected to trip. If insufficient residual voltage is generated, operation of the outgoing feeder IDMT protection cannot be guaranteed. (Note: If the outgoing feeders are radial, the option of making their IDMT protection non-directional exists).

- And, (2) Sufficient residual voltage is generated for an earth fault which would result in IN>3 bus zone protection pickup, and so requires reliable blocking signals to be issued to the incoming feeder and bus section relays of the unfaulted bus zone(s).

In practice, criterion (1) above is usually the most onerous, and so the voltage check calculation can be made at this stage. If criterion (1) is satisfied, then criterion (2) should be met. The two fault scenarios are shown as F1 and F2 respectively in Figure 14.

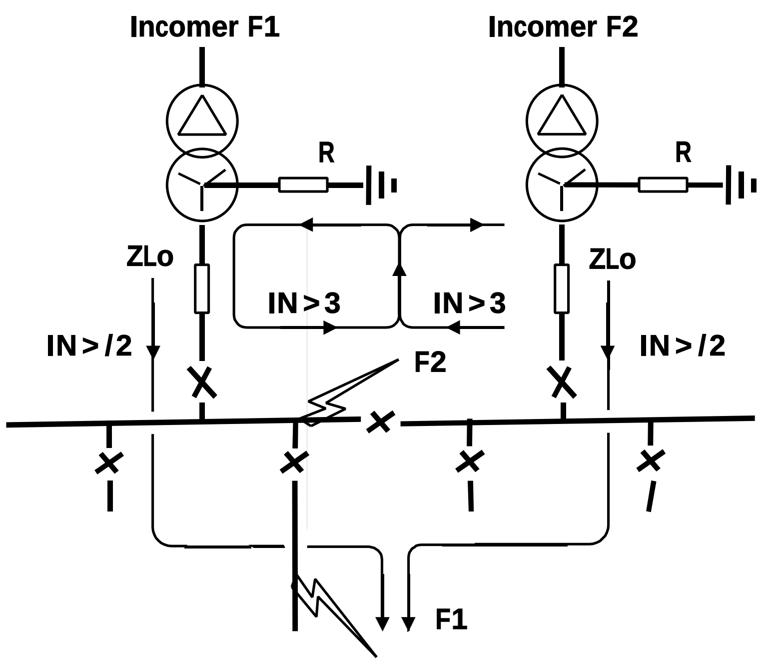

Figure 14. Faults Considered for Residual Voltage Check

Note that for faults F1 and F2, the fault current will flow in parallel via both incoming feeders. The current will return to the transformer neutral-earth connections upstream. In order to calculate the residual voltage developed for fault F1:

Vres = (IN> / 2) x (Z_{LO} + X_{TO} + 3R) <u>Must be greater than VN>pol. setting</u>.

Where:

IN> = Outgoing feeder earth fault current setting;

Z_{LO} = Upstream line zero sequence impedance (zero if transformers are at this substation);

X_{TO} = Transformer zero sequence reactance;

R = Transformer neutral earthing resistance (zero if transformers are solidly earthed).

To calculate X_{TO} in ohms, given the system voltage (“V” in kV), transformer rating (“S” in MVA), and a reactance quoted as a percentage (“X%”), use:

$$X_{TO} = (V^2 / S) \times (X\% / 100) \quad \Omega$$

6.3 Grading Outgoing Feeder I>1 / IN>1 Elements with Downstream Protection

Here, conventional time grading principles are used, as in Publication R4013.

6.4 Incomer I>2 and IN>2 Current Settings (also Applied at Bus Section)

Conventional current pickup and time grading principles are used, as in Publication R4013. Incoming feeder IDMT elements are still required for non-directional back-up protection, as in traditional applications. The bus section relay makes use of similar pickup settings for FWD (I>1/IN>1) and REV (I>2/IN>2) starts.

6.5 Grading Incomer I>2 / IN>2 Elements with Outgoing Feeders

As previous section 6.4 and R4013. The busbar fault level for grading purposes is that for just one incoming feeder in service, where all fault current would flow via one incoming feeder, rather than via the two incomers in parallel.

6.6 Bus Zone Trip I>3 and IN>3 Current Settings

The I>3 setting for bus zone protection must exceed the maximum transient load current, in a similar way to section 6.1. The primary I>3 setting for the incomer protection should also exceed the highest primary I>1 setting of an outgoing feeder relay by at least 25% in order to ensure full co-ordination of the busbar protection scheme. This setting recommendation is based on the assumption that there are no interconnecting paths between remote ends of the outgoing feeders (ie. all outgoing feeders are radials, none are parallelled, and none form part of a ring main). Those cases would have to be carefully considered in order to determine a suitably safe margin between the primary I>3 overcurrent setting for the incomers and the primary I>1 setting for the outgoing feeders.

In this application, earth fault elements are included in the busbar protection scheme to provide tripping even for a low level of busbar earth fault current. The incomer primary I_N>3 setting should exceed the highest feeder I_N>1 setting by <u>at least 25%.</u> Also, the incomer I_N>3 setting should ideally be less than 30% of the minimum bus earth fault level, to ensure fast fault clearance.

The bus section relay makes use of similar I>3 and IN>3 pickup settings for I>3/I>4 and IN>4/IN>4 respectively.

6.7 Bus Zone Trip I>3 and IN>3 Time Delay Settings

Time delay settings for I>3 and IN>3 on the incoming feeder relay can be chosen from the following Table, with <u>both time delays set to the same value</u>. In Table 6, X/R is the primary system reactance/resistance ratio, and the maximum system fault current level is expressed as a multiple of the smallest CT rating used in the scheme (ie: a “times In” figure).

Maximum System Fault Level	X/R Ratio			
	£ **10**	£ **15**	≤ 20	≤ 25
≤ 20 In	120	130	150	160
≤ 30 In	120	130	150	200
≤ 40 In	120	130	200	200
≤ 50 In	200	200	200	200

Table 6. Typical Minimum Bus Zone Delay Settings (ms) (50Hz)

Typical X/R ratios for distribution systems are shown in bold in Table 6 (ie. 5 to 15). Thus, it can be seen that <u>times in the range 130 to 200ms</u> are typical. Time delays much less than those shown could be determined by system-specific stability testing.

The bus section relay makes use of the same time delay for its Zone 1 and Zone 2 bus zone trips.

6.8 Check on Trip Time for Genuine Busbar Faults

Protection trip times for a genuine busbar fault will be approx. 20ms slower than the set I>3 / IN>3 delay. Thus, 150-200ms is a typical operating time.

6.9 Breaker Failure Protection Settings

The principle of operation is described in Technical Guide TG8612, Chapter 2, Section 2.17. A typical tBF time delay would be 200ms where vacuum circuit breakers (VCBs) are used, possibly slower for oil-filled switchgear (OCBs). Typical I< and IN< undercurrent settings are 20% of In, or half of the respective phase and earth fault overcurrent settings, if lower.

Section 7. PROTECTION OF A SECTIONALISED BUSBAR WITH TWO INCOMING FEEDERS - RELAY CONFIGURATION

7.1 Relay Input/Output Assignments - Incoming Feeder

The busbar blocking scheme can be configured by a modification of the default opto input and output contact assignments, using the MiCOM S1 Programmable Scheme Logic editor. The relevant connections used in scheme are:

	Logic Inputs		Output Relays
L3	**Blocking Bus (Block I>3/IN>3) -** **F1: Blocking Bus 1,** **F2: Blocking Bus 2.**	RL1	**I>1 / IN>1 Start (FWD)**
L6 #	**Bus Zone Trip (for Breaker Fail)** **F1: Bus Trip Zone 1,** **F2: Bus Trip Zone 2.**	RL3	**Trip Circuit Breaker**
		RL5	**Backtrip Bus Zone (Breaker Fail)** **F1: Backtrip Bus Zone 1,**

			<u>F2:</u> Backtrip Bus Zone 2.

Table 7. Incoming Feeder Input/Output Assignment

<u>Note #:</u> Any "Bus Zone Trip" command received via this opto input is routed directly to the relay's trip output contact, RL3.

<u>7.2 Relay Input/Output Assignments - Outgoing Feeder</u>

	Logic Inputs		Output Relays
L3	**Blocking Bus (Block I>3/IN>3) -** **<u>1A, 1B:</u> Blocking Bus 1,** **<u>2A, 2B:</u> Blocking Bus 2.**	RL1	**I>1 / IN>1 Start (FWD)**
L6 #	**Bus Zone Trip (for Breaker Fail)** **<u>1A, 1B:</u> Bus Trip Zone 1,** **<u>2A, 2B:</u> Bus Trip Zone 2.**	RL3	**Trip Circuit Breaker**
		RL5	**Backtrip Bus Zone (Breaker Fail)** **<u>1A, 1B:</u> Backtrip Bus Zone 1,** **<u>2A, 2B:</u> Backtrip Bus Zone 2.**

Table 8. Outgoing Feeder Input/Output Assignment

<u>Note #:</u> Any "Bus Zone Trip" command received via this opto input is routed directly to the relay's trip output contact, RL3.

<u>7.3 Relay Input/Output Assignments – Bus Section</u>

	Logic Inputs		Output Relays

L3	**Blocking Bus 1 (Block I>3/IN>3)**	RL1	**I>1 / IN>1 Start (FWD)**
L4	**Blocking Bus 2 (Block I>4/IN>4)**	RL2	**I>2 / IN>2 Start (REV)**
L5 #	**Bus Zone 2 Trip (for Breaker Fail)**	RL3	**Trip Circuit Breaker**
L6 #	**Bus Zone 1 Trip (for Breaker Fail)**	RL4	**Backtrip Bus Zone 2 (Breaker Fail)**
		RL5	**Backtrip Bus Zone 1 (Breaker Fail)**

Table 9. Bus Section Input/Output Assignment

Note #: Any "Bus Zone Trip" command received via this opto input is routed directly to the relay's trip output contact, RL3.

7.4 Relay Settings - Incoming Feeder

Settings specific to the busbar scheme are listed below, other elements may be enabled if required. Please refer to Chapter 2 Application Notes in Technical Guide TG8612 for guidance. Settings which require a change from the factory defaults are shown in **bold** type.

SYSTEM DATA

Frequency	50 or **60Hz** as appropriate

CONFIGURATION

Overcurrent	Enabled
Earth Fault 1 #	Enabled
CB Fail	**Enabled**

Note #: - Earth Fault 1 elements are driven from the C11-C12 "IN" current input for 1A relays, C10-C11 for 5A relays. This input is usually connected as a residual current measurement from the line CTs.

CT & VT RATIOS

Main VT Primary	**All as appropriate….**
Main VT Secondary	
Phase CT Primary	
Phase CT Secondary	
E/F CT Primary	**Same as Phase CT when using the residual connection.**
E/F CT Secondary	

GROUP 1 OVERCURRENT

I>1 Function	IEC S Inverse
I>1 Direction	**Directional Fwd**
I>1 Current Set	**Typically half CT Primary rating**
I>1 TMS	**Typically 0.10**
I>2 Function	**From Section 6.5**
I>2 Direction	Non-Directional
I>2 Current Set	**From Section 6.4**
I>2 TMS	**From Section 6.5**
I>3 Status	**Enabled**
I>3 Direction	**Directional Rev**
I>3 Current Set	**From Section 6.6**
I>3 Time Delay	**From Section 6.7**
I> Char Angle	**See Application Notes in Manual TG8612**

Note: The I>3 bus zone element is best set for 2/3 tripping in MiCOM S1 PSL.

GROUP 1 EARTH FAULT 1

IN1>1 Function	IEC S Inverse
IN1>1 Direction	**Directional Fwd**
IN1>1 Current Set	**As appropriate**
IN1>1 TMS	**Typically 0.10**
IN1>2 Function	**From Section 6.5**
IN1>2 Direction	Non-Directional
IN1>2 Current Set	**From Section 6.4**
IN1>2 TMS	**From Section 6.5**
IN1>3 Status	**Enabled**
IN1>3 Direction	**Directional Rev**
IN1>3 Current Set	**From Section 6.6**
IN1>3 Time Delay	**From Section 6.7**
IN1> Char Angle	**See Application Notes in Manual TG8612**
IN1> Pol	Zero Sequence
IN1> VN Pol Set	**From Section 6.2**

GROUP1 CB FAIL & I<

CB Fail 1 Status	Enabled
CB Fail 1 Timer	**From Section 6.9**
I< Current Set	**From Section 6.9**
IN< Current Set	**From Section 6.9**

7.5 Relay Settings - Outgoing Feeder

Settings specific to the busbar scheme are listed below, other elements may be enabled if required. Please refer to Chapter 2 Application Notes in Technical Guide TG8612 for guidance. Settings which require a change from the factory defaults are shown in **bold** type.

SYSTEM DATA

Frequency	50 or **60Hz** as appropriate

CONFIGURATION

Overcurrent	Enabled
Earth Fault 1 #	Enabled
CB Fail	**Enabled**

Note #: - Earth Fault 1 elements are driven from the C11-C12 “IN” current input for 1A relays, C10-C11 for 5A relays. This input is usually connected as a residual current measurement from the line CTs.

CT & VT RATIOS

<table>
<tr><td>Main VT Primary</td><td rowspan="4">All as appropriate….</td></tr>
<tr><td>Main VT Secondary</td></tr>
<tr><td>Phase CT Primary</td></tr>
<tr><td>Phase CT Secondary</td></tr>
<tr><td>E/F CT Primary</td><td rowspan="2">Same as Phase CT when using the residual connection.</td></tr>
<tr><td>E/F CT Secondary</td></tr>
</table>

GROUP 1 OVERCURRENT

I>1 Function	**Curve type from Section 6.3**
I>1 Direction	Non-Directional
I>1 Current Set	**From Section 6.1**

I>1 TMS	**From Section 6.3**

GROUP 1 EARTH FAULT 1

IN1>1 Function	**Curve type from Section 6.3**
IN1>1 Direction	Non-Directional
IN1>1 Current Set	**From Section 6.1**
IN1>1 TMS	**From Section 6.3**

GROUP1 CB FAIL & I<

CB Fail 1 Status	Enabled
CB Fail 1 Timer	**From Section 6.9**
I< Current Set	**From Section 6.9**
IN< Current Set	**From Section 6.9**

7.6 Relay Settings – Bus Section

Settings specific to the busbar scheme are listed below, other elements may be enabled if required. Please refer to Chapter 2 Application Notes in Technical Guide TG8612 for guidance. Settings which require a change from the factory defaults are shown in **bold** type.

SYSTEM DATA

Frequency	50 or **60Hz** as appropriate

CONFIGURATION

Overcurrent	Enabled
Earth Fault 1 #	Enabled
CB Fail	**Enabled**

Note #: - Earth Fault 1 elements are driven from the C11-C12 "IN" current input for 1A relays, C10-C11 for 5A relays. This input is usually connected as a residual current measurement from the line CTs.

CT & VT RATIOS

Main VT Primary	**All as appropriate….**
Main VT Secondary	
Phase CT Primary	
Phase CT Secondary	
E/F CT Primary	**Same as Phase CT when using the residual connection.**
E/F CT Secondary	

GROUP 1 OVERCURRENT

I>1 Function	IEC S Inverse
I>1 Direction	**Directional Fwd**
I>1 Current Set	**From Section 6.4**
I>1 TMS	**Typically set high (=1.2), or disable tripping in PSL**
I>2 Function	IEC S Inverse
I>2 Direction	**Directional Rev**
I>2 Current Set	**From Section 6.4**
I>2 TMS	**Typically set high (=1.2), or disable tripping in PSL**
I>3 Status	**Enabled**
I>3 Direction	**Directional Rev**
I>3 Current Set	**From Section 6.6**
I>3 Time Delay	**From Section 6.7**
I>4 Status	**Enabled**

I>4 Direction	**Directional Fwd**
I>4 Current Set	**From Section 6.6**
I>4 Time Delay	**From Section 6.7**
I> Char Angle	**See Application Notes in Manual TG8612**

Note: The I>3 and I>4 bus zone elements are set for 2/3 tripping in MiCOM S1 PSL.

GROUP 1 EARTH FAULT 1

IN1>1 Function	IEC S Inverse
IN1>1 Direction	**Directional Fwd**
IN1>1 Current Set	**As appropriate**
IN1>1 TMS	**Typically 0.10**
IN1>2 Function	**From Section 6.5**
IN1>2 Direction	Non-Directional
IN1>2 Current Set	**From Section 6.4**
IN1>2 TMS	**From Section 6.5**
IN1>3 Status	**Enabled**
IN1>3 Direction	**Directional Rev**
IN1>3 Current Set	**From Section 6.6**
IN1>3 Time Delay	**From Section 6.7**
IN1>4 Status	**Enabled**
IN1>4 Direction	**Directional Rev**
IN1>4 Current Set	**From Section 6.6**
IN1>4 Time Delay	**From Section 6.7**
IN1> Char Angle	**See Application Notes in Manual TG8612**

IN1> Pol	Zero Sequence
IN1> VN Pol Set	**From Section 6.2**

GROUP1 CB FAIL & I<

CB Fail 1 Status	Enabled
CB Fail 1 Timer	**From Section 6.9**
I< Current Set	**From Section 6.9**
IN< Current Set	**From Section 6.9**

7.7 Programmable Scheme Logic – All Relays

Modifications to MiCOM P140 relay PSL files need to be made, as summarised in Table 10 below:

Description	**Incoming Feeder**	**Outgoing Feeder (*)**	**Bus Section**
Route only phase and earth fault I>1 / IN>1 starts to RL1, via an OR gate	√	√	√
Remove phase fault start from RL2	√	√	√
Route only phase and earth fault I>2 / IN>2 starts to RL2, via an OR gate			√
Remove I>3 trip from tripping RL3, and replace with I>3 phase segregated trips in 2/3 logic	√		√
Remove I>4 trip from tripping RL3, and replace with I>4 phase segregated trips in 2/3 logic			√
Route I>3 trip in 2/3 logic as above to close RL5, “OR”ed with the Bfail1 signal already assigned	√		√
Remove alarm signals from RL4			√
Route I>4 trip in 2/3 logic as above to close RL4,			√

"OR"ed with the Bfail1 signal			
Remove blocking assignments from opto input L3	√	√	√
Assign blocking opto input L3 to block only I>3 and IN1>3	√		√
Remove blocking assignments from opto input L4	√	√	√
Assign blocking opto input L4 to block only I>4 and IN1>4			√
Route L6 External Trip opto into the OR gate feeding RL3	√	√	√
Remove reset mappings from opto input L5			√
Route renamed L5 External Trip opto into the OR gate feeding RL3			√

Table 10. Modifications Required to P140 Programmable Scheme Logic

Note (*): It is often advantageous to configure the PSL for outgoing feeders to match that for incomers, for commonality, and to allow for future conversion to non-radial feeding.

7.8 Sectionalised Busbar - Interconnecting Wiring

Figure 15 shows the hard-wired interconnections between MiCOM P140 series relays required to configure the blocking scheme. All relays except the bus section make connections to three buswires, namely the +48V Field Supply Buswire, a Blocking Buswire, and a Bus Zone Trip Buswire. There is no need to run –48V buswires as the cathodes (negative terminal) of all opto inputs are commoned together at each relay, and then connected to the negative terminal of the field voltage supply. Note that unlike in Figure 9, there are two distinct zones of protection, and so there are two Blocking Buswires (Zone 1 and Zone 2), and also two Bus Trip Buswires. The bus section relay is connected to all five buswires. Only three relays are shown, for simplicity. The buswires extend along the length of the switchgear, marshalling the scheme I/O for all feeders. Figure 9 shows how buswires may run within K-marshalling cables, giving the benefits of easy interconnection, and allowing standardisation within racks of feeder protection.

NOTES: As for simple overcurrent protection, **RL3 is assigned as the Trip output contact**, tripping the relevant feeder circuit breaker. Also, when using the P143 relay, terminals H1, H2 … H12 are used instead of E1, E2 … E12; and terminals J8 and J9 are used instead of F8 and F9.

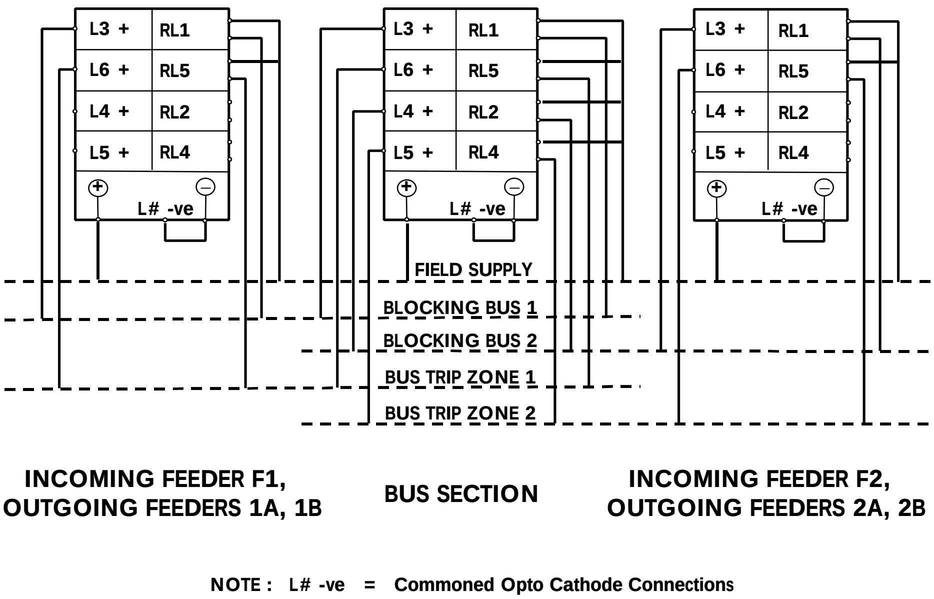

Figure 15. Relay Interconnections to the Scheme Buswires

Section 8. CONTACTS FOR ASSISTANCE

UK Advice and assistance can be provided by the following departments, at the contact address shown on the front cover of these Application Notes:

- General Technical Queries - UK Sales & Service;
- Prefabricated Racks and Schemes - Systems Projects Department;
- Sales Queries - Sales, UK Sales & Service.

Outside of the UK, please contact your local ALSTOM Sales and Service representative