7SG11 Argus 7

Check and System Synchronising 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

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1 Introduction

Argus 7 is a combined check and system synchronising relay which can automatically select check or system synchronise, as appropriate, from measurements of the relative phase angles between the line and bus voltages. The relay will prevent closure of the circuit breaker if the phase angle, slip frequency or the voltage magnitudes of the incoming and running voltages fall outside prescribed limits.

If these calculated quantities are within the relays' setting limits the relay will issue an output which can be used to close the circuit breaker directly or in conjunction with an autoreclose scheme. Both the check and system synchronise functions have independent settings and blocking features. The relay also includes split system detection with a variable time delay, which can be used for blocking purposes within delayed autoreclose (DAR) schemes.

Synchronising bypass logic is provided to connect a dead line or bus to a live line or bus. For manual synchronising the relay includes a circuit breaker close guard feature which is used to prevent the control switch being held closed during a synchronising operation. This feature is implemented using internal logic and removes the need for an external guard relay.

2 General Information

2.1 Voltage Threshold

The relay has a minimum voltage threshold below which the frequency and phase angle measurements are blocked from operation. This is preset to 5V rms and cannot be changed by the user. On initial switch on of AC volts to the relay, if both the line and bus volts exceed 5V rms, then the relay will wait for 0.96 second before any output can be given. This is to allow time for the frequency and phase measuring elements to settle and establish healthy outputs and also to allow for any transient conditions on voltage switch-on to pass.

2.2 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 5ms. Any software decision or external interrupt to the microcontroller involves a maximum possible delay of 5ms while the software completes the loop. This time should be added to the contact closure time of 7ms to give a maximum closure 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. 5ms) + O/P contact closure (typ. 7ms).

This gives a total time of < 17ms + Status PU delay setting.

2.3 Synchronising Enable Modes

The Argus 7 relay has been designed to conform to NGTS 3.7.7 and therefore must be able to be set up as a check synchronising relay, for applications such as manually bringing a generator online, and also as a check and system synchronising relay for applications where two power systems are to be connected. The following examples show various ways that the relay can be enabled for these different applications.

The check sync (CS) and system sync (SS) functions each have independent enable modes. If the requirement is for the relay to be used as a check for manually synchronising a generator for example, then system sync is not required.

1. Set CS Enable to **MANUAL** (or **AUTO**)

   Set System Split Detector to **OFF**

Setting the split detector to OFF will ensure that the relay never goes into system synchronising mode. The relay will continue to issue a check sync close if the power system conditions fall within the relay setting parameters.

If the requirement is for a check and system synchronising scheme where a lockout of the relay is required if the system splits, then

2. Set CS Enable to **MANUAL** (or **AUTO**)

Set System Split Detector to a suitable angle e.g. **170°**

Set SS Enable to **LOCKOUT**

This will ensure that if the power system splits the relay will not go into system synchronising mode but revert to lockout mode. The relay will at this point issue a lockout alarm via the LCD and generate an Event Record.

If the requirement is for a check and system synchronising scheme where system synchronising is required if the system splits, then

3. Set CS Enable to **MANUAL** (or **AUTO**)

Set System Split Detector to a suitable angle e.g. **170°**

Set SS Enable to **MANUAL** (or **AUTO**)

This will ensure that if the power system splits the relay will system synchronise.

It should be noted that at any time during a synchronising sequence, the relay can be inhibited from operation using the Check Sync Inhibit or System Sync Inhibit command from the control system.

Note : the relay settings groups could be used to switch between the different modes of the relay. The relay could be set up to be a check synchroniser in settings Group 1 and a check and system synchronising relay in settings Group 2. The group selection and thus the actual relay mode of operation could then be changed remotely using a status input signal or a communications command from a control system.

2.4 Manual Synchronising

In applications where the relay is used for manual synchronising of e.g. generators, a close guard feature can be used to ensure that the operator uses the relay as a check for synchronism and does not give all the responsibility for the close to the relay. Previously this functionality has been achieved using external auxiliary guard relays to prevent the operator from pre-closing the switch and waiting for the relay to issue its close signal. This can now be achieved without the external guard elements but by using a status input and internal logic.

To use the close guard feature :

- CS Enable has to be set to **MANUAL**
- Close Guard is set to **ON**

When the Check Sync close status input is received, internal logic will only allow the relay to issue a close if the system conditions were in synchronism and the relay was issuing a Check Sync close before the status input was activated.

2.5 Typical Voltage Settings

2.5.1 Rated Voltage Setting – V.T. Connection

The Argus 7 relay can be connected either single-phase (e.g. phase-neutral of a 3 phase V.T.) or phase-phase (e.g. of Vee connected or 3 phase V.T.). The same reference voltage must be employed for both Line and Bus voltages.

V.T. ratings for secondary connections are normally either 100V or 110V for phase-phase, with the associated phase-neutral ratings being 57.7V and 63.5V respectively. For phase-neutral connections the Rated Voltage setting should be set to 63.5V. For phase-phase connections the Rated Voltage setting should be set to 110V.

Where V.T.'s with 100 / 57.7V ratings are employed the 110V or 63.5V settings, as appropriate, should be chosen. It is only necessary to ensure that the associated settings e.g. V.T. ratio, dead line / bus voltage, live line / bus voltage and line / bus undervoltage detector settings are based on ratings of 100 / 57.7V and not 110 / 63.5V.

2.5.2 Undervoltage Detector Settings

The relay undervoltage blocking elements, if enabled, can be used to block the close operation if either the line (incoming) or bus (running) voltages fall below a certain percentage of rated voltage. Typically, the undervoltage elements are set somewhere between 80% and 90% of rating.

Note : when using the undervoltage elements care should be taken to ensure that the reset of the element occurs at below the expected minimum operating voltage of the system. The undervoltage elements reset at <103% of the operate level. If the system is expected to run at less than the rated voltage, the undervoltage element reset level must be set to operate at a value below this plus a discrimination margin.

e.g. - for a phase to neutral connection nominally at 63.5 Vrms but which can run as low as 59 Vrms,

the undervoltage setting should be set no higher than 59 V – 1 V (margin) = 58V / 103% = 56.31V (the actual setting would have to be 56.5V). This is equivalent to approximately 89% of rated voltage. If the setting is set higher than this then the element may never reset and will continuously block.

2.5.3 Differential Voltage Detector Settings

A differential voltage detector is incorporated and this, if enabled, blocks the synchronising function if the difference between the measured voltages is greater than the setting. This is used to prevent closing of the circuit breaker with a large voltage differential between the line (incoming) or bus (running) voltages, which could overstress the electrical systems. Typically, the differential voltage elements are set below 10% of rated voltage.

2.6 Synchronising Bypass Logic

The relay Dead and Live voltage monitors are used along with corresponding internal logic to bypass the synchronising operation of the relay. Typically, anywhere above 80% to 90% of rating can be classed as a live line or live bus. The dead voltage monitors should be set to somewhere above the expected level of induced voltages on the line or bus. It should be noted that a dead line or dead bus can have a considerable potential induced onto it from a parallel line or via capacitance across open breaker contacts. This potential can be as high as 30% of rated voltage.

The synchronising Bypass logic can be enabled, if required, to provide Dead Line and Live Bus closing, Live Line and Dead Bus closing, Dead Line and Dead Bus closing, Dead Line or Dead Bus closing and Dead Line xor Dead Bus closing. A truth table showing the close logic for all of the possible combinations is shown in Table 1.

		Sync Bypass Setting				
		DL & LB	**LL & DB**	**DL & DB**	**DL or DB**	**DL xor DB**
Line Status	**Bus Status**	**Allow Close**	**Allow Close**	**Allow Close**	**Allow Close**	**Allow Close**
Dead	Dead	No	No	Yes	Yes	No
Dead	Live	Yes	No	No	Yes	Yes
Live	Dead	No	Yes	No	Yes	Yes
Live	Live	No	No	No	No	No

Table 1 - Bypass Close Logic

2.7 Slip and Phase Angle Relationship

Slip frequency is defined as the difference between two frequencies. Where a slip frequency exists between two separate systems, during a ‘slip’ cycle the two voltage vectors will be in anti-phase at one point in time. The phase angle difference will vary between being in phase and anti-phase. Argus 7 relays can be set to measure slip frequency in two ways. One way is to measure the two system frequencies directly and calculate the difference. Another way is to measure the phase difference between the two systems and check that the phase angle change in a defined time period is less than a predetermined value. If F1 and F2 represent the frequencies of two systems then it can be shown that for check synchronising operation,

$$\Delta F = F1 - F2 = \frac{1}{Td} \times \frac{\theta}{180^\circ}$$

where Td = time delay setting and θ = phase angle setting.

For system synchronising operation the following formula is used because in this mode the relay will only issue a close signal if the phase angle is decreasing in value. It will not issue a close if the phase angle is increasing in value.

$$\Delta F = F1 - F2 = \frac{1}{Td} \times \frac{\theta}{360°}$$

where Td = time delay setting and θ = phase angle setting.

The Argus 7 relay has both a frequency measuring element and phase detector and so can be set up to measure slip either directly or by the phase detector plus timer method. Use of either method is perfectly valid, as is use of both at the same time.

Note : if using both the slip frequency detector and the phase angle plus slip timer for a particular scheme then care has to be taken in setting selection. It is possible to set the relay up with an incorrect slip timer setting which will prevent the relay from issuing a valid close signal.

e.g. - a system with a high rate of slip which is within the allowable slip frequency limit, could be set up with too long a slip timer setting. This would mean that the incoming vector could pass through the valid close window too quickly and not allow the slip timer to time out and give a valid output.

2.8 Check Synchronising Settings

The check synchronising operation of the relay is used mainly in switching operations which link two parts of a system which are weakly tied via other paths elsewhere in the system. In this synchronous system there should be no frequency difference across the breaker but significant differences in phase angle and voltage magnitude may exist due to the transmission line characteristics such as its length and type of loading.

For check synchronising operation the relay should be set to the maximum phase angle and maximum voltage differences which still permit the circuit breaker to close without causing large disturbances to the system. For most systems the phase angle can be set between 20° and 30°. There should not be any slip frequency but a setting of 50mHz is typically applied as a check against loss of synchronism. Table 2 shows some possible check synchronising settings when using the phase detector plus time delay method. This shows a range of phase angles and the required slip timer settings to achieve a slip frequency limit of 50mHz. Note that due to the step resolution of the timer, an exact 50mHz slip limit is not always achievable.

CS Phase Angle Setting (θ°)	CS Slip Timer Setting (sec)	Slip Frequency Limit (mHz)
± 10°	1.1	50.51
± 15°	1.7	49.02
± 20°	2.2	50.51
± 25°	2.8	49.60
± 30°	3.3	50.51
± 35°	3.9	49.86
± 40°	4.4	50.51
± 45°	5.0	50.00

Table 2 - Typical Check Synchronising Settings

Alternatively, if the slip frequency detector is used and the slip timer turned OFF, a setting of 50mHz could be applied to the slip frequency detector directly to achieve the same ends.

Note : in check synchronising mode the valid phase difference window for closing is actually twice the phase angle setting value because the valid Check Sync close can be given when the phase angle is either decreasing or increasing. It should also be noted that the Check Sync close output will stay on for a minimum of 100 ms and for the whole duration of the time that the close parameters are met.

2.9 System Synchronising Settings

The system synchronising operation of the relay can automatically start if the two systems become asynchronous i.e. there are no ties between the two systems and one system is effectively ‘islanded’. If this situation occurs the frequencies will slip past each other and may cause the phase angle to come into the system split limits. The system split detector can be set anywhere from 90° to 175° and is typically set to 170°. This will start system synchronising automatically if the enable has been set to AUTO.

When there are high rates of slip between the two systems greater care is needed when closing the breaker and for this reason the system synchronising mode has independent settings from the check synchronising mode. The allowable phase angle close window is usually set much narrower than for check synchronising operation. Also, the close decision from the relay is only given in the case of the phase angle decreasing. It will not issue a close if the phase angle is increasing in value. Typically the slip frequency will be set to a limit of 250mHz or less and the phase angle to 10° or 15°. Table 3 shows some possible system synchronising settings for limits of 100mHz and 250mHz. Note that due to the step resolution of the timer, an exact 100mHz or 250mHz slip limit is not always achievable.

SS Phase Angle Setting (□°)	SS Slip Timer Setting (sec)	Slip Frequency Limit (mHz)
± 10°	0.3	92.59
± 15°	0.4	104.17
± 10°	0.1	277.78
± 15°	0.2	208.33

Table 3 - Typical System Synchronising Settings

Alternatively, if the slip frequency detector is used and the slip timer turned OFF, settings of 100mHz or 250mHz could be applied to the slip frequency detector directly to achieve the same ends.

Note : the system sync close output pulse is on for a minimum of 100 ms but can be extended if necessary by using the SS Close Pulse setting.

2.10 Example Setting Calculations For Slip Timer

In Check Synchronising operation the relay will issue a Check Sync close if the system conditions are such that the phase angle and slip frequency are within limits. There is a possibility, however, that a Check Sync close could be issued at a point where the phase angle is approaching the angular limits, say + 20°, and the slip frequency is at the maximum allowable value. The consequence of this is that due to the inherent closing time of the CB the actual CB close occurs outside of the phase angle limits. The angle overshoot being dependent on the actual slip frequency and the total CB closing delay.

The total delays involved in this process include the main software timing loop which issues the close command, the output relay time to pick up and the actual breaker closing time delays. To reduce the risk of a late closure it is common practice to set the slip timer setting (Td) to typically 10x the CB closing time. This will ensure that the CB will close no later than 1.2x the actual phase angle setting of the relay e.g. ± 24° for a ± 20° setting.

e.g. :-

The change in phase angle between two waveforms is directly related to the frequency difference, or slip, between them. The change in phase angle $\Delta\theta$ for a system with 1Hz slip is 360□ in 1 second. Thus,

Change in phase angle $\Delta\theta = (\text{Slip} \times 360)$ °/sec.

The distance the phasor can travel during the breaker close time can therefore be given by,

$\Delta\theta = (\text{Slip} \times 360 \times t_{CB})$ - where t_{CB} is the breaker close time in seconds.

Using the equation given in section 2.7 for check synchronising,

$\text{Slip} = \frac{1}{\text{Td}} \times \frac{\theta}{180°}$ and substituting this into $\Delta\theta = (\text{Slip} \times 360 \times t_{CB})$ gives the following,

$\Delta\theta = \frac{1}{\text{Td}} \times \frac{\theta}{180°} \times 360° \times t_{CB}$ which gives $\Delta\theta = 2 \times \theta \times \frac{t_{CB}}{\text{Td}}$

It was stated that the slip timer setting Td should be set to 10x the breaker closing time t_{CB}.

Substituting for this in the above equation gives,

$\Delta\theta = \frac{(2 \times \theta)}{10}$ or $\Delta\theta = 0.2 \times \theta$

Thus for a slip timer setting (Td) of 10x breaker closing time (t_{CB}) the actual change in phase angle will be 20% of the phase angle setting. The maximum closing angle will be 120% of phase angle setting.

In practice, however, the relay operating times need to be taken into consideration. A typical example now follows :

- Maximum allowed phase angle for closure = 30°.

- Circuit breaker closure time = 150ms.

- Maximum relay delays : Software timing loop + Output relay delays = 5ms + 7ms = 12ms.

Therefore slip timer time delay should be set to 10x (150ms + 12ms) = 1.62sec. In practice this will have to be set to 1.6sec due to the resolution of the slip timer.

The phase angle setting should be set to 80% of the maximum allowable closing angle, which is 24°.

If the relay was to issue a close right on the boundary of 24° then the breaker will not close outside of 30°.

With an angle of 24° and a slip timer delay (Td) of 1.6sec, using the equation from section 2.7, the slip is therefore,

24 / (1.6 x 180) = 83mHz. If the relay were to close on the boundary the phase angle traversed in the 160ms total delay time is given by,

$\Delta\theta = (\mathrm{Slip} \times 360) \times (t_{CB} + t_{RELAY})$ = 0.083 x 360 x 0.16 = 4.80°.

Therefore the CB will close at 24° + 4.80° = 28.80°.

2.11 Diagrams

At the back of this section Figure 1 shows a typical connection diagram for the Argus 7 check synchronising relay. Figure 2 shows a programming matrix, which is a convenient way of recording the input / output logic for the relay.

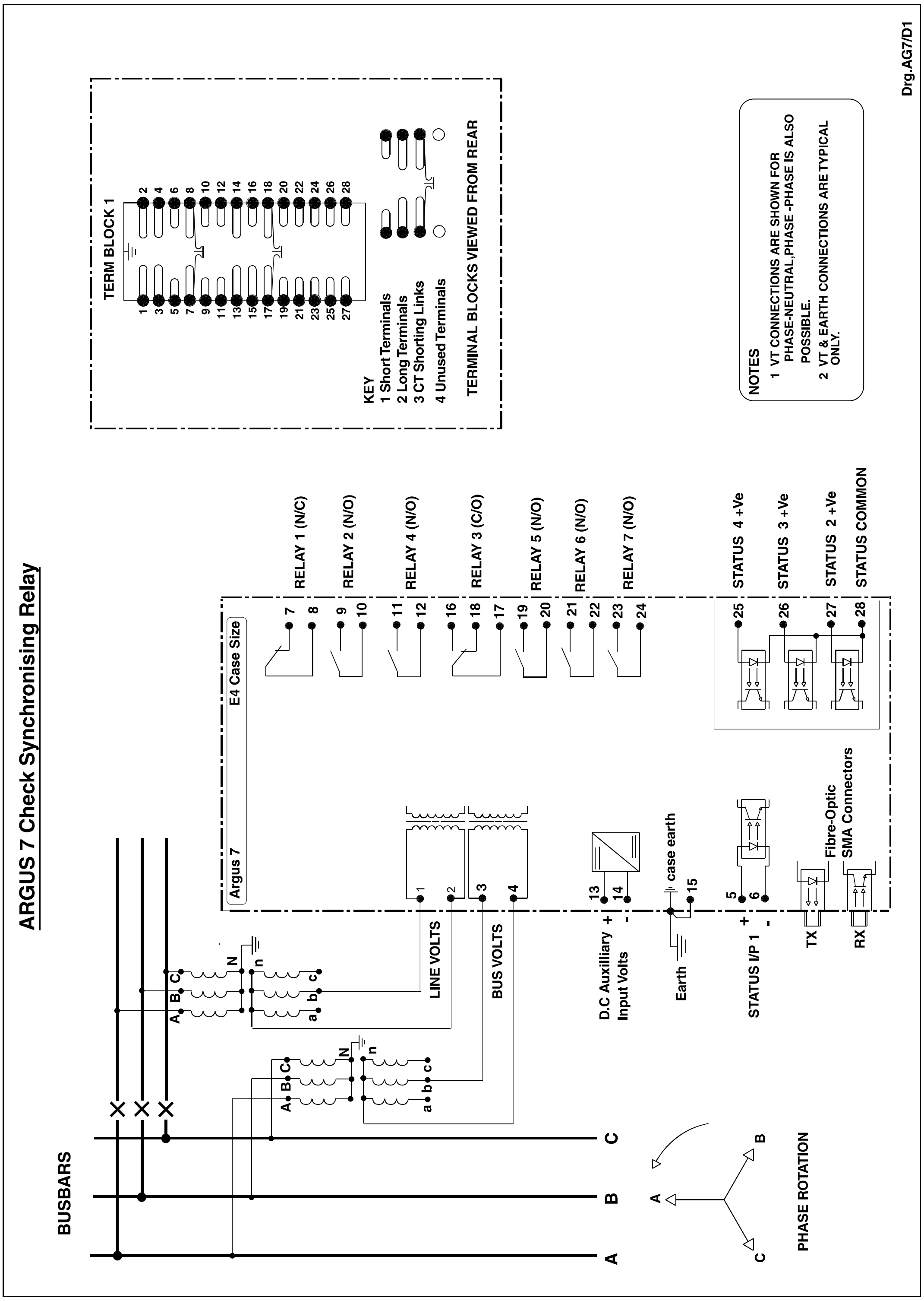

Figure 1 - Typical Connection Diagram

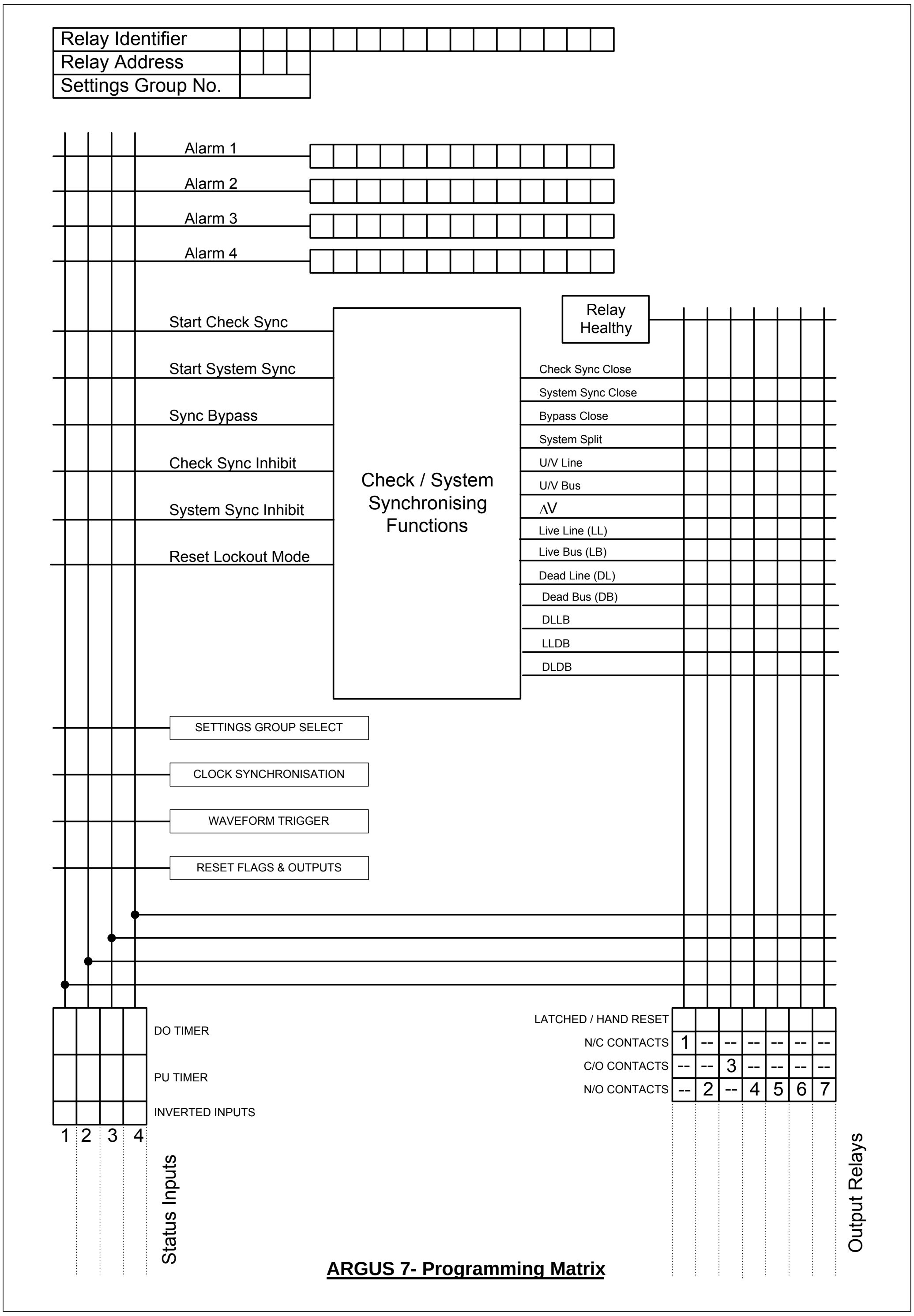

Figure 2 - Argus 7 Programming Matrix