7SG11 Argus 8

Voltage and Frequency Relays

Document Release History

This document is issue 2010/02. The list of revisions up to and including this issue is:

Pre release

2010/02	Document reformat due to rebrand

Software Revision History

2011/11	2422H80004R7	Fault trigger when the voltage blocking threshold is OFF. IEC 60870-5-103 fault numbering for fault and its measurands

Contents

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1 Introduction

There are numerous applications for the Argus 8 series of relays, which have been developed suitable for generation, industrial, distribution and transmission systems. This application guide will illustrate some typical examples, though actual setting guidelines or recommendations will be limited, as these are very much system dependent.

2 General Information

2.1 Relay External Connections

The Argus 8 relay can be configured in many different ways, which usually involve different external connections to the relay. For phase-neutral and phase-phase connections the relay assumes nominal 63.5V and 110V systems respectively. This does not mean that the relay cannot be applied to nominal 57.7V and 100V systems. For these systems the normal operation of the relay is identical to that of the 63.5 / 110V systems.

Note, however, that if the relay is used in 57.7 / 100V systems and the communications interface is accessing the relay's measurand data, any Class 2 measurands will be normalised to 63.5 / 110V nominal secondary voltages.

Figures 2 through to 7 are typical application diagrams, which show ways of connecting and using the relays in different configurations.

2.2 Voltage Blocking Element

The voltage blocking element acts as a block to the Voltage, Frequency and NPS elements in the relay. If all phase voltages fall below the threshold level then the blocking operation will operate. This block does not apply to the NVD elements.

The voltage blocking element performs a number of functions :

1. If the relay has been set up with undervoltage elements enabled and is switched on with no volts applied to its inputs then, an undervoltage starter would pickup and the relay may issue a trip. The relay would then stay locked in this trip condition until volts are applied and the element is reset. To prevent this from happening the voltage blocking threshold has to see volts above its set level otherwise the relay is fully blocked and no starter or trip operation will follow.
2. In auto-reclose schemes the voltage blocking threshold can be used to prevent unnecessary operations of the undervoltage elements during the time when the line is de-energised. For this type of blocking operation the threshold is typically set to 20% of rated volts, though it should always be set to a value above the expected level of induced voltages on the line.
3. Where the Relay is used in Under / Over Voltage schemes the relay can discriminate between the condition of a true system Undervoltage which exists for some time i.e. a progressive reduction in system voltage, caused by increase in loading or due to switching or as a result of problems with tap changers, and for which a Trip output must be given; or, the condition of an Undervoltage due to loss of system voltage due to an upstream circuit breaker being opened which results in a rapid voltage collapse to a much lower voltage, this voltage value being determined by coupling from parallel lines or grading capacitors across series break contacts in Circuit Breakers, and for which it may not be desirable for a Trip to be issued, note that resultant differential coupling voltages may also cause the NPS Element threshold to be exceeded and the NPS element to operate. Setting the Voltage Blocking Threshold to a setting above the expected induced dead-line voltage causes the Undervoltage block to be raised to inhibit U/V & NPS elements to prevent unwanted Trips / alarms from being generated.

The Voltage Blocking Threshold setting should be set either to the minimum setting of 1 volt or to a value graded above the expected dead-line voltage.

In schemes where detection and Alarm /Trip outputs for absolute zero volts is also required the UnderVoltage Block output ‘ V Block Alarm ‘ should be mapped to the relevant output relay(s). If a Time delay is needed then the output relay should be connected to a Status input to make use of its Pick-up and Drop-off time delays.

2.3 **Output Contact Delay Time**

The output relay contacts have a typical close response time of 7ms.This inherent delay is not, however, the only factor determining the actual contact closure time. The relay has a main software control loop of 10ms. Any software decision or external interrupt to the microcontroller involves a maximum possible delay of 10ms while the software completes the loop. This time should be added to the contact closure time of 7ms to give a maximum response time.

e.g. - if an energisation signal is applied to a status input which is programmed to directly operate an output relay the following delays should be added:

Status I/P response time (< 5ms) + Status PU delay setting + S/W loop (max. 10ms) + O/P contact closure (typically 7ms).

This gives a total time of < 22ms + Status PU delay setting.

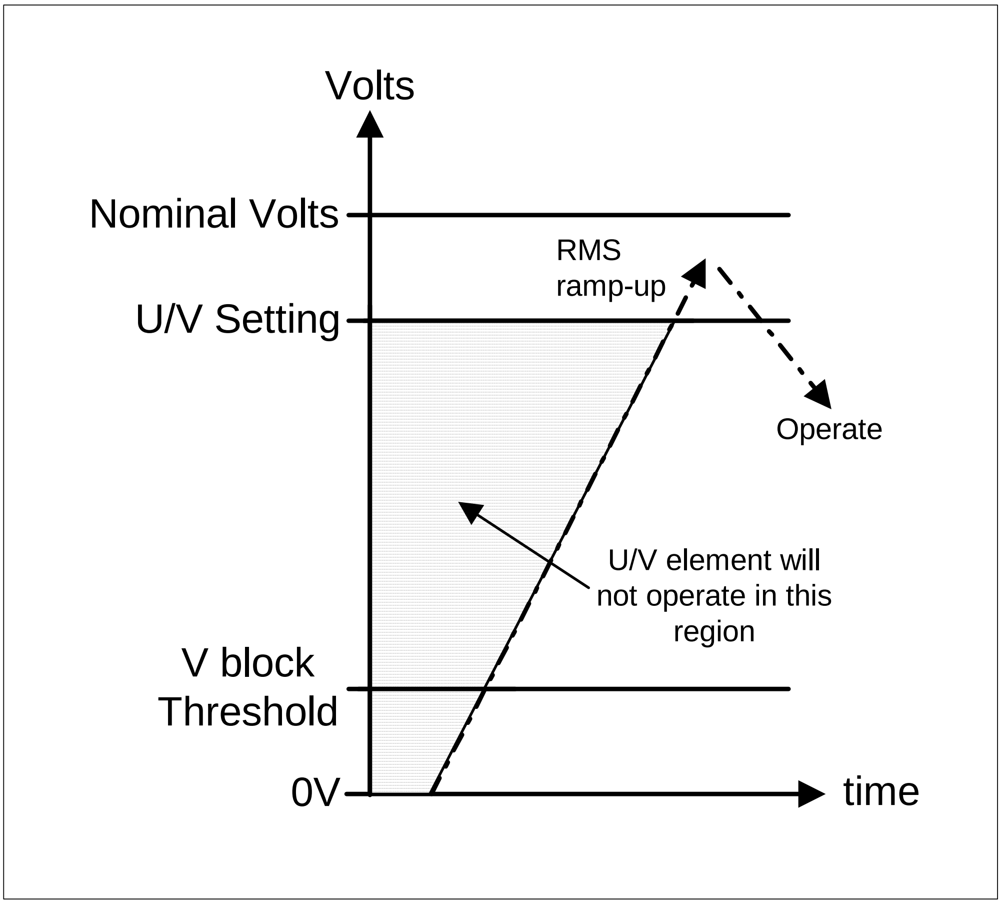
2.4 **Setting DTL Times**

When applying a DTL timer with any of the protection elements the instantaneous operate time of the element will have to be determined so that the overall required time delay can be set.

Total Delay Time = Instantaneous Operate Time + DTL Time

The performance specification - Section 2 of this manual gives typical instantaneous operate times for all of the different characteristics. The instantaneous operate time of an under voltage element for example can vary between < 65ms to about 47ms at its fastest. This variation is due to the level of applied undervoltage and is in fact a function of the method of calculation.

Note that the instantaneous operate time of an undervoltage element is marginally slower than that for an equivalent overvoltage element. This is because the undervoltage element is deliberately ‘slugged’ so that, when nominal voltage is applied, the RMS calculation has time to ramp up to the correct level without issuing an invalid trip during the ramp up sequence. This is shown in the diagram below:



2.5 Voltage Element Hysteresis

Each under and over voltage element has a variable hysteresis setting which allows the user to alter the pick-up / drop-off ratio (or drop-off / pick-up ratio) of the element. Note that the NPS, NVD and frequency elements have fixed levels of hysteresis which are not adjustable.

When using the variable hysteresis, care has to be taken to ensure that with undervoltage elements, the reset level of the element is not set to a value higher than that at which the system rated voltage is expected to operate. The system rated voltage will have a tolerance of typically +/- 6% and so the upper level of the hysteresis must be below the lower limit of the tolerance, otherwise the element might not reset in practice. Conversely, the level of hysteresis set for an overvoltage element should not be set below that at which the system rated voltage is expected to run.

Typical values for the amount of hysteresis applied to a voltage element are < 5%. When setting the hysteresis level the user has to be aware that if the amount of hysteresis is set too low e.g. 1%, then for large frequency excursions and low values of voltage element setting, the element might become unstable and ‘chatter’. This will produce nuisance alarms / tripping and generate large numbers of stored event records. A minimum recommended level is 2% for this reason.

2.6 Trip Circuit Supervision

Argus relay can be used to supervise trip circuits while the associated circuit breaker (CB) is either open or closed. A low value of dc current, derived from the auxiliary supply, is passed through the entire trip circuit to monitor the trip coil, its auxiliary switch, the CB secondary isolating contacts and the relevant wiring. If the current flow ceases, the energised status input drops off and if it is user-programmed to operate one of the output relays, this relay will close an output contact to signal trip circuit failure. In addition, the LCD display on the Argus relay will indicate ‘Trip Circuit Fail’.

To avoid giving spurious alarm messages while the CB is operating, or protection device on adjacent supply circuits is operating, the status input should be programmed to have a 500ms drop-off delay.

The Electricity Association H6 Scheme is shown in Figure 1.

3 Application of Functions

3.1 Undervoltage Protection

Undervoltages are reasonably frequent events on power systems and can occur for a number of different reasons. Faults on the system can cause the phase voltages to be depressed, the actual voltage drop being dependent upon a number of factors including the fault type and system earthing etc. During system earth fault conditions, the undervoltage protection is not generally required to operate and thus connecting the relay in the phase-phase configuration will make it less susceptible to single-phase voltage depressions.

Another cause of undervoltage is an increase in system loading, which should be corrected by system regulating equipment such as tap-changers and AVR’s. However, if this equipment is defective then an undesirable situation will occur which will require an undervoltage relay to trip non-essential loads to correct for this voltage excursion and to bring it back to its nominal level. This tripping should happen after an appropriate time delay has expired. Generally, wherever voltage relays are employed, timing elements should be used to prevent operation during transient disturbances.

If the system is supplying 3-phase induction motors or variable frequency thyristor drives, undervoltages can have the following effect. Voltage depressions down to approximately 80% of rated voltage cause the load current to increase, possibly resulting in a larger voltage depression due to the supply source impedance. Below 80% the current drawn is proportional to the voltage and an induction motor is likely to stall. The current drawn is then dependent on the drive design e.g. thyristor drives include current limitation. An undervoltage element can be set to trip out a motor circuit when the voltage falls below a preset value, selected based on the motor drive and system design parameters, and after a preset time delay. The time delay is required to ensure voltage dips due to remote system faults do not result in an unnecessary trip.

If the system supply to a group of motors is lost, undervoltage protection can be applied to ensure that each of the motor circuit breakers or contactors are tripped so that on restoration of the main supply, it is not overloaded by the simultaneous starting of all the motors. A 3-phase undervoltage relay may be used for this task of tripping a feeder for the detection of a complete loss of voltage. Also, where a supply to induction motors is lost, the undervoltage relay can be used to detect the loss of supply or to monitor any busbar residual voltage e.g. resulting from back e.m.f. generated by the induction motors as they run down. The relay can act as a guard prior to re-connecting a supply from an alternative source.

Where undervoltage relays are used on a system, the voltage elements should be set to a value below that where a normal system voltage excursion can be expected. (See also section 2.5). Typically the set values may be of the order of 65-80% of nominal for protection of the system or plant. For confirmation that a monitored supply is 'dead' or that any residual voltage has reduced to a safe level, typical set values should be of the order of 10-30% of nominal voltage.

3.2 Overvoltage Protection

Overvoltages may be caused for a number of different reasons. On generator sets for example, it may be caused by defective operation of the voltage regulator, or, if there is a sudden loss of load due to line tripping. Under this load rejection situation the generator set may overspeed causing a dangerous voltage rise. This should be corrected by system regulating equipment such as tap changers and AVR's, but if this equipment mal-functions then voltage levels may rise. High levels of overvoltages on a system cannot be sustained for long periods because they can cause damage to the system insulation and severely affect the life of the insulation. An overvoltage element with an appropriate DTL time delay setting to allow for the normal system regulating equipment to operate can be used to protect against this type of condition.

With a maximum of four overvoltage elements available, the Argus 8 relay can provide for a variety of different applications. If the overvoltage condition is only small a relatively long DTL time delay can be set on an element to clear the fault. If the overvoltage is more severe then another element, set at a higher pickup level and with a faster DTL time, can be used to clear the fault more quickly. Alternatively, elements can be set to provide alarm and tripping stages, with the alarm levels set lower than the tripping stages.

Note - the use of instantaneous and wide ranging DTL settings allows a simple and secure grading system to be applied to co-ordinate the network design, the regulating plant design and system plant insulation withstand. The use of IDMTL protection is not recommended because of the difficulty of choosing settings to ensure correct co-ordination and security of supply.

Generally, wherever voltage relays are employed, timing elements should be used to prevent operation during transient disturbances. Also, overvoltage relays must be co-ordinated with other overvoltage relays elsewhere on the system.

3.3 Neutral Voltage Displacement Protection

The three phases of a balanced healthy system summate to zero. When a single-phase earth fault occurs, the system balance is upset and a 'residual' voltage is produced. The residual voltage is therefore a means of detecting earth fault conditions without any measurement of current. This may be essential for high impedance earthed or insulated systems where it might not be viable to provide core balance CT's on each feeder.

The residual voltage can be measured at the secondary terminals of a VT having an 'open delta' secondary connection. The VT must be a standard five limb type or three single phase VT's can be used. This is because the residual voltage is three times the zero sequence voltage and therefore zero sequence flux has to flow in the core. For this to happen there must be a return path for the resultant summated flux and this occurs on a five limb type because the outer limbs are unwound. Where three single phase VT's are used, each phase unit has a core with a closed magnetic circuit. A three limb VT is not suitable for this application because there is no magnetic path, through the core, which the zero sequence flux can flow.

Another requirement for the VT is that the primary winding neutral has to be earthed. Without this, an earth zero sequence exciting current cannot flow. Figures 4 and 7 are typical connection diagrams showing the two versions of relay with a residual voltage connection to a five limb VT.

Internally the relay performs a zero sequence calculation, which is multiplied by 3 to derive the residual voltage. (The actual residual voltage element setting is referred to as 3Vo). Note that the 'Vo' instrument in the 'Instruments Display Menu' displays the zero sequence voltage regardless of whether the residual voltage is directly measured or calculated internally. The actual system residual voltage is three times the indicated Vo reading.

The output voltage of the open delta winding can contain triplen harmonics, with the 3rd being the most predominant. These triplen harmonics appear across the open delta winding even when there is no earth fault on the network and no zero sequence voltage. The relay's main measuring algorithm being based upon a DFT, coupled with the anti-aliasing filter in the input stage, ensures that any 3rd harmonic present is heavily attenuated and will not cause a mal-trip.

Where a power transformer delta or unearthed star winding is connected to a transformer feeder it is essential to ensure that this unearthed winding cannot remain energised under system earth-fault conditions. This condition will result in danger to life and possible hazard to the sound phases due to intermittent arcing via system earth capacitance. Initiation of tripping may be by means of a neutral displacement relay arranged to detect residual voltage to earth at the transformer using either a voltage transformer or coupling capacitors. The relay will operate for external as well as internal feeder faults and must, therefore, be provided with a time delay to ensure discrimination.

The NVD protection in the relay consists of 2 independent stages which can be used for alarm and trip purposes. Each has a user settable DTL time delay element associated with it. These are useful for applications such as insulated systems where, following an earth fault, the phase voltages may have to withstand sustained overvoltages. An alarm from the first stage can be issued after a short delay to indicate that there is an earth fault on the system. If this is not satisfactorily cleared then the second stage can issue a trip signal to isolate the fault.

3.4 NPS Overvoltage Protection

Unbalanced voltage on 3-phase network results as a consequence of unbalanced load current causing unequal voltage drops in network impedances. The unbalanced load current could be the result of single phase open circuits (isolator failures, broken conductors etc.), or because of loads generating harmonics (e.g. thyristor drives). Unbalanced voltage generated at a busbar has the knock-on effect of causing healthy balanced loads to become unbalanced.

In the case of generators, unbalanced loading causes negative phase sequence (NPS) currents in the generator stator, which induces double frequency currents in the rotor causing heating of the machine. If the NPS current exceeds the limit of the generator, protection on the generator will operate and could result in all the generators connected being tripped. Induction motors also are vulnerable to NPS current and again, as for generators, NPS overcurrent protection is provided and included on the majority of industrial plant motors.

The NPS or unbalanced voltage function in the Argus 8 relay can be employed to monitor the quality of the 3-phase ac supply and thus provide early warning of developing problems of NPS currents, which might cause tripping of generators or motors. In this respect the NPS overvoltage protection is very beneficial.

The NPS protection consists of 2 independent stages, each with a user settable DTL time delay element associated with it. These can be used for both alarm and tripping purposes.

Where the 3-phase VT's supplying an Argus 8 relay are protected by fuses, special consideration has to be made. Any single fuse operating e.g. due to ageing or a winding / wiring fault, will result in NPS voltage in the input to the relay. Where miniature circuit breakers (MCB's) are employed they can be provided with an “all phases trip” feature which prevents the mal-operation of an NPS voltage monitoring relay. (An “all phases trip” MCB will operate for any fault condition). However, where fuses are employed, allowance must be made for the impact of a single fuse operation. If the NPS overvoltage function of the relay is used only for alarm purposes, there is no serious consequence. If, however if it used for delayed tripping, then consideration should be given to blocking for single fuse failure. One method is to use the two separate NPS stages, one set as a high set instantaneous for blocking a trip and the other as a lower set, time delayed stage for protection of the rotating plant. However, a problem arises in that a broken primary circuit phase has a similar effect to single fuse operation. The preferred solution is to provide MCB's with an “all phases trip” feature for the secondary circuit protection.

3.5 Frequency Protection

When a power system is in stable operation at normal frequency, the total mechanical power input from the prime movers to the generators is equal to the sum of all the connected loads, plus all real power losses in the system. Any frequency variation is an indication of generator-load imbalance in the system. If an interconnected system splits, for example, there might be a situation where the load in one of the subsystems is in excess of the generator capacity in that subsystem. In this instance the generator speed will begin to decrease causing a proportional frequency drop. An underfrequency condition at nominal voltage can lead to over-fluxing of plant such as generators and transformers. If the governors and other regulating equipment cannot respond quickly enough, a sustained underfrequency condition may lead to a system collapse. Conversely, if there is an excess of generation in the subsystem then the generator speed will increase causing a proportional frequency rise. This may be unacceptable to industrial loads, for example, where the running speeds of synchronous motors will be affected.

In the situation where the system frequency is collapsing rapidly it is common practise to disconnect non-essential loads for short periods of time, until the generation-load requirements and network configuration can be corrected. This is designed to preserve system integrity and minimise outages. Normally utilities will avoid intentionally interrupting service, but in this case non-critical loads can be interrupted for short periods. This type of scheme is known as an underfrequency load shedding scheme. Usually, automatic load shedding, based on underfrequency, is necessary since sudden, moderate-to-severe frequency shifts can throw a system into a dangerous state much faster than an operator can react. Underfrequency relays are usually installed at distribution substations, or industrial plant, where selected loads can be disconnected and where similar priority loads are often grouped together.

The object of load shedding is to re-establish the generator-load equation. At the instant of a disturbance a measure of the amount of overload is not readily available and thus load is shed in stages until the frequency stabilises and returns to within the nominal band. An example scheme would have the first load shedding stage set just below the nominal frequency, e.g. between 49.0 - 49.5Hz. A time delay element would be associated with this and this would be set to allow for transient dips in frequency, as well as to provide a time for the system regulating equipment to respond. The first load shedding stage would be set to shed a significant percentage of the system load. If this drop is sufficient, the frequency will stabilise and perhaps increase and return to nominal. If, however, this is not sufficient then a second load shedding stage, set at a lower frequency, will now shed a smaller percentage of load until the overload is relieved. This process will continue until all stages have operated. In the event of the load shedding being unsuccessful, a final stage of underfrequency protection should be provided to totally isolate all loads before plant is damaged, e.g. due to overfluxing.

An alternative type of load shedding scheme would be to set all underfrequency stages to about the same frequency setting but to have different length time delays set on each stage. If after the first stage is shed the frequency doesn’t recover then subsequent stages will shed after longer time delays have elapsed.

As has been mentioned earlier, where there is an excess of generation in a subsystem the frequency will rise. This is most commonly due to loss of load situations, which cause the generators to speed up. Normally the generator control equipment will respond to regain the normal running speed, but if this equipment fails then the overfrequency protection can be used as a backup. The settings for the overfrequency elements should be set to allow for transient frequency excursions following a loss of load condition and allow time for the generator control systems to recover the situation.

The Argus 8 relay has four frequency elements, each of which can be set for underfrequency operation. These, coupled with independent voltage elements and a large number of output contacts available, enable economic application for complex load shedding schemes. The accuracy and security of operation built into the numeric algorithms makes them ideally suited for this type of application. All frequency elements can be blocked in a number of different ways. Section 1 - 3.5 of this manual describes the ways in which this can be achieved. It is important to note that where there is other load shedding equipment on a system, the Argus 8 relay should be set to co-ordinate with it.

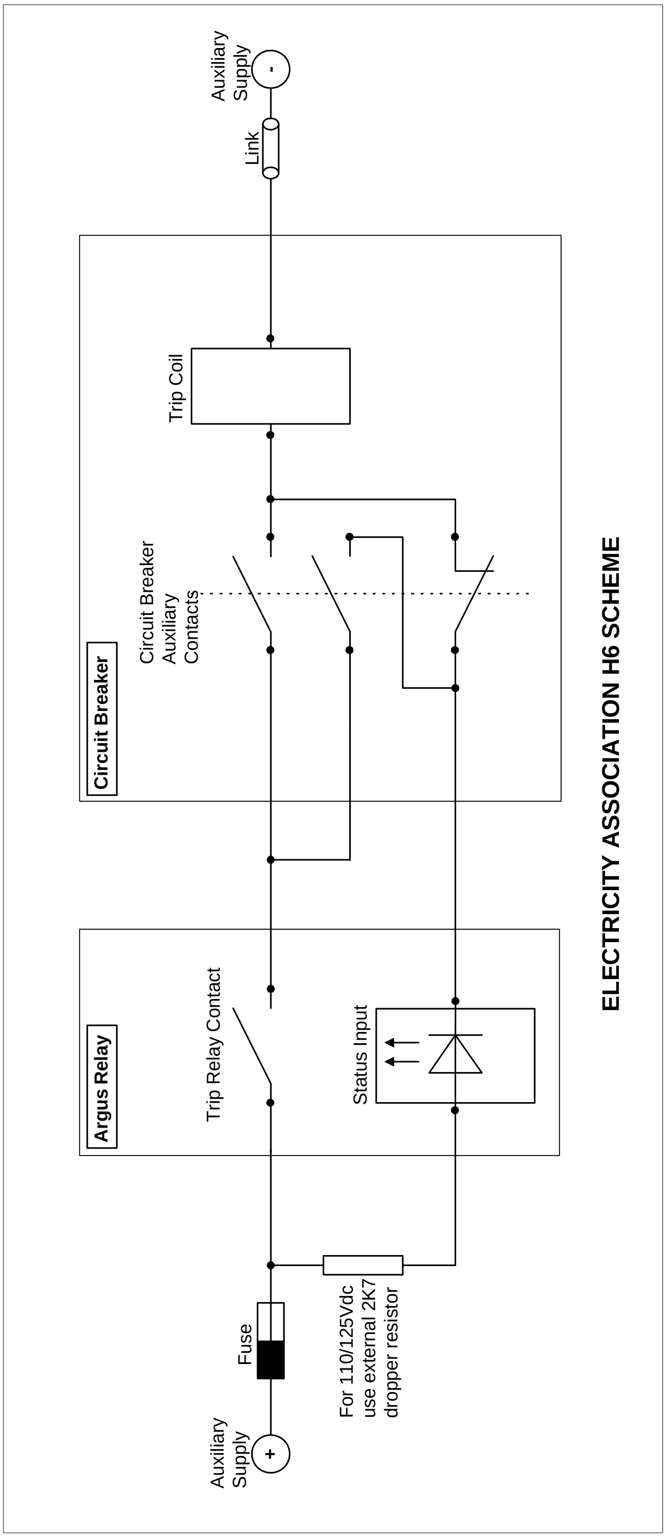


Figure 1 – Trip Circuit Supervision Scheme

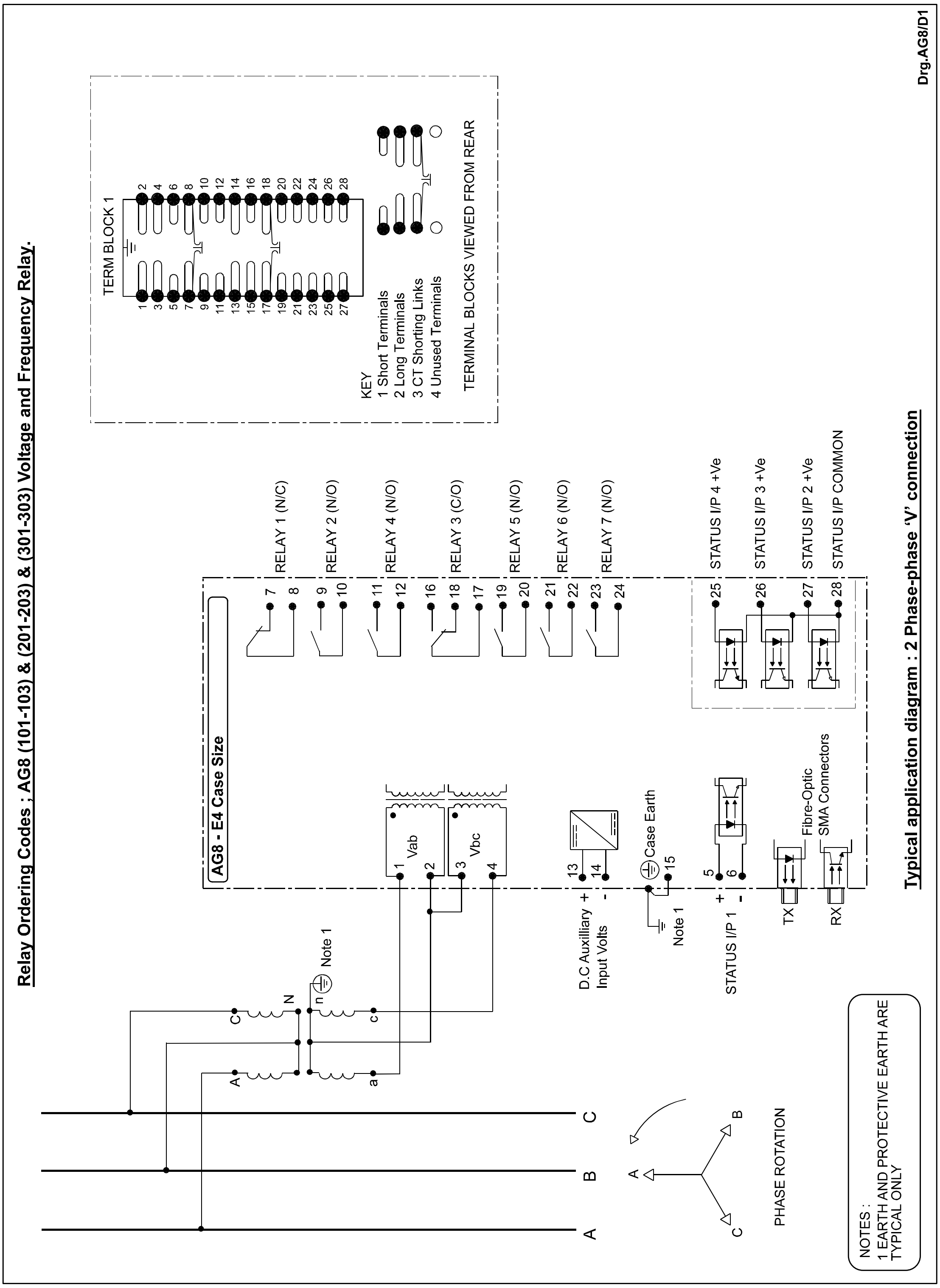


Figure 2 – 2 Phase-Phase 'V' Connection

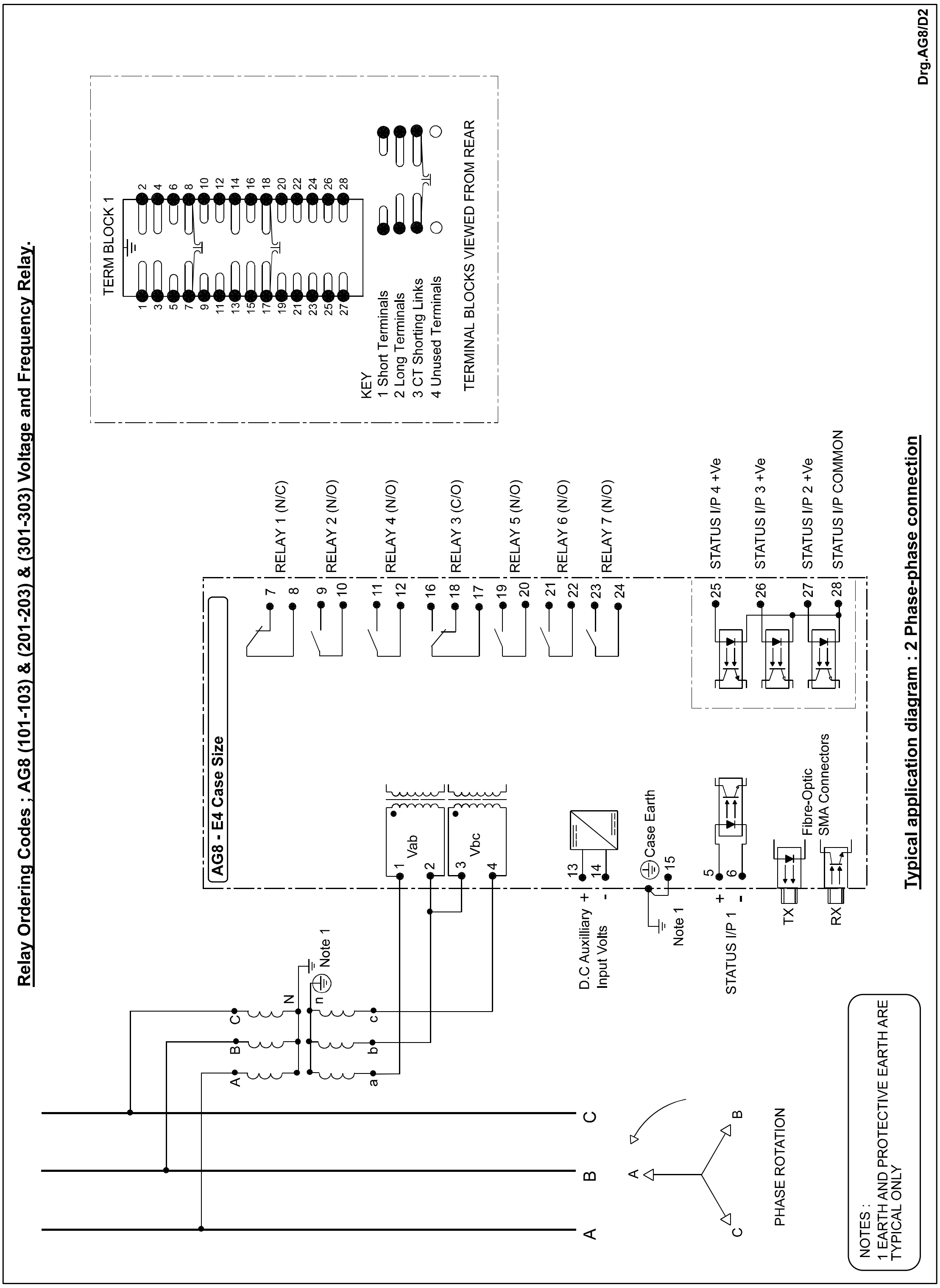


Figure 3 – 2 Phase-Phase Connection

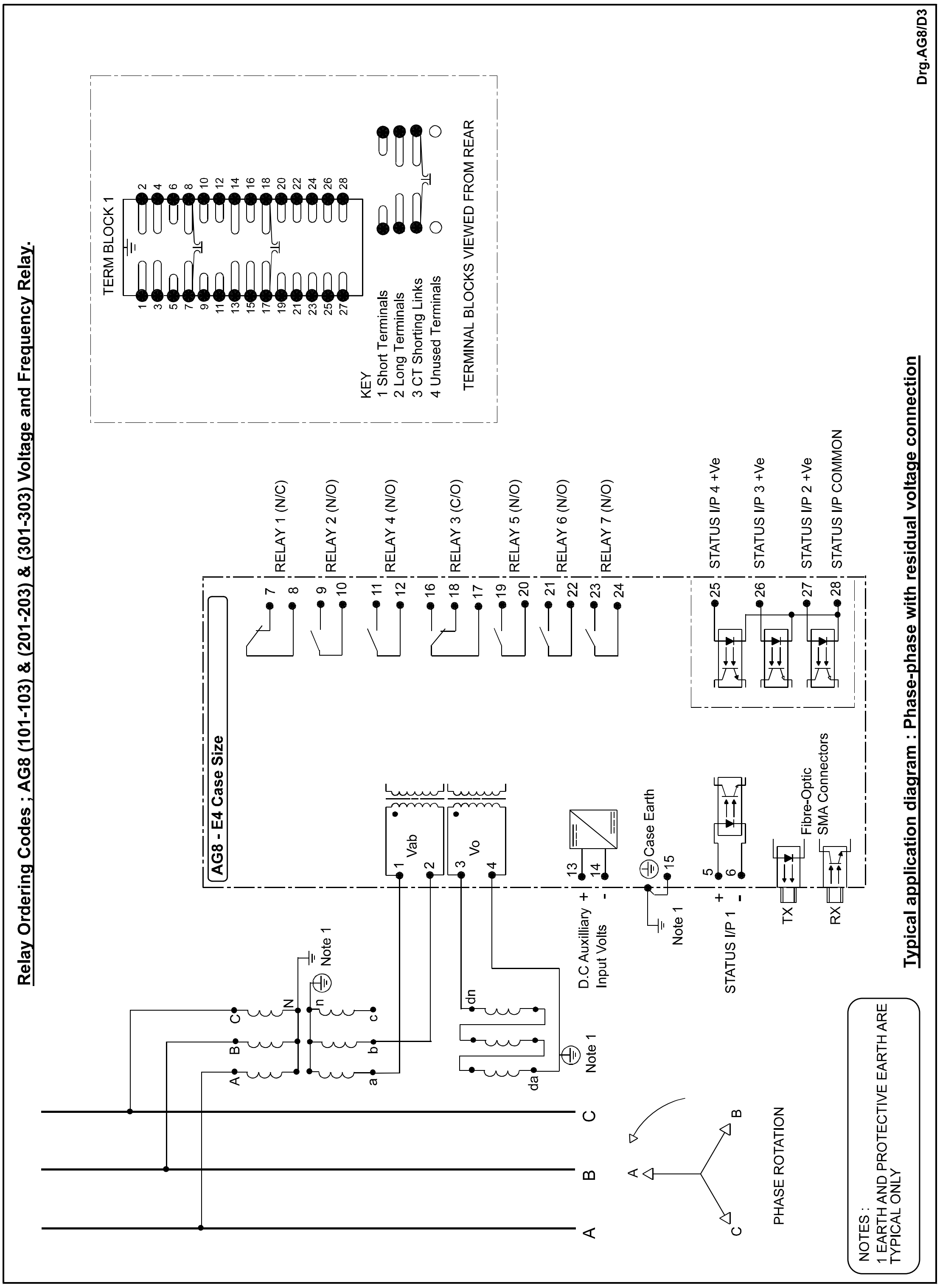


Figure 4 – Phase-Phase with Residual Voltage Connection

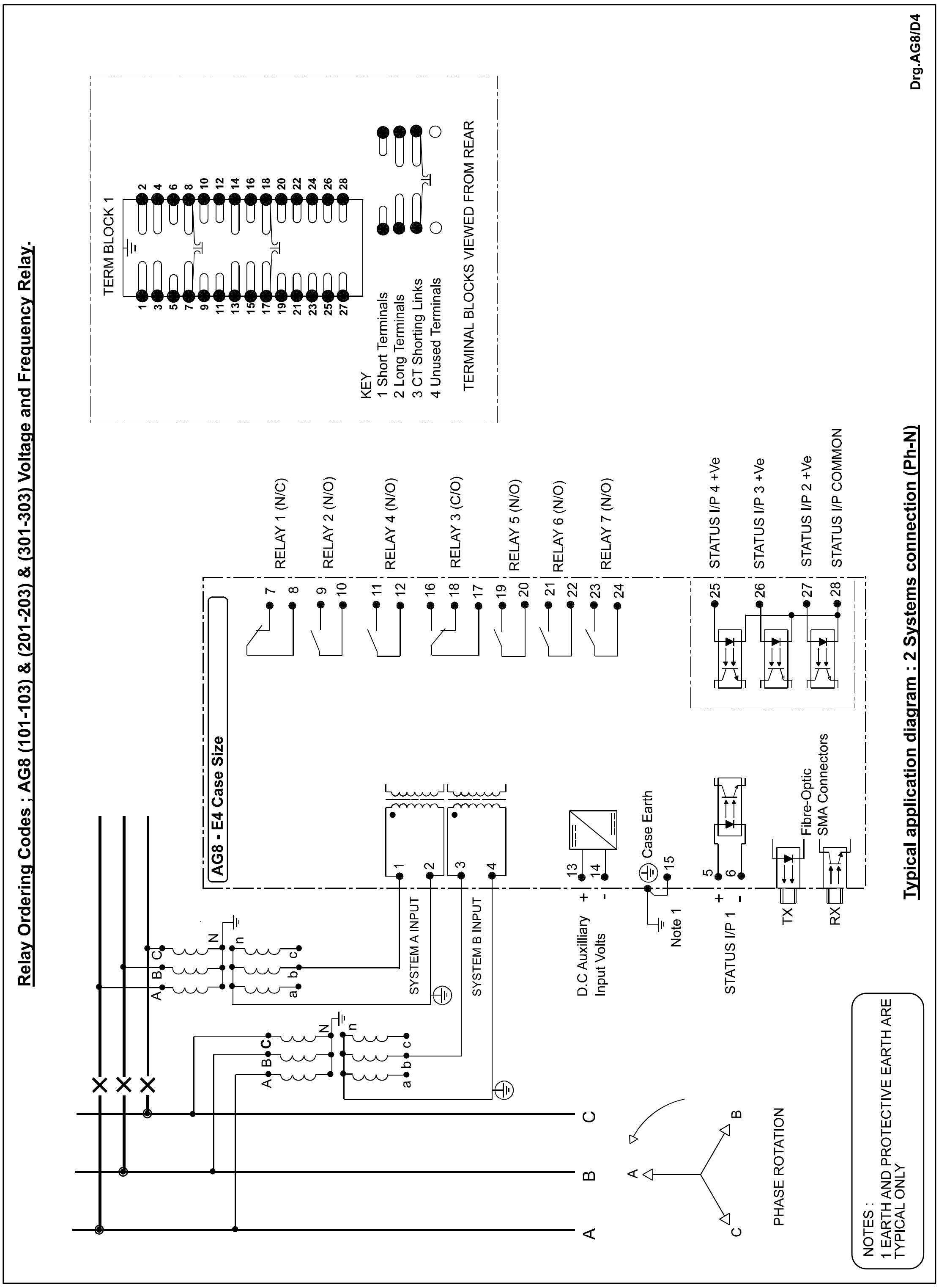


Figure 5 – 2 Systems Connection (Ph-N)

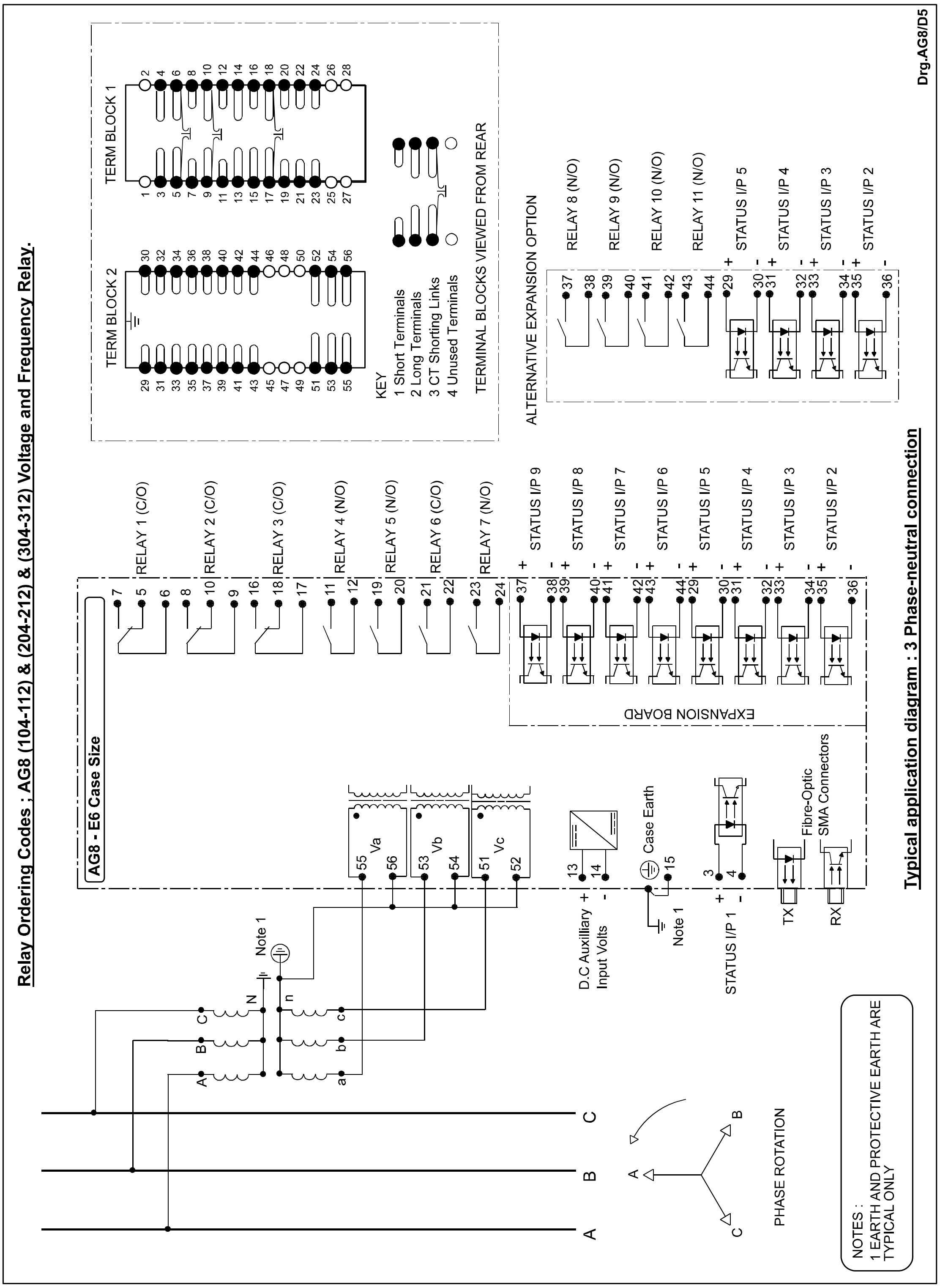


Figure 6 – 3 Phase-Neutral Connection

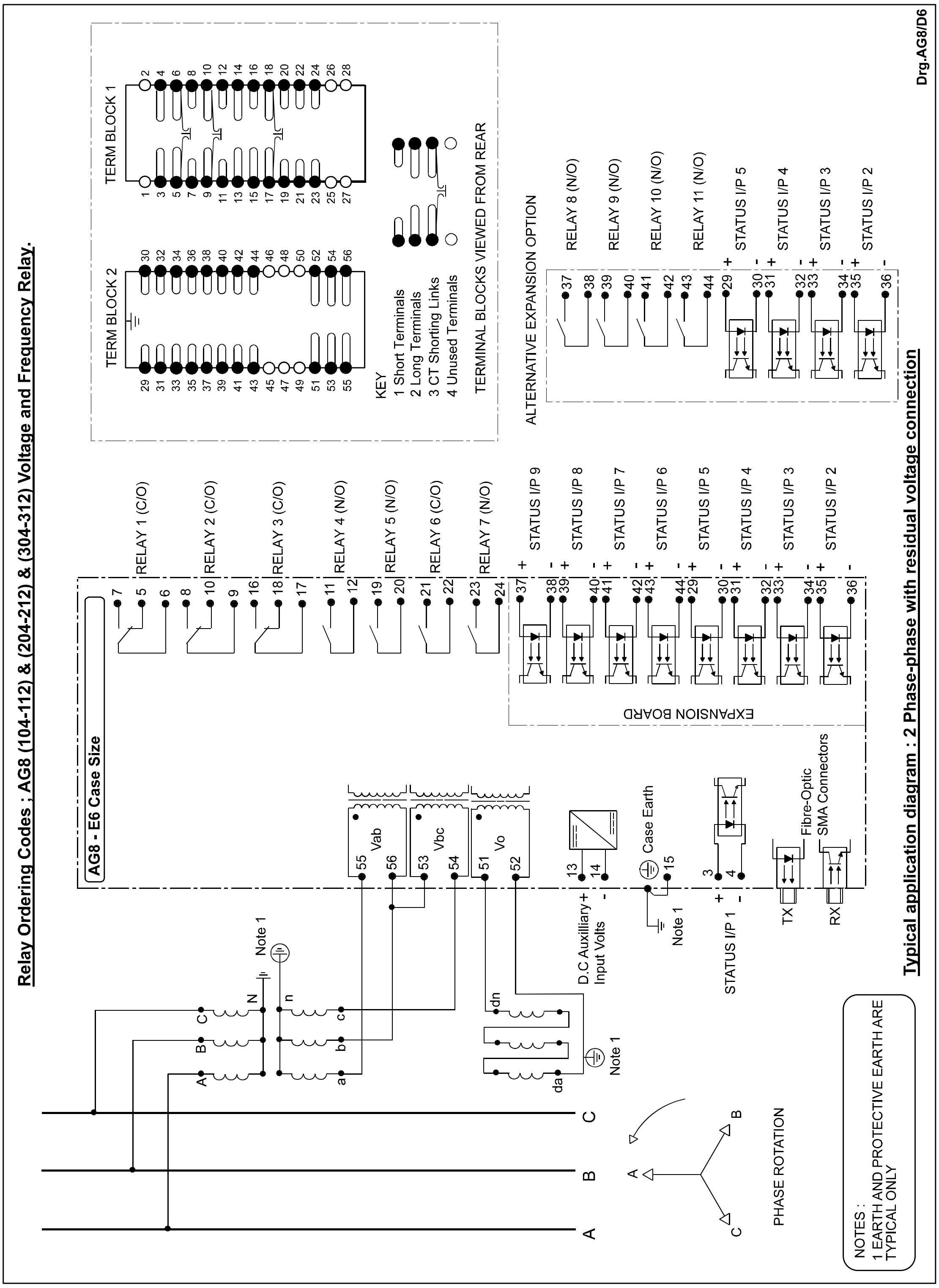


Figure 7 – 2 Phase-Phase with Residual Voltage Connection

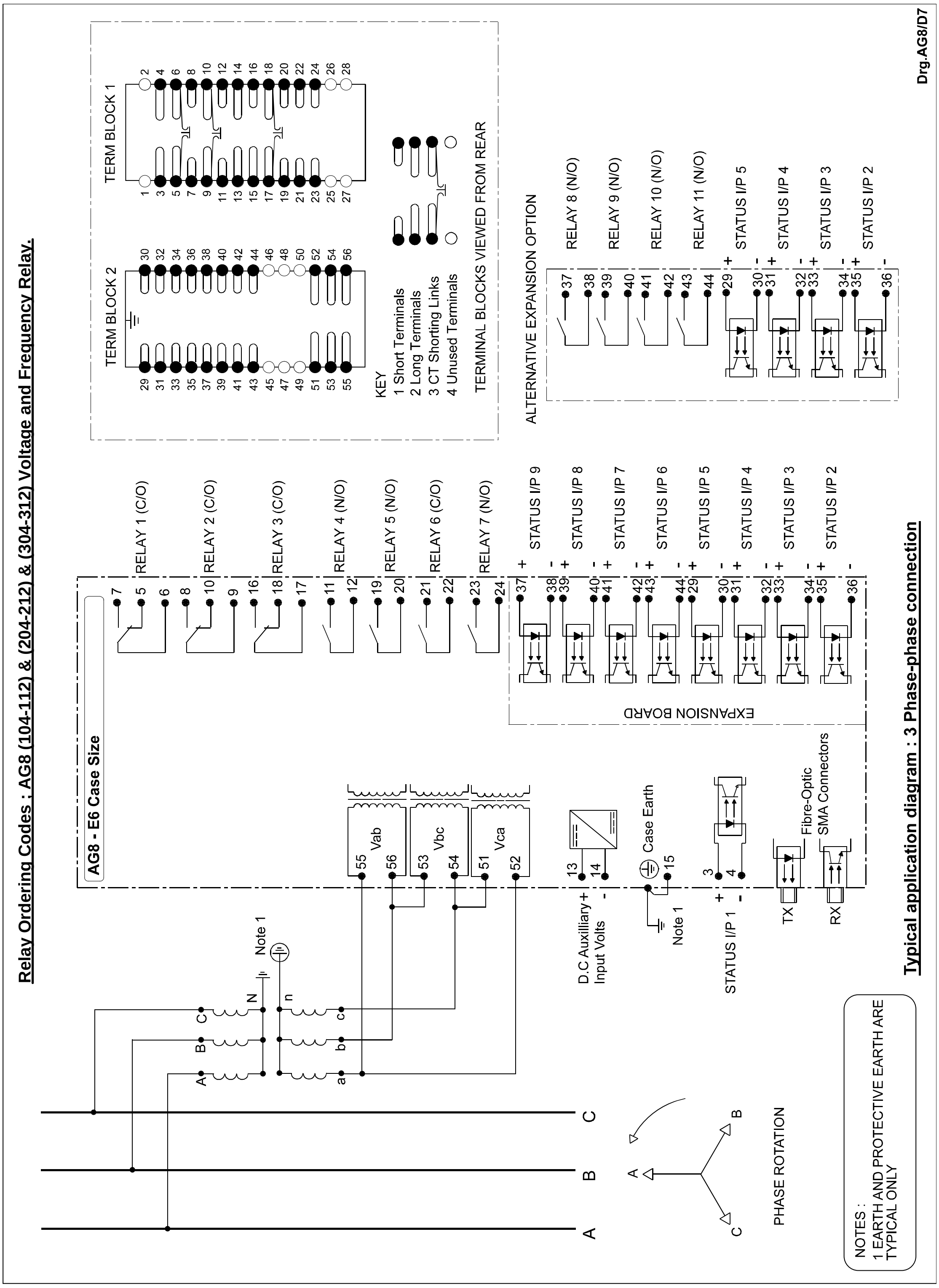


Figure 8 – 3 Phase-Phase Connection