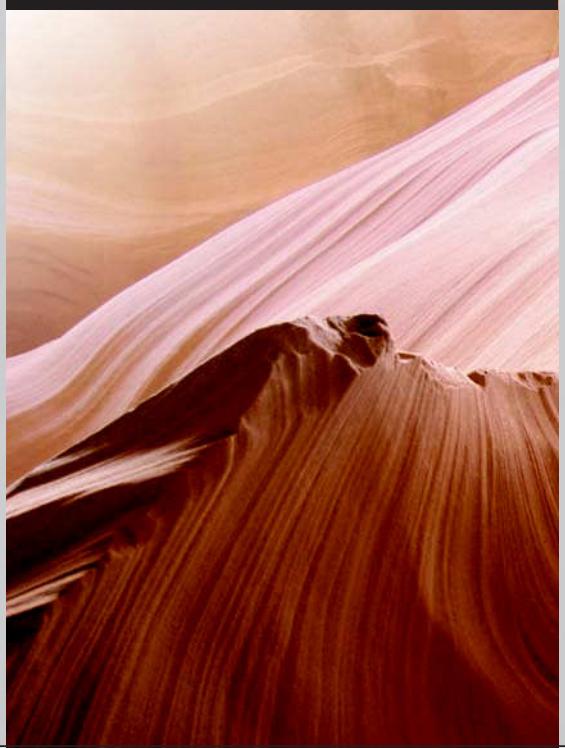
TOSHIBA

Leading Innovation

GRE140

Protection and Control
for MV Systems



FEATURES

- Four stage non-directional and directional overcurrent protection for phase and earth faults with IDMTL or DTL.
- Polarizing voltage memory.
- Directional earth fault command protection.
- Programmable reset characteristics.
- Directional sensitive earth fault protection.
- Restricted earth fault protection.
- Undercurrent protection with DTL.
- Thermal overload protection.
- Directional negative phase sequence overcurrent protection.
- Phase under/overvoltage protection.
- Zero phase sequence overvoltage (neutral voltage displacement) protection.
- Negative phase sequence overvoltage protection.
- Under / Over frequency protection.
- Frequency rate-of-change protection.
- Reverse Power protection.
- Broken conductor detection.
- Circuit breaker fail protection.
- Cold load pick-up feature.
- CT and VT supervision.
- Configurable binary inputs and outputs.
- Circuit breaker condition monitoring.
- Trip circuit supervision.
- Automatic self-supervision.
- Menu-based HMI system.
- Configurable LED indication.
- Metering and recording functions.
- Front-mounted USB port for communication to a local PC.
- Data communication with substation control and automation systems is supported according to the Modbus® RTU, DNP3, IEC 61850 and IEC 60870-5-103 standards.
- IRIG-B port for external clock

For 400 and 420 models (Feeder protection)

- Five shot, three phase auto-reclose (six trips to lockout).
- Synchronizm check.
- Sequence co-ordination with in-series auto-reclosing devices.
- Fault Locator.

For 700 and 720 model (Motor protection)

- Motor status LED indication.
- Start protection.
- Stalled motor protection.
- Locked rotor protection.
- Restart inhibit.

APPLICATION

GRE140 is a range of fully numeric, multi-function, directional protection relays designed for feeder protection applications in medium voltage networks. GRE140 has some models which differ according to the application and type of inputs fitted, see Table 1.

Table 1 GRE140 Models

Model	Configuration
GRE140-40*A	Directional Three Phase Fault and Earth Fault
GRE140-42*A	Directional Three Phase Fault, Earth Fault and Sensitive Earth Fault
GRE140-70*A	Directional Three Phase Fault and Earth Fault and motor protection
GRE140-72*A	Directional Three Phase Fault and Sensitive Earth Fault and motor protection

All models include multiple, high accuracy, overcurrent protection elements (for phase and/or earth fault) with inverse time and definite time delay functions. All phase, earth and sensitive earth fault overcurrent elements can be independently subject to directional control.

In addition, GRE140-40* and 42* provide multi-shot, three phase auto-reclose with/without synchronizm check, with independent sequences for phase fault, and earth fault and sensitive earth fault. Auto-reclosing can also be triggered by external protection devices. GRE140-70* and 72* provide high accuracy motor protection elements such as thermal protection based on IEC 60255-8, motor status monitoring, locked rotor protection, restart inhibit and temperature calculation on current basis.

Other protection functions are available according to model type. See Table 2 for details of the protection functions available in each model.

All models provide continuous monitoring of internal circuits and of software. External circuits are also monitored, by trip circuit supervision, CT and VT supervision, and CB condition monitoring features.

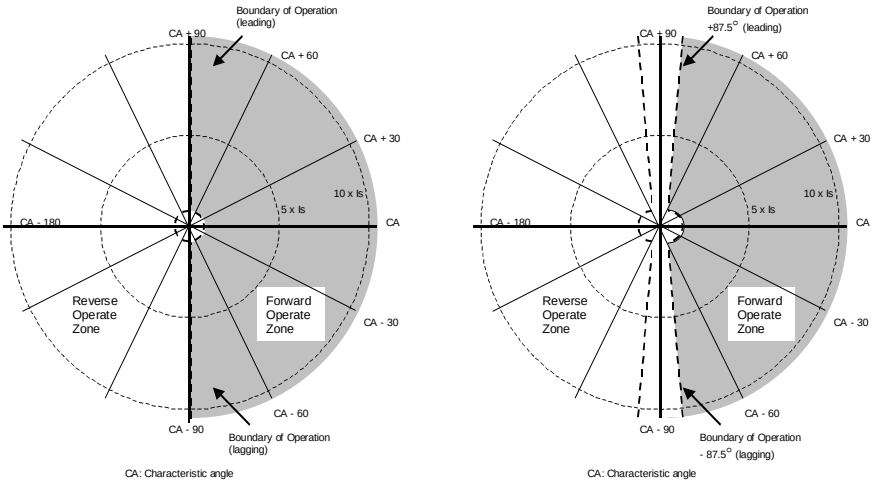
A user-friendly HMI is provided through a backlit LCD, programmable LEDs and menu-based operating system. PC access is also provided, either for local connection via a front-mounted USB port. The communication system allows the user to access data gathered by the relay's metering and recording functions.

Data available either via the relay HMI or communication ports includes the following functions.

- Metering
- Fault recording
- Event recording
- Disturbance recording

Table 2 - GRE140 Features

Model Number	GRE140 -			
	40*	42*	70*	72*
Directional Phase Fault O/C (67/50P, 67/51P)	✓	✓	✓	✓
Directional Earth Fault O/C (67/50N, 67/51N)	✓	✓	✓	✓
Directional Sensitive Earth Fault O/C (67/50N, 67/51N)		✓		✓
Phase Undercurrent (37P)	✓	✓	✓	✓
Thermal Overload (49)	✓	✓	✓	✓
Directional Negative Phase Sequence Overcurrent (67/46)	✓	✓	✓	✓
Phase Overvoltage (59)	✓	✓	✓	✓
Phase Undervoltage (27)	✓	✓	✓	✓
Zero Phase Sequence Overvoltage (59N)	✓	✓	✓	✓
Negative Phase Sequence Overvoltage (47)	✓	✓	✓	✓
Under/Over frequency (81U/81O)	✓	✓	✓	✓
Frequency rate-of-change (df/dt)	✓	✓	✓	✓
Reverse Power (32)	✓	✓	✓	✓
Broken Conductor (46BC)	✓	✓	✓	✓
Circuit Breaker Fail (50BF)	✓	✓	✓	✓
Cold Load Protection	✓	✓	✓	✓
Inrush Current detector	✓	✓	✓	✓
Auto-reclose (79)	✓	✓		
Synchronism Check (25)	✓	✓		
Start Protection (48)			✓	✓
Stalled motor Protection (50S)			✓	✓
Locked Rotor Protection (51LR)			✓	✓
Restart Inhibit (66)			✓	✓
Fault Locator	✓	✓		
CT / VT Supervision	✓	✓	✓	✓
Trip circuit supervision (74TC)	✓	✓	✓	✓
Self supervision	✓	✓	✓	✓
CB State Monitoring	✓	✓	✓	✓
Trip Counter Alarm	✓	✓	✓	✓
$\sum I^y$ Alarm	✓	✓	✓	✓
CB Operate Time Alarm	✓	✓	✓	✓
Two settings groups	✓	✓	✓	✓
Motor Status Monitoring			✓	✓
Metering	✓	✓	✓	✓
Fault / Event / Disturbance records	✓	✓	✓	✓
Modbus Communication	✓	✓	✓	✓
IEC 60870-5-103 Communication	✓	✓	✓	✓
DNP3 Communication	✓	✓	✓	✓
IEC 61850 Communication	✓	✓	✓	✓



(a) Characteristic for Phase Fault and Earth Fault **(b) Characteristic for Sensitive Earth Fault**

Figure 1 - Directional Operate Characteristic

PROTECTION FUNCTIONS

Directional Phase Fault Overcurrent Protection

GRE140 can provide three phase directional overcurrent protection. Each provides four independent overcurrent stages. Stage 1 and 2 may be set for inverse time or definite time operation. If inverse time is selected, then any one of nine curves may be chosen, including IEC and IEEE/ANSI standard characteristics, (see Figure 3). Alternatively, a user-configurable curve may be created.

Stages 3 and 4 may be set for definite time, or instantaneous operation.

These elements are immune to the effects of transformer magnetising inrush and dc offset transient over-reach.

Stage 1 and 2 have a programmable reset feature, selectable for instantaneous, definite time or dependent time operation. This feature can be used to protect against flashing fault conditions, or to grade correctly with electromechanical overcurrent relays.

All elements can be inhibited by binary input signals for operation in blocked overcurrent schemes and busbar zone blocking protection.

Figure 1 illustrates the directional characteristic, with the forward operate zone shaded. Polarisation is achieved by the 90° quadrature method, whereby each current's phase angle is compared with the phase to phase voltage between the other two phases. Since the voltage inputs to the relay are connected phase to neutral, the polarising phase to phase voltages are derived internally.

In the event of a close-up three phase fault, all three polarising signals will collapse below the minimum threshold. Voltage memory provides a temporary polarising signal in these circumstances. GRE140 maintains the polarising signal for 500ms by reconstructing the pre-fault voltages.

To cover applications where a 2:1:1 current distribution may be experienced, it is possible to program the directional phase fault protection such that a trip output will only be given if two or more phases detect fault current in the same operate zone.

Directional Earth Fault Protection

The standard directional earth fault protection is available in all models, and provides four independent overcurrent stages. Protection functionality is the same as for the phase fault elements.

Each earth fault threshold can be independently configured for directional operation, in the same manner as the phase fault elements. The system residual voltage is used as the polarising signal. This may be obtained either by direct measurement, commonly using the open delta tertiary winding of a five limb VT, or it may be derived internally by calculating the zero sequence voltage from the three phase-to-neutral voltages.

The directional earth fault elements have a user selectable minimum voltage threshold.

GRE140 can provide directional earth fault command protection by using two stages of directional earth fault elements of which one is for tripping and the other is for blocking or for current reverse detection.

Directional Sensitive Earth Fault (SEF) Protection

GRE140-420 and 720 provide directional earth fault protection with more sensitive settings for use in applications where the fault current magnitude may be very low.

The sensitive earth fault element includes a digital filter which rejects all harmonics other than the fundamental power system frequency.

The sensitive earth fault quantity is measured directly, using a dedicated core balance earth fault CT.

This input can also be used in transformer restricted earth fault applications, by the use of external metrosils and setting resistors.

The sensitive earth fault elements can be configured for directional operation in the same way as the standard earth fault pole, by polarising against the residual voltage.

Phase Undercurrent Protection

Protection against loss of load is provided by the phase undercurrent protection. Two independent stages are provided, each with a programmable definite time delay.

Thermal Overload Protection

The thermal overload feature provides protection for cables and other plant against the effects of prolonged operation under excess load conditions. A thermal replica algorithm is applied to create a model for the thermal characteristics of the protected plant. Tripping times depend not only on the level of overload current,

but also on the level of prior load current, the thermal replica providing ‘memory’ of previous conditions.

The thermal characteristics of the system are defined by entering settings for full load current and thermal time constant. GRE140 issues a trip according to the ‘cold’ and ‘hot’ curves specified in IEC60255-8 (see Figure 4), to prevent the protected system from exceeding its thermal capacity. The cold curve tripping times are applicable when the system is first energised, while the hot curves are relevant when the system has already been carrying some prior load for a period of time. An alarm output is also available to give early warning of high load current, set as a percentage of thermal capacity.

Directional Negative Phase Sequence Overcurrent Protection

Negative Phase Sequence Overcurrent (NOC) protection can be used in applications where certain fault conditions may not be detected by the normal phase and earth overcurrent protections, for example, in the case of a relay applied on the delta side of a delta-star transformer, to detect an earth fault on the star side. Alternatively, NPS can be used to protect a three-phase motor against the severe overheating which results from operating with an unbalanced supply.

Two independent stages are provided, each with a programmable definite time delay. The negative phase sequence overcurrent elements can be directionalised by polarising against the negative phase sequence voltage.

Under/Overvoltage Protection

Two undervoltage and two overvoltage stages are provided. In each case, the two stages can be programmed with definite time delays, and one is also available with an inverse delay.

Zero Phase Sequence Overvoltage (ZOV) (Neutral Voltage Displacement) Protection

Two Zero Phase Sequence Overvoltage stages are provided for detection of earth faults in high impedance earthed or isolated systems. The two stages can be programmed with definite time delays, and one is also available with an inverse delay. The zero sequence voltage may be derived from the phase voltages, or directly measured.

Negative Phase Sequence Overvoltage Protection (NOV)

For detection of unbalanced supply voltages, two NOV overvoltage thresholds are available, both of which can be programmed with definite time delays, and one is also available with an inverse delay.

Under/Overfrequency Protection

GRE140 provides over/under frequency protection and frequency rate-of-change protection.

These protections provide four independent frequency protection stages. The over/under frequency protection is programmable for either under- or over-frequency operation, and each has an associated DTL timer. The frequency rate-of-change protection calculates the gradient of frequency change (df/dt).

Broken Conductor Protection

The unbalance condition caused by an open circuited conductor is detected by the broken conductor protection. An unbalance threshold with programmable definite time delay is provided.

Circuit Breaker Fail (CBF) Protection

Two stage CBF protection provides outputs for re-tripping of the local circuit breaker and/or back-tripping to upstream circuit breakers. The CBF functions can also be initiated by external protections via a binary input if required.

Cold Load Protection

The cold load function modifies the overcurrent protection settings for a period after energising the system. This feature is used to prevent unwanted protection operation when closing on to the type of load which takes a high level of current for a period after energisation.

Inrush Current Detector (ICD)

The inrush current detector is used to prevent an incorrect operation of overcurrent protections from a magnetising inrush current during transformer energisation. Inrush current detector ICD detects second harmonic inrush current during transformer energisation.

PLC Function

GRE140 is provided with a PLC (Programmable Logic Control) function allowing user-configurable sequence logics on binary signals and binary inputs.

Auto-Reclose (ARC)

GRE140-40* and 42* provide four independent sequences, one for each of the following:

- Phase fault
- Earth fault
- Sensitive earth fault
- External trip (initiated by a binary input)

Each sequence is independently programmable for single shot, two shot, three shot, four shot or five shot (i.e. six trips to lock-out) auto-reclose. Each protection trip is programmable for instantaneous or delayed operation, and each ARC shot has a programmable dead time. Sequence co-ordination is maintained between the auto-reclose sequences of in-series relays on a feeder.

Synchronism Check

For the correct operation of three-phase auto-reclose, voltage and synchronism check are necessary. Characteristics of the synchronism check element are shown in Figure 2.

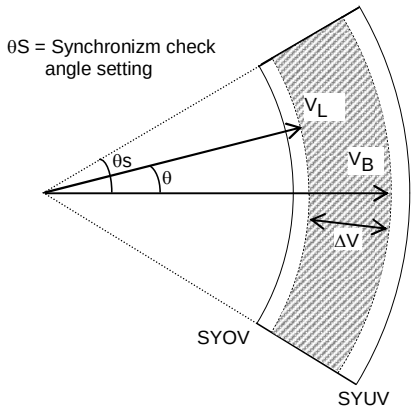


Figure 2 Synchronism check element

A detected maximum slip cycle is determined by the following equation:

$$f_{sc} = \frac{\theta s}{180° \times T_{SYN}}$$

where,

f_{SC}: slip cycle

θ_S: synchronism check angle setting

T_{SYN}: synchronism check timer setting

The frequency difference check function as mentioned below is also available by the setting for the split synchronizm check.

$$\Delta f = |f_{VL} - f_{VB}| \leq \Delta fs$$

where,

Δf = frequency difference

f_{VB} = frequency of busbar voltage VB

f_{VL} = frequency of line voltage VL

Δf_S= frequency difference setting

Start Protection

GRE140-700 and 720 provide start protection for motor failure on start up. When the start-up time exceeds setting time, it detects as a motor failure.

Stalled Motor Protection

The stalled motor protection can be detected the restraint rotor on start-up. The restraint rotor on start-up can be detected input signal from tachometer and the overcurrent.

Locked Rotor Protection

GRE140-700 and 720 provide the locked rotor protection on motor running. Burnout of the motor can be protected by the rotor temperature prediction based on stator temperature prediction of IEC60255-8 and detection of current value.

Restart Inhibit

The restart Inhibit provides protection of motor burnout by start-up current or number-of-start-up restriction per hour. From temperature prediction of rotor and the temperature rise prediction by start-up current, when the exceeding rotor permissible temperature by start-up current, the restart inhibit function forbids motor restart.

CONTROL FUNCTIONS

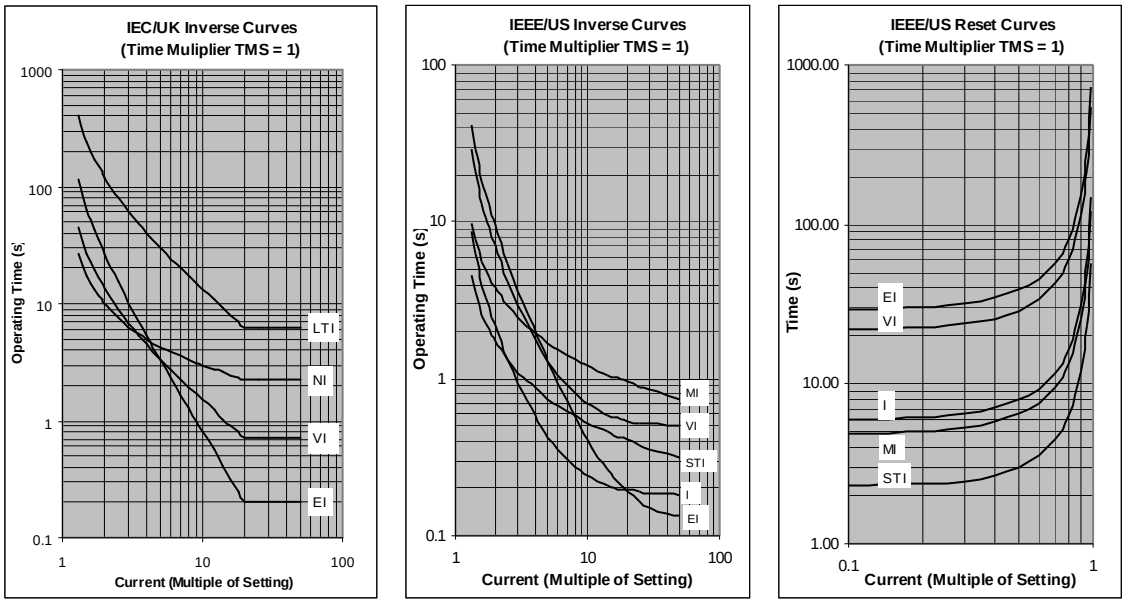
Switchgear Control

GRE140 provides the facility for switchgear control on the relay front panel. Two-stepped operation (select-control) is applied for the control procedure of circuit breakers to ensure highly secure operation. An interlock check function is included for safe operation of the switchgear. Password protection is provided for the above functions.

A local/remote selector switch is also provided on the relay front panel so that remote control from station level or load dispatching centre can be chosen.

Equipment status (Open or Closed) is indicated on front LEDs and relay fascia LCD.

Inverse Time Operate and Reset Curves



IDMT characteristics are defined by the following equations in accordance with IEC 60255-151.

$$t = TMS \times \left\{ \left[\frac{k}{\left(I/Is \right)^{\alpha} - 1} \right] + c \right\}$$

Inverse time operate function

$$t = RTMS \times \left[\frac{k_r}{1 - \left(I/I_S \right)^{\beta}} \right]$$

Dependent time reset function

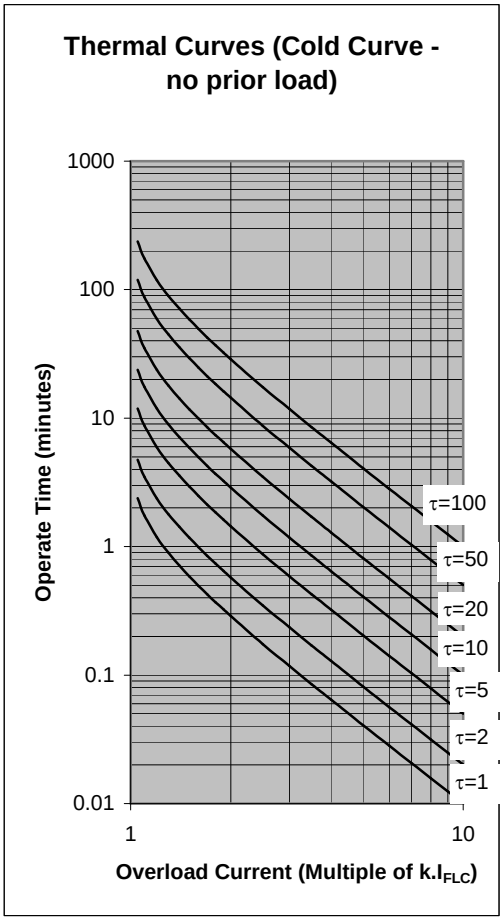
TMS setting range ; 0.010 – 1.500 in 0.001 steps
RTMS setting range ; 0.010 – 1.500 in 0.001 steps
Gs setting range :0.10 – 25.00A in 0.01A steps

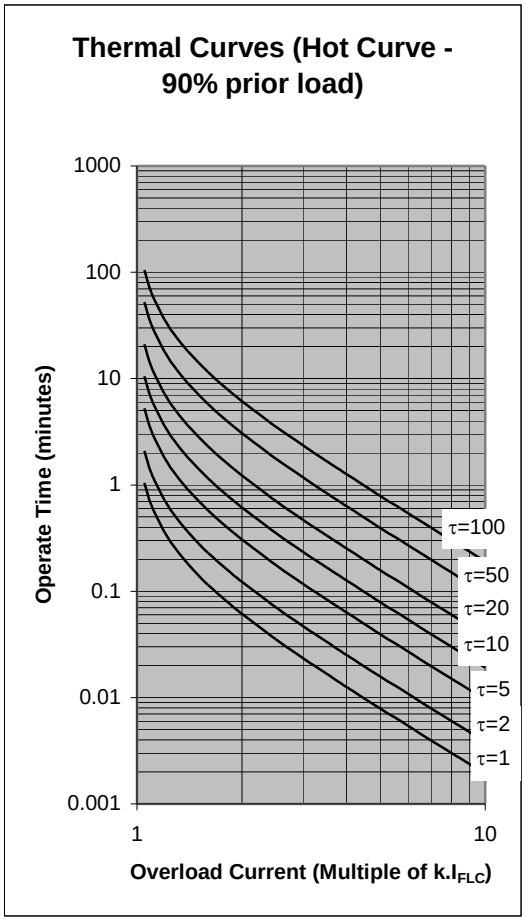
Constants for dependent time curves

Curve Type (IEC60255-151)	Curve Description	k	α	c	t_r	β
A	**IEC Normal Inverse (NI)**	0.14	0.02	0	-	-
B	**IEC Very Inverse (VI)**	13.5	1	0	-	-
C	**IEC Extremely Inverse (EI)**	80	2	0	-	-
--	**UK Long Time Inverse (LTI)**	120	1	0	-	-
D	**IEEE Moderately Inverse (MI)**	0.0515	0.02	0.114	4.85	2
E	**IEEE Very Inverse (VI)**	19.61	2	0.491	21.6	2
F	**IEEE Extremely Inverse (EI)**	28.2	2	0.1217	29.1	2
--	**US CO8 Inverse**	5.95	2	0.18	5.95	2
--	**US CO2 Short Time Inverse**	0.02394	0.02	0.01694	2.261	2
--	**User configurable setting**	0.00 – 30.000	0.00 – 5.00	0.000 – 5.000	0.000 – 30.000	0.00 – 5.00

Figure 3 - Operate and Reset Characteristics

IEC60255-8 Thermal Characteristics





$$t = \tau.Ln\left[\frac{I^2}{I^2 - \left(k.I_{FLC}\right)^2}\right];$$

IEC60255-8 'Cold' Curve

$$t = \tau.Ln\left[\frac{I^2 - I_P^2}{I^2 - \left(k.I_{FLC}\right)^2}\right]$$

IEC60255-8 'Hot' Curve

t = time to trip for constant overload current I (seconds)

I = overload current (largest phase current) (pu)

I_P = previous load current (pu)

$k.I_{FLC}$ (or I_θ) = thermal overload current setting (pu)

τ = thermal time constant (seconds)

Ln = natural logarithm

Figure 4 - IEC60255-8 Thermal Characteristics

MONITORING FUNCTIONS

Trip Circuit Supervision

The circuit breaker tripping control circuit can be GRE140 provides a high-integrity trip circuit supervision scheme. Trip circuits can be monitored with the circuit breaker either closed or open using two binary inputs as shown in Figure 5.

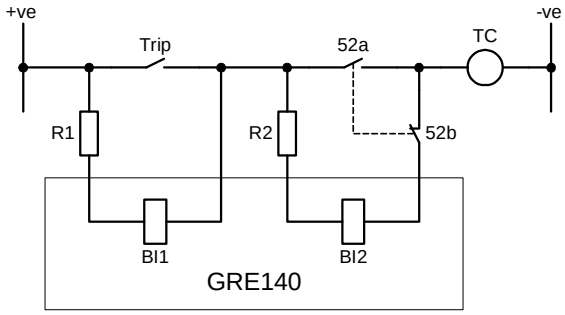


Figure 5 – Trip Circuit Supervision Scheme

CB Closed:
Under healthy conditions, binary input BI1 is energised via external resistor, R1. If the trip circuit becomes open, BI1 resets and a Trip Circuit Fail alarm is raised.

CB Open:
Under healthy conditions, binary inputs BI1 & BI2 are energised via external resistors, R1 & R2 respectively.If the trip circuit becomes open, both inputs reset and a Trip Circuit Fail alarm is raised.

The Trip Circuit Fail alarm incorporates a time delay of 400ms to prevent false alarms during normal tripping operations or voltage dips and is given in the form of an output contact operation and LCD/LED indication.

Automatic Self-Supervision

Automatic monitoring of internal circuits and software is provided. In the event of a failure being detected, the ALARM LED or the RELAY FAIL on the relay front panel is illuminated, the 'RELAY FAILURE' binary output operates, and the date and time of the failure is recorded in the event record.

Circuit Breaker State Monitoring

If two binary inputs are programmed to the functions 'CB OPEN' and 'CB CLOSED' then the CB State Monitoring function becomes active. In normal circumstances these inputs are in opposite states. If both show the same state then a 'CB Defective' alarm is raised.

Circuit Breaker Condition Monitoring

The following CB condition monitoring functions are provided:

- The trip counter increments the number of tripping operations performed. An alarm is issued when the count exceeds a user-defined setting.
- The $\sum I^y$ counter increments the value of current to the power 'y', recorded at the time of issuing the tripping signal, on a phase by phase basis. An alarm is issued when the count for any phase exceeds a user-defined setting.
- The operating time monitor records the time between issuing the tripping signal and the phase currents falling to zero. An alarm is issued when the operate time for any phase exceeds a user-defined setting.

The CB condition monitoring functions are triggered each time a trip is issued, and they can also be triggered by an external device via a binary input.

Motor status Monitoring

GRE140-700 and 720 provide motor statuses stopped, start-up and running monitoring function at Motor Status LED. Motor status LED is indicated light off is motor stopped, flicker is start-up and light on is running.

METERING AND RECORDING

Metering

The following data is continuously available on the relay front panel LCD and at a local or remote PC.

- Primary and secondary currents for each input.
- Positive and negative phase sequence currents.
- Ratio of negative phase sequence to positive phase sequence currents.
- Primary and secondary voltages for each input.
- Positive and negative phase sequence voltages.
- System residual voltage.
- Power frequency.
- Active and reactive power.
- Power factor.
- Peak phase power demand.
- Peak phase current demand.
- Thermal condition of system.
- Relay element output status.
- Watt-Hour
- Var-Hour
- Binary input and output status.

For 700 and 720 model (motor protection)

- Thermal condition of stator and rotor.
- Motor running time.
- Start-up time of the last motor start-up.
- Maximum current during the last motor start-up.
- Number of start-ups (total, cold and hot starts).

Event Record

Records are stored for the 200 most recent events, time-tagged to 1ms resolution. The event record is available on the relay front panel LCD and at a local or remote PC. Events are recorded as follows:

- Tripping operations.
- Alarms.
- Operation of protection elements.
- Change of state of binary inputs / outputs.
- Change of relay setting.
- Failure detected by automatic supervision

Fault Record

A relay trip initiates fault recording. Records are stored for the 4 most recent faults, time-tagged to 1ms resolution. The fault record is available on the relay fascia LCD and at a local or remote PC. Fault records include the following data:

- Date and time of trip operation
- Operating phase
- Protection element responsible for trip
- Measured current and voltage data

For 400 and 420 model

- Auto-reclose operation
- Fault location

Disturbance Record

The relay can record 8 analog and 32 binary signals, initiated by relay tripping and initiating relay elements. Post-trigger recording time can be set, and the maximum number of records which can be stored is dependent on the recording times chosen.

Fault Location

Fault location is initiated by a tripping operation and is indicated in km and % of line length. The result of fault location is stored as fault record data.

USER INTERFACE

Relay Front Panel

A user friendly interface is provided on the relay front panel. A menu-based system provides for easy programming of relay functions and access to real-time and stored data. The front panel includes the following features.

- 16 character, 8-line LCD with back light.
- 14 LEDs (9 fixed display and 5 configurable).
- Keypad.
- USB2.0 port for connection of local PC

Local PC Connection

The user can communicate with the GRE140 from a local PC via the USB2.0 port on the front panel. Using RSM100 software, the user can view and modify settings and analyse recorded data.

Relay Setting

The user can modify relay settings either using the front panel keypad or using the RSM100 software from a local PC. Password protection is available for added security.

Two settings groups are provided, allowing the user to set one group for normal conditions, while the other groups may be set to cover alternative operating conditions.

Using the RSM software, the user can create a settings file on a PC (without being connected to a relay), and store the file ready for download to a relay at a later date.

Modbus and DNP3 Communications

GRE140 supports the Modbus and DNP3 communication protocol. These protocols are used for communication with a substation control and monitoring system or automation system to be linked with SCADA or regional control center, and are used to transfer measurand data, status data and general commands between the relay and the control system.

IEC 60870-5-103 Communications

GRE140 supports the IEC 60870-5-103 communication protocol. This protocol is used for communication with a substation control and monitoring system and is used to transfer measured data, status data and general commands between the relay and the control system via RS485.

IEC 61850 Communication

GRE140 can support data communication according to the IEC 61850 standard via an optional communication port.

Binary Outputs

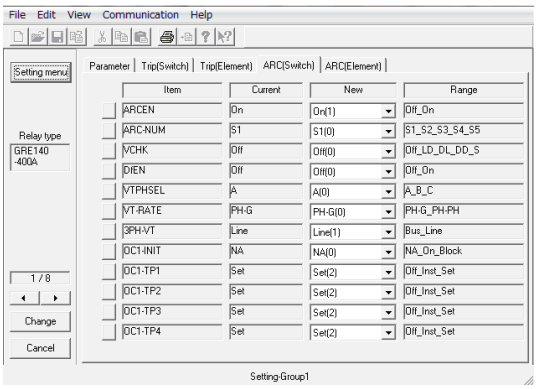
GRE140 provides four, ten or sixteen binary output contacts for tripping and alarm. Each of the programmable binary outputs is driven via a logic gate which can be programmed for OR gate or AND gate operation. Further, each output has a programmable reset characteristic, settable for instantaneous drop-off, delayed drop-off, dwell timer or for latching operation. If latching operation is selected then an operated relay must be reset by the user, either by pressing the RESET button, by energising a binary input which has been programmed for 'Remote Reset' operation, or by a communications command.

Binary Inputs

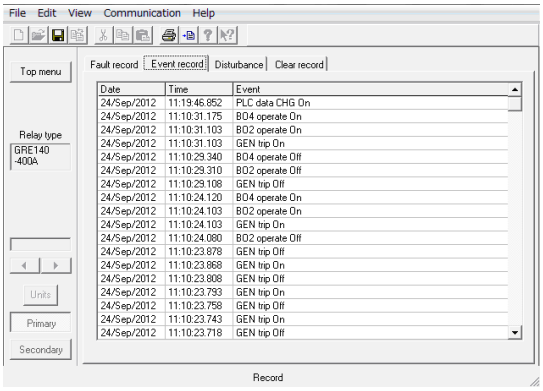
GRE140 provides six, twelve or eighteen programmable binary inputs. Each binary input is individually user-programmable for normal or inverted operation and for delayed pick-up and/or drop-off. Each input can also be used to switch relay operation to a different settings group.

General purpose alarm functions are also included. The user can define a text message for each alarm. Then when inputs associated with that alarm are raised, the defined text is displayed on the LCD.

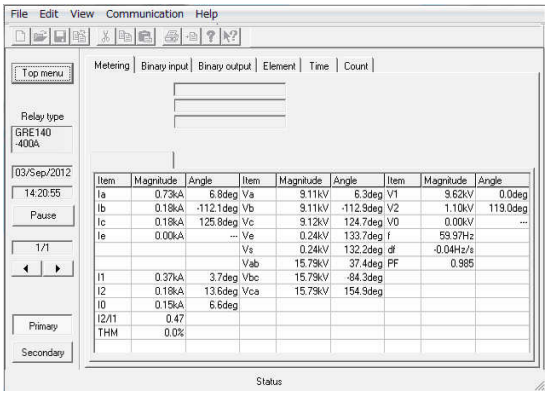
PC DISPLAY



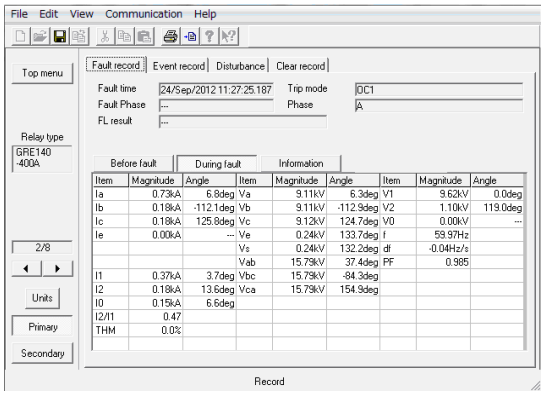
Setting



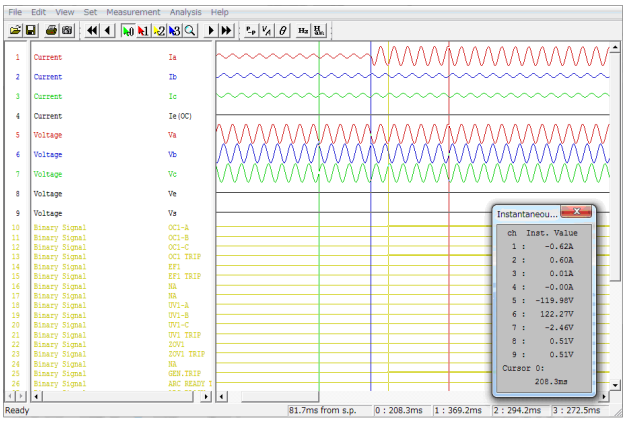
Event record



Metering



Fault record



Data analysis

Figure 6 - Relay Setting and Monitoring System - PC Displays

TECHNICAL DATA

Ratings	
AC current In:	1/5A
AC voltage Vn:	100 - 240 V
Frequency:	50/60Hz
Auxiliary supply:	110 – 250Vdc / 100-220Vac (Operative range: 88 – 300Vdc / 80 – 264Vac) 48－110Vdc (Operative range: 38.4 – 132Vdc) 24 – 48Vdc (Operative range: 19.2 – 60.0Vdc)
Superimposed AC ripple on DC supply:	maximum 12%
DC supply interruption:	maximum 50ms at 110V
Binary input circuit DC voltage:	For alarm indication 110 – 250Vdc (Operative range: 88 – 300Vdc) 48-110Vdc (Operative range: 38.4 – 132Vdc) 24V – 48Vdc (Operative range: 19.2 – 60.0Vdc) For trip circuit surpervision Operative range: ≥38.4V (for 110Vdc rating) ≥88V (for 220/250Vdc rating) ≥19.2V (for 48Vdc rating) ≥9.6V (for 24Vdc rating)
Overload Ratings	
AC current inputs:	4 times rated current continuous 100 times rated current for 1 second
AC voltage inputs:	2 times rated voltage continuous
Burden	
AC phase current inputs:	≤ 0.3VA
AC earth current inputs:	≤ 0.5VA
AC sensitive earth inputs:	≤ 1.2VA
AC voltage inputs:	≤ 0.1VA (at rated voltage)
Power supply:	≤ 10W (quiescent) ≤ 15W (maximum)
Binary input circuit:	≤ 0.5W per input at 220Vdc
Current Transformer Requirements	
Phase Inputs	Typically 5P20 with rated burden according to load. (refer to manual for detailed instructions)
Standard Earth Inputs:	Core balance CT or residual connection of phase CTs.
Sensitive Earth Inputs:	Core balance CT.
Directional Phase Overcurrent Protection (67)	
P/F 1st Overcurrent threshold:	OFF, 0.10 – 25.00A in 0.01A steps
Delay type:	DTL, IDMTL (IEC 60255-151): IEC NI, IEC VI, IEC EI, UK LTI, IEEE MI, IEEE VI, IEEE EI, US CO8 I, US CO2 STI
IDMTL Time Multiplier Setting TMS:	0.010 – 1.500 in 0.001 steps
DTL delay:	0.00 – 300.00s in 0.01s steps
Reset Type:	Definite Time or Dependent Time(IEC 60255-151)
Reset Definite Delay:	0.0 – 300.0s in 0.1s steps
Reset Time Multiplier Setting RTMS:	0.010 – 1.500 in 0.001 steps
P/F 2nd Overcurrent threshold:	OFF, 0.10 – 25.00A in 0.01A steps
P/F 3rd, 4th Overcurrent thresholds:	OFF, 0.10 – 150.00A in 0.01A steps
DTL delay:	0.00 – 300.00s in 0.01s steps
P/F Characteristic Angle:	–95° to +95° in 1° steps

Directional Earth Fault Protection (67N)	
E/F 1st Overcurrent threshold:	OFF, 0.05 – 25.00A in 0.01A steps
Delay type:	DTL, IDMTL(IEC 60255-151): IEC NI, IEC VI, IEC EI, UK LTI, IEEE MI, IEEE VI, IEEE EI, US CO8 I, US CO2 STI
IDMTL Time Multiplier Setting TMS:	0.010 – 1.500 in 0.001 steps
DTL delay:	0.00 – 300.00s in 0.01s steps
Reset Type:	Definite Time or Dependent Time(IEC 60255-151)
Reset Definite Delay:	0.0 – 300.00s in 0.01s steps
Reset Time Multiplier Setting RTMS:	0.010 – 1.500 in 0.001 steps
E/F 2nd threshold:	OFF, 0.05 – 25.00A in 0.01A steps
E/F 3rd, 4th thresholds:	OFF, 0.05 – 100.00A in 0.01A steps
DTL delay:	0.00 – 300.00s in 0.01s steps
E/F Characteristic angle:	–95° to +95° in 1° steps
E/F directional voltage threshold:	0.5 – 100.0V in 0.1V steps
Directional Sensitive Earth Fault Protection (67SEF)	
SEF 1st Overcurrent threshold:	OFF, 0.001 – 0.2500A in 0.001A steps
Delay Type:	DTL, IDMTL(IEC 60255-151): IEC NI, IEC VI, IEC EI, UK LTI, IEEE MI, IEEE VI, IEEE EI, US CO8 I, US CO2 STI
IDMTL Time Multiplier Setting TMS:	0.010 – 1.500 in 0.001 steps
DTL delay:	0.00 – 300.00s in 0.01s steps
Reset Type:	Definite Time or Dependent Time(IEC 60255-151)
Reset Definite Delay:	0.0 – 300.0s in 0.1s steps
Reset Time Multiplier Setting RTMS:	0.010 – 1.500 in 0.001 steps
DTL delay (back-up timer):	0.00 – 300.00s in 0.01s steps
SEF 2nd, 3rd, 4th threshold:	OFF, 0.001 – 0.250A in 0.001A steps
DTL delay:	0.00 – 300.00s in 0.01s steps
SEF Characteristic angle:	–95° to +95° in 1° steps
SEF Boundary of operation:	±87.5°, ±90°
SEF directional voltage threshold:	0.5 – 100.0V in 0.1V steps
Residual power threshold:	OFF, 0.00 – 100.00W in 0.01W steps
Phase Undercurrent Protection (37)	
Undercurrent 1st, 2nd threshold:	OFF, 0.10 – 10.00A in 0.01A steps
DTL Delay:	0.00 – 300.00s in 0.01s steps
Thermal Overload Protection (49)	
$I_\theta = k.I_{FLC}$ (Thermal setting):	OFF, 0.50 – 10.00A in 0.01A steps
Previous load current (I_P)	0.00 – 5.00A in 0.01A steps
Time constant (τ):	0.5 – 500.0mins in 0.1min steps
Thermal alarm:	OFF, 50% to 99% in 1% steps
Inrush Current Detector	
Second harmonic ratio setting	10 – 50% in 1% steps
Overcurrent threshold	1.0 – 25.0A in 0.1A steps
Reverse Power Protection (32)	
Reverse Power 1st, 2nd threshold:	OFF, -500.0 - -1.0W in 0.1W steps
DTL Delay:	0.00 – 300.00s in 0.01s steps
DO/PU ratio	5 – 98% in 1% steps
Broken Conductor Protection (46BC)	
Broken conductor threshold (I_2/I_1):	OFF, 0.10 – 1.00 in 0.01 steps
DTL delay:	0.00 – 300.00s in 0.01s steps
CBF Protection (50BF)	
CBF threshold:	OFF, 0.10 – 10.00A in 0.01A steps
CBF stage 1 (Backup trip) DTL:	0.00 – 300.00s in 0.01s steps
CBF stage 2 (Re-trip) DTL:	0.00 – 300.00s in 0.01s steps

Directional Negative Phase Sequence Overcurrent Protection (67/46)	
NOC 1st, 2nd threshold:	OFF, 0.10 – 10.00A in 0.01A steps
Delay type:	DTL, IDMTL(IEC 60255-151): IEC NI, IEC VI, IEC EI, UK LTI, IEEE MI, IEEE VI, IEEE EI, US CO8 I, US CO2 STI
IDMTL Time Multiplier Setting TMS:	0.010 – 1.500 in 0.001 steps
DTL delay:	0.00 – 300.00s in 0.01s steps
Reset Type:	Definite Time or Dependent Time(IEC 60255-151)
Reset Definite Delay:	0.0 – 300.0s in 0.1s steps
Reset Time Multiplier Setting RTMS:	0.010 – 1.500 in 0.001 steps
NOC Characteristic angle:	–95° to +95° in 1° steps
NOC Directional voltage threshold	0.5 – 25.0V in 0.1V steps
Overvoltage Protection (59)	
1st, 2nd Overvoltage thresholds:	OFF, 10.0 – 200.0V in 0.1V steps
Delay type (1st threshold only):	DTL, IDMTL(complied with IEC 60255-127)
IDMTL Time Multiplier Setting TMS:	0.05 – 100.00 in 0.01 steps
DTL delay:	0.00 – 300.00s in 0.01s steps
DO/PU ratio	10 – 98% in 1% steps
Reset Delay:	0.0 – 300.0s in 0.1s steps
Undervoltage Protection (27)	
1st, 2nd Undervoltage thresholds:	OFF, 5.0 – 130.0V in 0.1V steps
Delay type (1st threshold only):	DTL, IDMTL(complied with IEC 60255-127)
IDMTL Time Multiplier Setting TMS:	0.05 – 100.00 in 0.01 steps
DTL delay:	0.00 – 300.00s in 0.01s steps
Reset Delay:	0.0 – 300.0s in 0.1s steps
Undervoltage Block	5.0 – 20.0Vin 0.1V steps
Zero Phase Sequence Overvoltage Protection (59N)	
1st, 2nd ZOV Overvoltage thresholds:	OFF, 1.0 – 160.0V in 0.1V steps
Delay type (1st threshold only):	DTL, IDMTL(complied with IEC 60255-127)
IDMTL Time Multiplier Setting TMS:	0.05 – 100.00 in 0.01 steps
DTL delay:	0.00 – 300.00s in 0.01s steps
Reset Delay:	0.0 – 300.0s in 0.1s steps
Negative Phase Sequence Overvoltage Protection (47)	
1st, 2nd NOV Overvoltage thresholds:	OFF, 1.0 – 160.0V in 0.1V steps
Delay type (1st threshold only):	DTL, IDMTL(complied with IEC 60255-127)
IDMTL Time Multiplier Setting TMS:	0.05 – 100.00 in 0.01 steps
DTL delay:	0.00 – 300.00s in 0.01s steps
Reset Delay:	0.0 – 300.0s in 0.1s steps
Under/Over Frequency Protection (81U/O)	
1st - 4th under/overfrequency threshold	(F_{nom} – 10.00Hz) – (F_{nom} + 10.00Hz) in 0.01Hz steps F_{nom}: nominal frequency
DTL delay:	0.00 – 300.00s in 0.01s steps
Frequency UV Block	40.0 – 100.0V in 0.1V steps
Frequency rate-of-change	0.1 – 15.0Hz/s in 0.1Hz/s steps
Autoreclose (79)	for GRE140-40x and 42x model
ARC Reclaim Time	0.0– 600.0s in 0.1s steps
Close Pulse Width	0.01 – 10.00s in 0.01s steps
Lock-out Recovery Time	OFF, 0.1 – 600.0s in 0.1s steps
Sequences	1 – 5 Shots to Lock-out, each trip programmable for inst or Delayed operation
Dead Times(programmable for each shot)	0.01 – 300.00s in 0.01s steps

Voltage and Synchronizm Check (25)	for GRE140-40x and 42x model
Synchronism check angle (θ S)	5 to 75° in 1° steps
UV element (SYUV)	10 to 150V in 1V steps
OV element (SYOV)	10 to 150V in 1V steps
Voltage difference check (Δ V)	0 to 150V in 1V steps
Busbar or line dead check (VB)	10 to 150V in 1V steps
Busbar or line live check (VL)	10 to 150V in 1V steps
Frequency difference check (Δ f)	0.01 to 2.00Hz in 0.01 steps
Synchronism check time (TSYN)	0.01 to 10.00s in 0.01s steps
Voltage check time	0.01 to 10.00s in 0.01s steps
Start Protection (48)	for GRE140-70x and 72x model
Motor start protection time:	0.0 - 300.0s in 0.1s steps
Stalled Motor Protection (50S)	for GRE140-70x and 72x model
50S threshold:	OFF, 0.10 - 50.00A in 0.01A steps
DTL delay:	0.00 - 300.00s in 0.01s steps
Locked Rotor Protection (51LR)	for GRE140-70x and 72x model
Motor start-up current:	OFF, 0.10 – 100.00A in 0.01A steps
Rotor restraint permissible time:	1 – 300s in 1s steps
Rotor permissible heat range: the ratio from THM1 (stator)	50 – 500% in 1% steps
Restart Inhibit (66)	for GRE140-70x and 72x model
Motor start-up time:	1 – 300s in 1s steps
Rotor restraint permissible time:	1 – 300s in 1s steps (Common setting as 51LR)
Rotor permissible heat range: the ratio from THM1 (stator)	50 – 500% in 1% steps (Common setting as 51LR)
Starts per hour: limit number-of-start-up	1 – 60 in 1 steps
Accuracy	
Overcurrent Pick-ups:	100% of setting ± 5% (Gs>0.2A)
Overcurrent PU/DO ratio:	approx, 95%
Undercurrent Pick-up:	100% of setting ± 5% (Gs>0.2A)
Undercurrent PU/DO ratio:	approx, 105%
Overvoltage Pick-ups:	100% of setting ± 5%
Undervoltage Pick-ups:	100% of setting ± 5%
Over Frequency Pick-ups:	Frequency threshold ± 0.05Hz (setting: ≤ 5.00Hz)
Under Frequency Pick-ups:	Frequency threshold ± 0.05Hz (setting: ≤ 5.00Hz)
Frequency rate-of-change Pick-ups:	100% of setting ± 0.05Hz/s (setting: ≤ 5.00Hz/s)
Inverse OC Operate Time:	IEC60255-151, ±5% or 50ms (2 ≤ G/Gs ≤ 20) GT = 1.1Gs GD = 20Gs (Gs ≤ 10A), 200A (Gs > 10A)
DOC Definite Operate Time:	≤ DTL + 45ms (DT, input: ≥ 200% of setting)
DEF Definite Operate Time:	≤ DTL + 45ms (DT, input: ≥ 200% of setting)
CBF Operate Time:	≤ DTL + 40ms (input: ≥ 200% of setting)
Inverse OV Operate Time:	IEC60255-127, ±5% or 50ms (OV; 1.2 ≤ G/Gs ≤ GD/Gs, UV; 0 ≤ G/Gs ≤ 1) GD = 300V
OV Definite Operate Time:	≤ DTL + 45ms (DT, input: ≥ 200% of setting)
UV Definite Operate Time:	≤ DTL + 50ms (DT, input: ≤ 80% of setting)
NOV Definite Operate Time:	≤ DTL + 50ms (DT, input: ≥ 200% of setting)
Under/Over Frequency Operate Time:	90 – 190ms (rated frequency: 50Hz) 70 – 160ms (rated frequency: 60Hz)
Frequency rate-of-change Operate Time:	160 – 310ms (rated frequency: 50Hz, input ≥ 200% of setting) 130 – 260ms (rated frequency: 60Hz, input ≥ 200% of setting)
Transient Overreach for instantaneous elements	<–5% for X/R = 100.
	Time delays include operating time of trip contacts.

Front Communication port - local PC (USB)	
Connector type:	USB-Type B
Cable length:	5m (max.)
Rear Communication port (RS485)	
RS485 I/F for Modbus and IEC60870-5-103:	
Connection	Multidrop (max. 32 relays)
Cable type	Twisted pair cable with shield
Cable length	1200m (max.)
Connection	Screw terminals
Isolation	1kVac for 1 min.
Transmission rate	9.6, 19.2kbps
Rear Communication port (Ethernet)	
100BASE-TX	RJ-45 connector
100BASE-FX	SC connector
Time synchronization port (IRIG-B port)	
IRIG Time Code	IRIG-B122
Input impedance	4k-ohm
Input voltage range	4Vp-p to 10Vp-p
Connector type	Screw terminal
Cable type	50 ohm coaxial cable
Binary Inputs	
Number	6 (4x0/7x0 model) / 12 (4x1/7x1 model) / 18 (4x2/7x2 model)
Operating voltage	For indication Typical 154Vdc (min. 110Vdc) for 220Vdc rating Typical 77Vdc(min. 70Vdc) for 110Vdc rating Typical 33.6Vdc(min. 24Vdc) for 48Vdc rating Typical 16.8Vdc(min. 12Vdc) for 24Vdc rating For trip circuit supervision ≥88V for 220Vdc rating ≥38.4V for 110Vdc rating ≥19.2V for 48Vdc rating ≥9.6V for 24Vdc rating
Binary Outputs	
Number	4 (4x0/7x0 model) / 10 (4x1/7x1 model) / 16 (4x2/7x2 model)
Ratings: model 4∗0 and 7∗0: BO1 and BO2	Make and carry: 5A continuously
model 4∗1 and 7∗1: BO1, BO2, BO5 and BO6	Make and carry: 30A, 250Vdc for 0.5s (L/R≥40ms)
model 4∗2 and 7∗2: BO1, BO2, BO5, BO6, BO11 and BO12	Break: 0.1A, 250Vdc (L/R=40ms)
Other BOs	Make and carry: 4A continuously Make and carry: 8A, 250Vdc for 0.5s (L/R≥40ms) Break: 0.1A, 250Vdc (L/R=40ms)
Durability:	Loaded contact: ≥1,000 operations Unloaded contact: ≥10,000 operations
Pickup time	Less than 15ms
Reset time	Less than 10ms
Mechanical design	
Weight	2.5kg (4x0 /7x0 model) 3.0kg (4x2/7x2 model)
Width	223mm
Height	177mm
Depth	180mm
Case color	Munsell No. 10YR8/0.5
Installation	Flush mounting with attachment kits

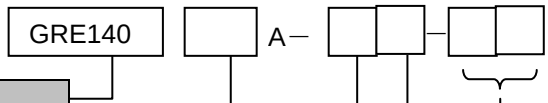
ENVIROMENTAL PERFORMANCE

Test	Standards	Details
Atmospheric Environment		
Temperature	IEC60068-2-1/2 IEC60068-2-30	Operating range: -20°C to +60°C. Storage / Transit: -25°C to +70°C.
Humidity	IEC60068-2-78	56 days at 40°C and 93% relative humidity.
Enclosure Protection	IEC60529	IP52(front), IP20 (rear), IP40 (top)
Mechanical Environment		
Vibration	IEC60255-21-1	Response - Class 1 Endurance - Class 1
Shock and Bump	IEC60255-21-2	Shock Response Class 1 Shock Withstand Class 1 Bump Class 1
Seismic	IEC60255-21-3	Class 1
Electrical Environment		
Dielectric Withstand	IEC60255-5	2kVrms for 1 minute between all terminals and earth. 2kVrms for 1 minute between independent circuits. 1kVrms for 1 minute across normally open contacts.
High Voltage Impulse	IEC60255-5	Three positive and three negative impulses of 5kV(peak), for CT, Power Supply Unit , BI and BO circuits; between terminals and earth, and between independent circuits. 3kV (peak) for RS485 circuit; between terminals and earth 3kV (peal) for BO circuit ; across normally open contacts 1.2/50μs, 0.5J between all terminals and between all terminals and earth.
Electromagnetic Environment		
High Frequency Disturbance / Damped Oscillatory Wave	IEC60255-22-1 Class 3, IEC61000-4-12, IEEE C37. 90. 1	1MHz 2.5kV to 3kV(peak) applied to all ports in common mode. 1MHz 1.0kV applied to all ports in differential mode.
Electrostatic Discharge	IEC60255-22-2 Class 3, IEC61000-4-2	6kV contact discharge, 8kV air discharge.
Radiated RF Electromagnetic Disturbance	IEC60255-22-3 Class 3, IEC61000-4-3	Field strength 10V/m for frequency sweeps of 80MHz to 1GHz and 1.7GHz to 2.2GHz. Additional spot tests at 80, 160, 450, 900 and 1890MHz.
Fast Transient Disturbance	IEC60255-22-4 Class A, IEC61000-4-4, IEEE C37. 90. 1	4kV, 2.5kHz, 5/50ns applied to all inputs.
Surge Immunity	IEC60255-22-5, IEC61000-4-5	1.2/50μs surge in common/differential modes: HV, Power Supply Unit and I/O ports: 2kV/1kV (peak) RS485 port: 1kV (peak)
Conducted RF Electromagnetic Disturbance	IEC60255-22-6 Class 3, IEC61000-4-6	10Vrms applied over frequency range 150kHz to 100MHz. Additional spot tests at 27 and 68MHz.
Power Frequency Disturbance	IEC60255-22-7 Class A, IEC61000-4-16	300V 50Hz for 10s applied to ports in common mode. 150V 50Hz for 10s applied to ports in differential mode. Not applicable to AC inputs.
Conducted and Radiated Emissions	IEC60255-25 Class A, EN55022 Class A, IEC61000-6-4	Conducted emissions: 0.15 to 0.50MHz: <79dB (peak) or <66dB (mean) 0.50 to 30MHz: <73dB (peak) or <60dB (mean) Radiated emissions (at 10m): 30 to 230MHz: <40dB 230 to 1000MHz: <47dB

Test	Standards	Details
European Commission Directives		
CE	89/336/EEC	Compliance with the European Commission Electromagnetic Compatibility Directive is demonstrated according to EN 61000-6-2 and EN 61000-6-4.
	73/23/EEC	Compliance with the European ommission Low Voltage Directive is demonstrated according to product safety standard EN 60255-27.

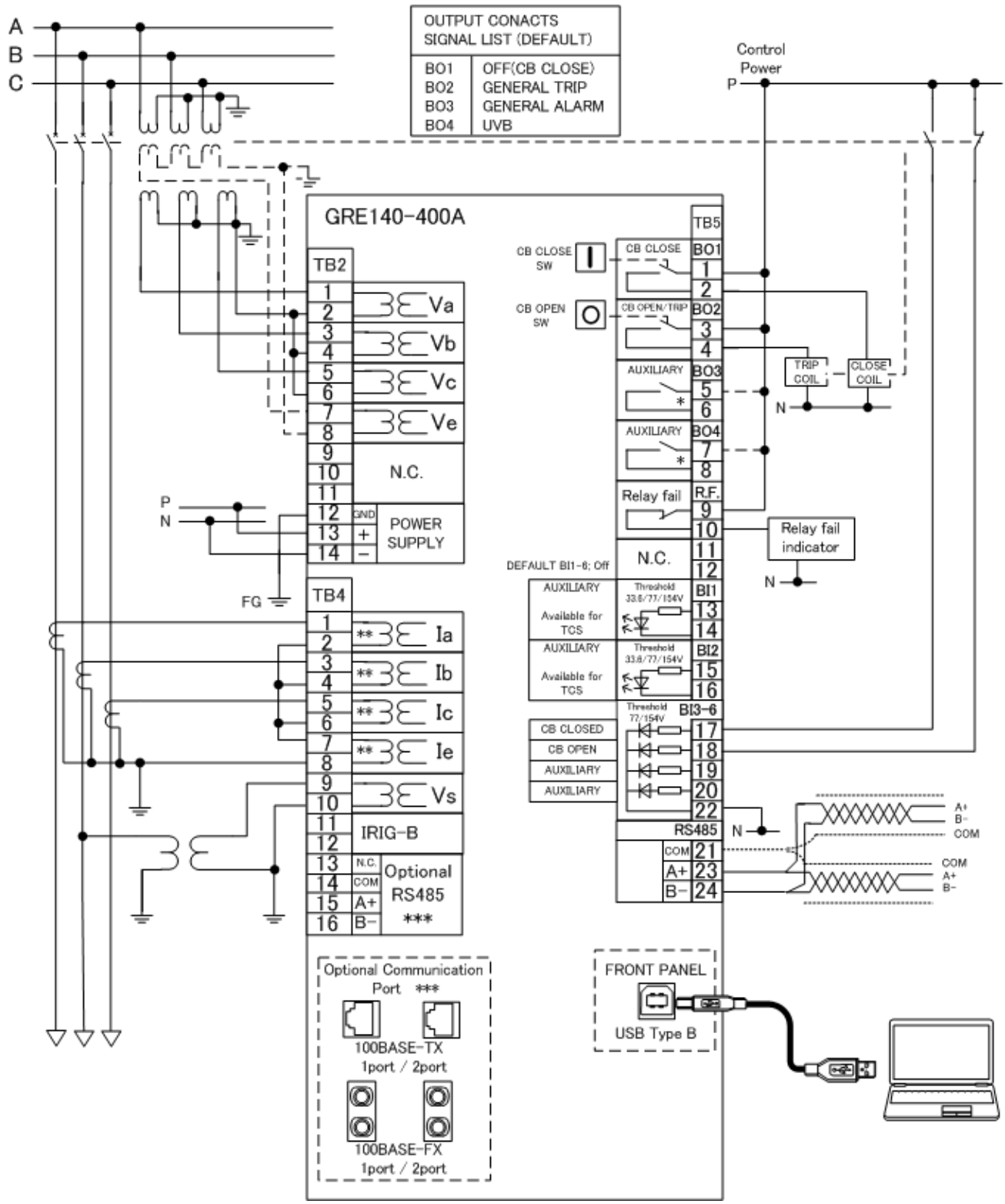
ORDERING

Directional Overcurrent Relay



Type:	
Directional Overcurrent / Motor protection Relay	GRE140
Model:	
- Model 400: Three phase and earth fault	
6 x BIs, 4 x BOs, 1 x Relay fail	400
12 x BIs, 10 x BOs, 1 x Relay fail	401
18 x BIs, 16 x BOs, 1 x Relay fail	402
- Model 420: Three phase and sensitive earth fault (SEF)	
6 x BIs, 4 x BOs, 1 x Relay fail	420
12 x BIs, 10 x BOs, 1 x Relay fail	421
18 x BIs, 16 x BOs, 1 x Relay fail	422
- Model 700: Motor protection	
6 x BIs, 4 x BOs, 1 x Relay fail	700
12 x BIs, 10 x BOs, 1 x Relay fail	701
18 x BIs, 16 x BOs, 1 x Relay fail	702
- Model 720: Motor protection with SEF	
6 x BIs, 4 x BOs, 1 x Relay fail	720
12 x BIs, 10 x BOs, 1 x Relay fail	721
18 x BIs, 16 x BOs, 1 x Relay fail	722
Rating:	
CT: 1/5A, f: 50/60Hz, 110-250Vdc or 100-220Vac	1
CT: 1/5A, f: 50/60Hz, 48-110Vdc	2
CT: 1/5A, f: 50/60Hz, 24-48Vdc	A
Standard and language:	
IEC (English)	0
ANSI (English)	1
Communication:	
RS485 1port (Modbus/IEC 60870-5-103)	10
RS485 1port (Modbus/DNP3)	11
100BASE-TX 1port (Modbus/IEC 61850) +RS485 1port (Modbus/IEC 60870-5-103)	A0
100BASE-TX 1port (Modbus/IEC 61850/DNP3) +RS485 1port (Modbus/DNP3)	A1
100BASE-FX 1port (Modbus/IEC 61850) +RS485 1port (Modbus/IEC 60870-5-103)	C0
100BASE-FX 1port (Modbus/IEC 61850/DNP3) +RS485 1port (Modbus/DNP3)	C1

EXTERNAL CONNECTION DIAGRAM

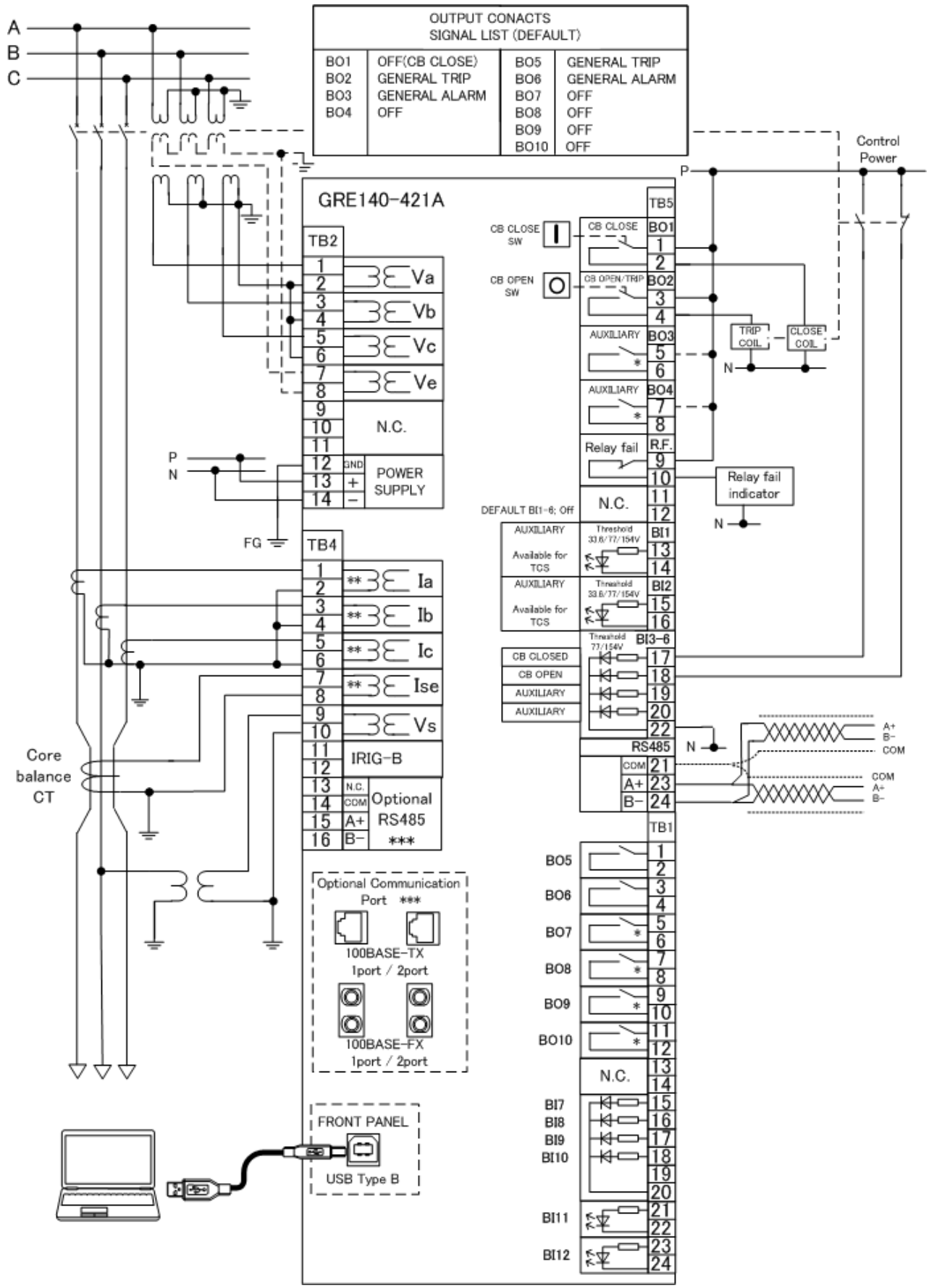


*BO3 – 4 are NOT applicable for direct CB coil connection.

**Analogue current input ports are shorted when the terminal block is removed. (TB4 1-2, 3-4, 5-6, 7-8)

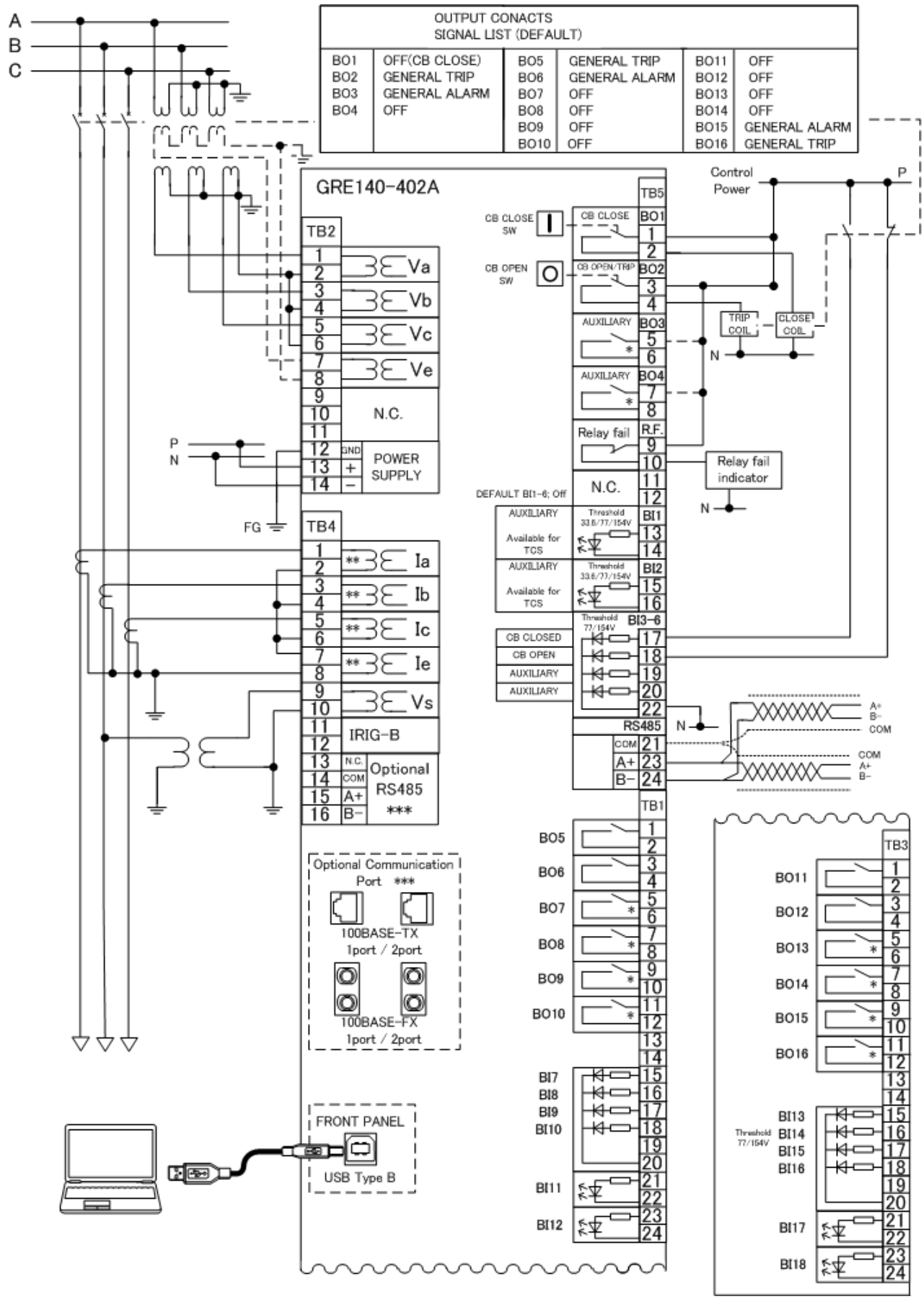
*** Available at one of the communication function is selected.

Figure 7 - GRE140-400A Typical External Connection Diagram



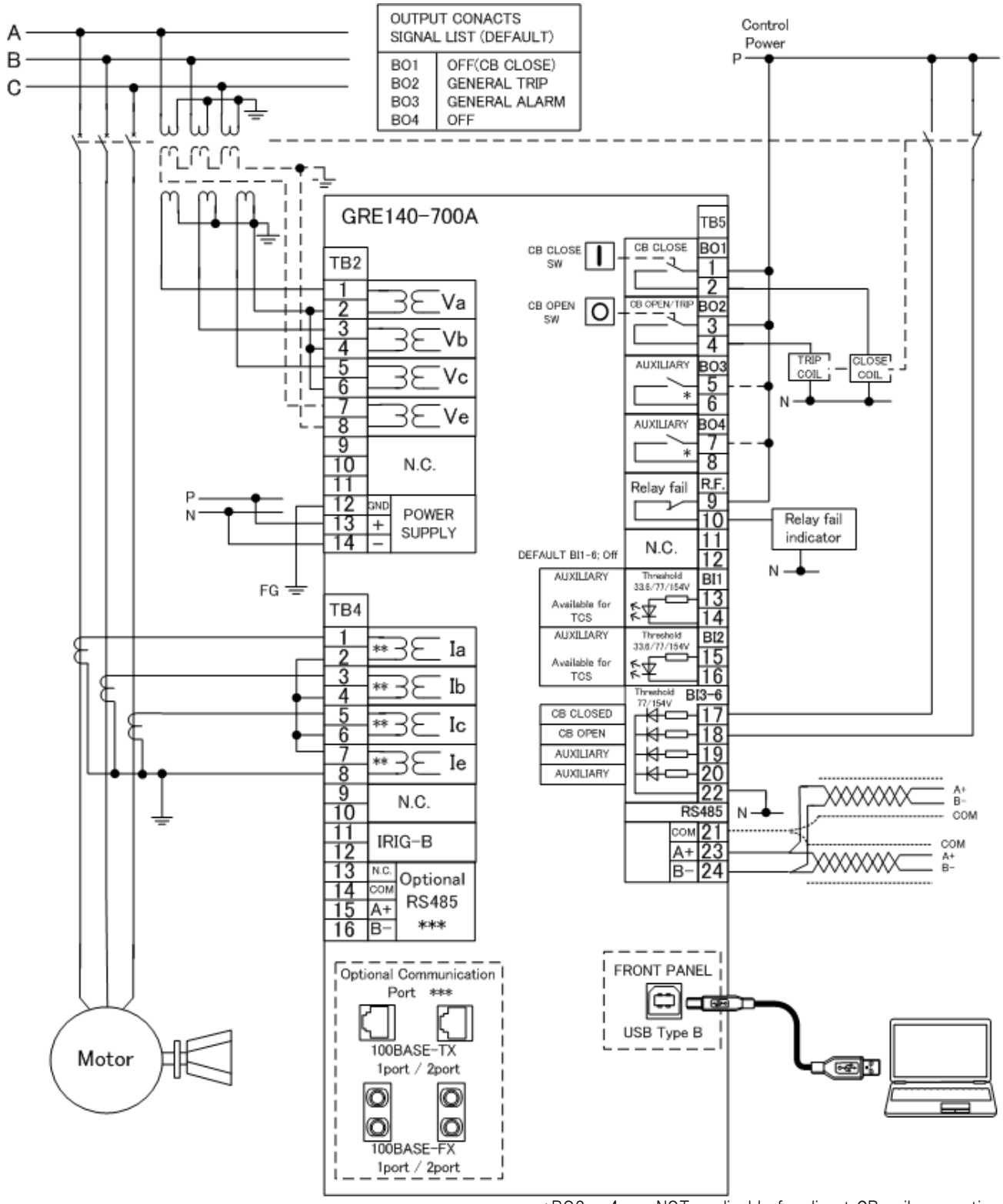
*BO3, 4, 7 - 12 are NOT applicable for direct CB coil connection.
**Analogue current input ports are shorted when the terminal block is removed. (TB4 1-2, 3-4, 5-6, 7-8)
*** Available at one of the communication function is selected.

Figure 8 - GRE140-421A Typical External Connection Diagram



*BO3, 4, 7 - 12, 13 - 16 are NOT applicable for direct CB coil connection.
**Analogue current input ports are shorted when the terminal block is removed. (TB4 1-2, 3-4, 5-6, 7-8)
*** Available at one of the communication function is selected.

Figure 9 - GRE140-402A Typical External Connection Diagram



*BO3 - 4 are NOT applicable for direct CB coil connection.
**Analogue current input ports are shorted when the terminal block is removed. (TB4 1-2, 3-4, 5-6, 7-8)
*** Available at one of the communication function is selected.

Figure 10 - GRE140-700A Typical External Connection Diagram

RELAY OUTLINE

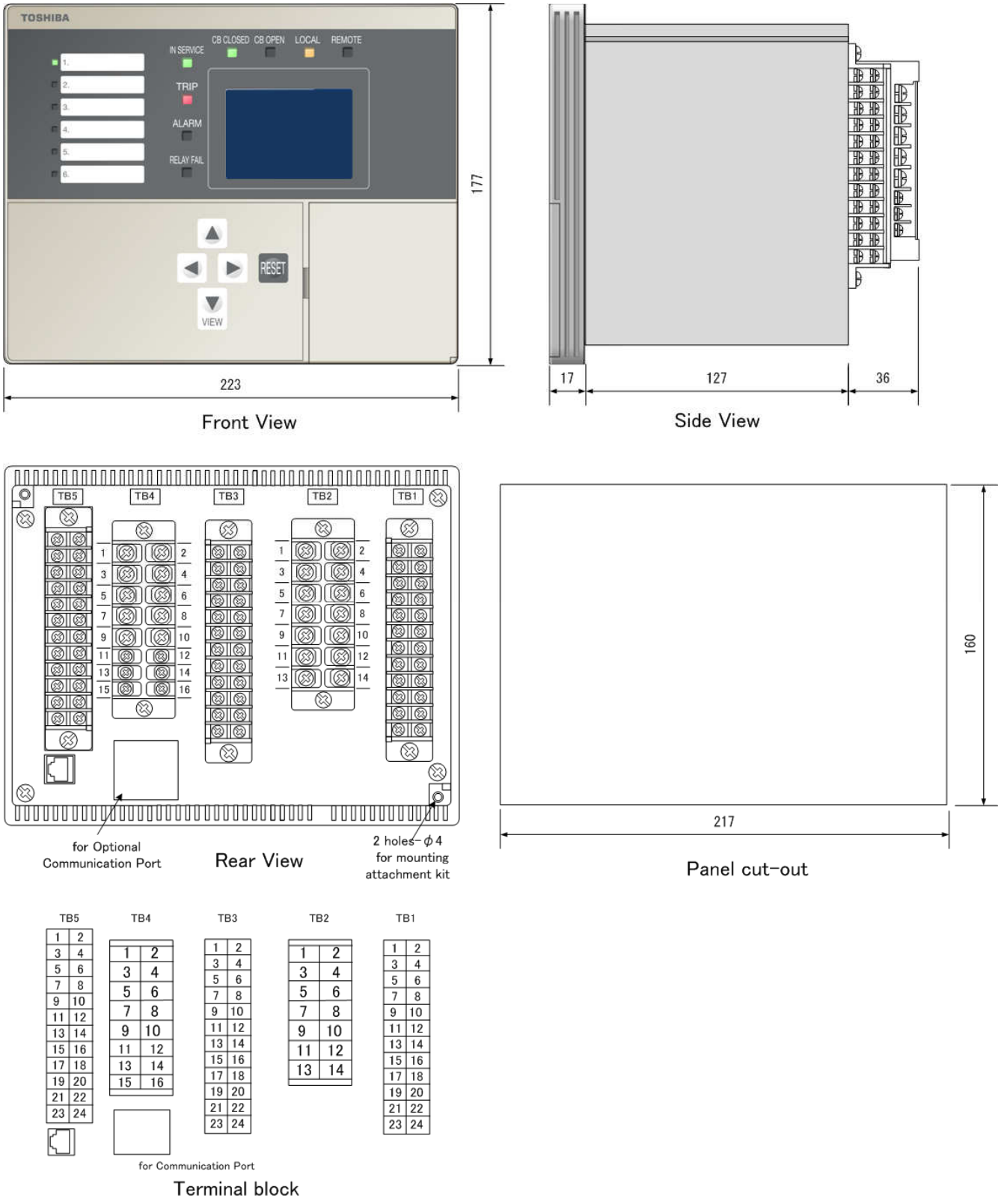


Figure 11 - GRE140 Outline Diagram

TOSHIBA

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