Question 1)

a) Determine Design Current I_b

Design Current (Three phase)

$$I_b = \frac{P}{\sqrt{3}\ x\ VL\ x\ cos\emptyset}$$

WHY NO P.F?

$$I_b = \frac{30\ kW}{1.732\ x\ 400\ x\ 1}\quad \frac{30{,}000W}{692.8}$$

I_b = **43.35 Amps** ✓

Technical data and types

Type code	TRIO-20.0-TL-OUTD	TRIO-27.6-TL-OUTD
Nominal output power	20000W	27600W
Maximum output power	22000W[1]	30000W[1]
Rated grid AC voltage	480V	

Can I apply diversity?

NO

OSG Table A2 Pg 137 – **PV not listed and almost impossible to determine due to atmospheric/weather conditions.**

b) Determine rating and type of overcurrent protective, consider additional protection if required.

Nominal Rating of Device **In**

(**Possible inrush current** to consider on startup?)

OSG Table 7.2.7 (ii) Pg 90

Select a BS EN 60898-1 **Type B**.

BS 7671 (2022) Table 41.3 Pg 68 / OSG Table B6 Pg 145

$I_n \geq I_b$ 45 ≥ 43.35 ✓

HOWEVER!

Remember what I said about checking either manufacturers data from the inverter, or to check if the OCPD is suitable for the load continually/continuous current?

Manufacturers data below to consider:

Maximum AC OCPD rating	40A	50A

- In addition, see adjacent image where a device has thermal damage from continuous current output from a solar PV inverter *(note: this was not an issue with the manufacturer – this was a device selection error!).*

In = **B50** ✓

Question 2)

d) Determine Installation number & Reference Method

Multicore armoured cable suspended in free air on a catenary wire.

BS7671 (2022) Table 4A2 Pg 435

Reference Method E or F (Installation number 35) ✓

TABLE 4A2 *(continued)*

Installation Method			Reference Method to be used to determine current-carrying capacity
Number	**Examples**	**Description**	
33		Single-core or multicore cables: - spaced more than 0.3 times the cable diameter from a wall	E, F or G[g]
34		Single-core or multicore cables: - on a ladder[c]	E or F
35		Single-core or multicore cable suspended from or incorporating a support wire or harness	E or F

e) Rating Factors to consider.

Temperature C_a= 1, however if you took it at 20 degrees it's **1.08 (not in BS7671 though).**

Ambient air temperature °C	Insulation	
	PVC	XLPE and EPR
10	1.22	1.15
15	1.17	1.12
20	1.12	1.08
25	1.06	1.04
30	1	1

Data/table taken from: [General method for cable sizing - Electrical Installation Guide (electrical-installation.org)]

BS 7671 (2022) Appendix 4 Table 4C1 Pg 443

Cg = 2x circuits in total – Item 1 - = 0.80

TABLE 4C1 – Rating factors for one circuit or one multicore cable or for a group of circuits, or a group of multicore cables, to be used with current-carrying capacities of Tables 4D1A to 4J4A

Item	Arrangement (cables touching)	Number of circuits or multicore cables												To be used with current-carrying capacities, Reference Method
		1	2	3	4	5	6	7	8	9	12	16	20	
1.	Bunched in air, on a surface, embedded or enclosed	1.00	0.80	0.70	0.65	0.60	0.57	0.54	0.52	0.50	0.45	0.41	0.38	A to F

***NO OTHER RATING FACTORS TO CONSIDER**

C_i: N/A
C_f: N/A
C_c: N/A
C_g: N/A

f) Determine CSA of cable required:

- **BS 7671 (2022)** Appendix 4 Pg 425

$$I_z = \frac{Ib}{Ca \; x \; Cg}$$

$$I_z = \frac{43.35}{1 \; x \; 0.80} = \mathbf{54.18\ A}$$

Or, if 20 degree value used at 1.08 for Ca

$$I_z = \frac{Ib}{Ca \; x \; Cg}$$

$$I_z = \frac{43.35}{1.08 \; x \; 0.80} = \mathbf{50.17\ A}$$

A cable needs to be selected that can carry at least **54.18 Amps.**

Q: Why has Ib and not In been used in the formula above!?

A: Solar PV inverters are <u>not</u> subject to overload; they are designed so that the generated module output power does not exceed the maximum output power of the inverter.

Question 3)

- **BS 7671 (2022)** Appendix 4, Table 4D4A, (column 5) Pg 454

10.0mm² conductor selected, which has an I_t **= 62 A**

$I_t \geq I_z$ (This gives compliance with **BS7671 (2022) Regulation 433.1.1**)

62 ≥ 54.18 ✓

TABLE 4D4A – Multicore armoured 70 °C thermoplastic insulated cables (COPPER CONDUCTORS)

Ambient temperature: 30 °C
Ground ambient temperature: 20 °C
Conductor operating temperature: 70 °C

CURRENT-CARRYING CAPACITY (amperes):

Conductor cross-sectional area	Reference Method C (clipped direct)		Reference Method E (in free air or on a perforated cable tray etc, horizontal or vertical)		Reference Method D (direct in ground or in ducting in ground, in or around buildings)	
	1 two-core cable, single-phase AC or DC	1 three- or four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or four-core cable, three-phase AC
1	2	3	4	5	6	7
(mm²)	(A)	(A)	(A)	(A)	(A)	(A)
1.5	21	18	22	19	22	18
2.5	28	25	31	26	29	24
4	38	33	41	35	37	30
6	49	42	53	45	46	38
10	67	58	72	62	60	50
16	89	77	97	83	78	64

Question 4)

c) **Calculate Volt Drop:** (based on the selection of 10.0mm²)

BS 7671 (2022) Appendix 4, Table 4D4B, Pg 455

Volt drop = $\frac{mV/A/m \ x \ Ib \ x \ Length}{1000}$

TABLE 4D4B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 70 °C

Conductor cross-sectional area	Two-core cable, DC	Two-core cable, single-phase AC	Three- or four-core cable, three-phase AC
1	2	3	4
(mm²)	(mV/A/m)	(mV/A/m)	(mV/A/m)
1.5	29	29	25
2.5	18	18	15
4	11	11	9.5
6	7.3	7.3	6.4
10	4.4	4.4	3.8
16	2.8	2.8	2.4

mV/A/m = BS 7671 (2022) Table 4D4B (column 4) Pg 455 = **3.8 mV/A/m**

Calculated volt drop = $\frac{3.8 \, x \, 43.35 \, x \, 83m}{1000}$ = 13.67 **V** ✓

PLUS the volt drop of 6V at PV DB 1
13.67 + 6 = 19.67V ✓

Max Volt drop is stated **BS 7671 (2022)** Table 4AB Pg 430.

For Power circuits **max volt drop** = 5% of Vl (400V) Max volt drop = $\frac{400 \, x \, 5}{100}$ = **20 V**

19.67V $\leq$ 20V ✓

Our calculated Volt drop is less than maximum allowed so is **acceptable.** ✓

6.4 Voltage drop in consumers' installations

The voltage drop between the origin of an installation and any load point should not be greater than the values in the table below expressed with respect to the value of the nominal voltage of the installation.

The calculated voltage drop should include any effects due to harmonic currents.

TABLE 4Ab – Voltage drop

	Lighting	Other uses
(i) Low voltage installations supplied directly from a public low voltage distribution system	3 %	5 %
(ii) Low voltage installation supplied from private LV supply (*)	6 %	8 %

(*) The voltage drop within each final circuit should not exceed the values given in (i).

Where the wiring systems of the installation are longer than 100 m, the voltage drops indicated above may be increased by 0.005 % per metre of the wiring system beyond 100 m, without this increase being greater than 0.5 %.

The voltage drop is determined from the demand of the current-using equipment, applying diversity factors where applicable, or from the value of the design current of the circuit.

***ALWAYS CHECK ANY SPECIAL LOCATIONS / ADDITIONAL REQUIREMENTS BEFORE DIVING IN!**

712.433.104 Protection of PV AC supply cable

When defining the rated current of the overcurrent protective device for the AC supply cable, the design current of the inverter shall be taken into account.

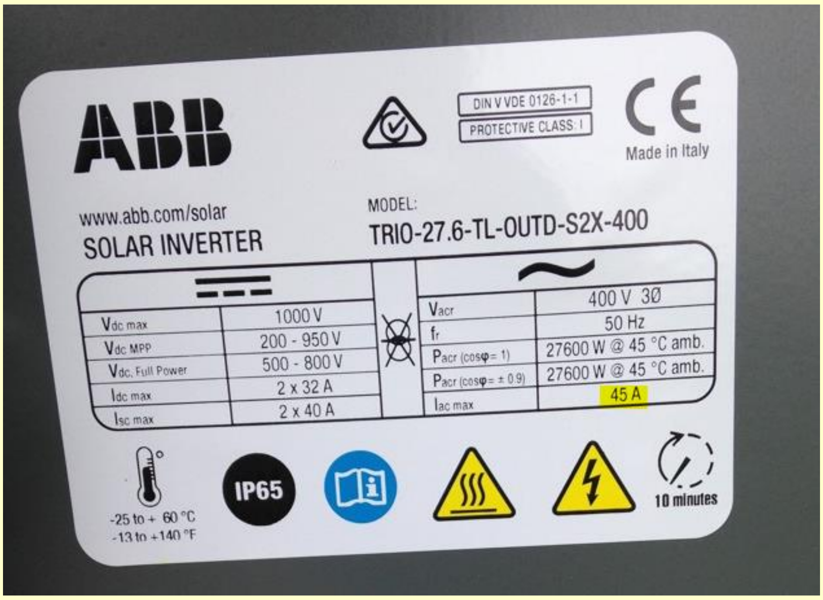
The inverter design current is either the maximum AC current given by the inverter manufacturer or, if not available, 1.1 times its rated AC current.

Output		
AC connection to the Grid	Three phase 3W or 4W+PE	
Rated output voltage (V_{acr})	400 Vac	
Output Voltage Range ($V_{acmin}...V_{acmax}$)	320...480 Vac (1)	
Rated Output Power (P_{acr})	20000 W	27600 W
Maximum Output Power (P_{acmax})	22000 W (3)	30000 W (4)
Maximum Output Current (I_{acmax})	33.0 A	45.0 A
Contribution to short-circuit current	35.0 A	46.0 A
Inrush current	Negligible	
Maximum fault current	<63Arms(100mS)	

000047EG

- 20 -

TRIO-20.0-27.6-TL-US_Product_Manual.pdf (abb.com)



GOTTA GO BACK TO Q4!

Original calculated volt drop = $\frac{3.8\ x\ 43.35\ x\ 83m}{1000}$ = 13.67 **V**

PLUS, the volt drop of 6V at PV DB 1

13.67 + 6 = 19.67V

NEW calculated volt drop = $\frac{3.8\ x\ 45\ x\ 83m}{1000}$ = 14.19 **V** ✓

PLUS, the volt drop of 6V at PV DB 1

14.19 + 6 = 20.19V

***Circuit does not comply as max VD is now exceeded!**

Let's try a 16mm then instead!

TABLE 4D4B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 70 °C

Conductor cross-sectional area	Two-core cable, DC	Two-core cable, single-phase AC	Three- or four-core cable, three-phase AC
1	2	3	4
(mm^2)	(mV/A/m)	(mV/A/m)	(mV/A/m)
1.5	29	29	25
2.5	18	18	15
4	11	11	9.5
6	7.3	7.3	6.4
10	4.4	4.4	3.8
16	2.8	2.8	2.4

mV/A/m = BS 7671 (2022) Table 4D4B (column 4) Pg 455 = **2.4 mV/A/m**

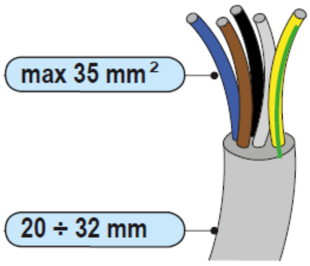
Volt drop = $\frac{mV/A/m\ x\ Ib\ x\ Length}{1000} = \frac{2.4\ x\ 45\ x\ 83m}{1000}$ = 8.96 V✓

PLUS, the volt drop of 6V at PV DB 1

8.96 + 6 = 14.96 V ✓

BUT DAVE, THE INVERTER MANUFACTURERS' RECOMMENDATIONS ON VOLTAGE DROP SHOULD BE TAKEN INTO ACCOUNT!

Characteristics and sizing of the line cable



The cross-section of the AC line conductor must be sized in order to prevent unwanted disconnections of the inverter from the grid due to high impedance of the line that connects the inverter to the power supply point; In fact, if the impedance is too high, it causes an increase in the AC voltage that, on reaching the limit set by the country of installation, causes the inverter to switch off.

The table shows the maximum length of the line conductor based on the cross-section of this conductor:

Cross-section of the line conductor (mm^2)	Maximum length of the line conductor (m)	
	TRIO-20.0-TL-OUTD	TRIO-27.6-TL-OUTD
10	42m	30m
16	70m	50m
25	100m	78m
35	138m	98m

The values are calculated in nominal power conditions, considering:
- loss of power along the line no greater than 1%
- use of copper cable, with HEPR rubber insulation and positioned in open air

A 1% VOLT-DROP MAY NOT BE PRACTICABLE IN MOST CASES AND MAY PROVE TO BE AN UNESSECARY EXPENSE!

IET'S C.O.P - Grid-connected Solar Photovoltaic Systems:

8.5 Cables

The cables used for the AC circuit that feeds the inverter(s) in a grid-connected PV system shall be selected and erected so as to comply with the requirements of BS 7671.

NOTE: De-rating factors will need to be considered – this will include consideration of the location (installation method) and grouping of cables.

The cables used for the AC circuit that feeds the inverter(s) shall be sized so as to minimize voltage drop and power loss. Inverter manufacturer's recommendations on voltage drop between the inverter and the origin of the installation should be taken into account, as exceeding these may lead to instability or excess harmonics.

Cables are sized to minimize voltage drop to ensure that the voltage at the inverter terminals is close to that at the mains connection point (the voltage at the inverter will always be higher than the mains connection point due to the voltage drop along the circuit). If the voltage difference is too large, the inverter may be prone to nuisance tripping at times where the grid voltage is high (while the grid voltage may be within statutory limits, the voltage seen at the inverter terminals may be above the trip point).

For the majority of domestic installations, a maximum voltage drop of 1 % (between the point of supply and the inverter) is recommended. However, for larger or more complex installations with long AC cable runs, a voltage drop above 1 % may be justified economically.

NOTE: Voltage drop requirements in Section 525 of BS 7671 relate only to the voltage drop between the origin of the installation, and loads (current-using equipment). These requirements, and the percentage voltage drops referred to in Appendix 4, Section 6.4, of BS 7671, are not relevant to solar PV inverter circuits, and exceed the recommendations of many inverter manufacturers.

BS 7671 DOES NOT GIVE ANY RECOMMENDATIONS / REQUIREMENTS FOR VOLT-DROP ON PV INSTALLATIONS - OTHER THAN 5% MAX AS USUAL

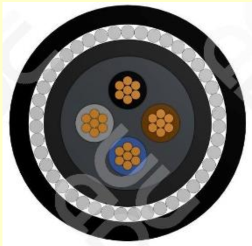
HOWEVER, G99 PARAMETERS WILL NEED TO BE TAKEN INTO ACCOUNT! (CLUE WAS THE IMAGE IN THE QUESTION – G99 RELAY)

What is G99?

G99 is a protection setting that PV systems (and others forms of generation over 16A) must comply with in order to be connected to the grid. This acts as a fail-safe when any over/undervoltages occur, of which protects the supply network and the PV system from potential faults.

G99 Calibration & Accuracy Tests	Phase	Setting	Time Delay	Lower Limit
Stage 1 Over Voltage	L1 – N L2 – N L3 – N	262.2V 230V system	1.0s	258.75
Stage 2 Over Voltage	L1 – N L2 – N L3 – N	273.7V 230V system	0.5s	270.25
Under Voltage	L1 – N L2 – N L3 – N	184.0V 230V system	2.5s	180.55

Question 5)



Determine the R_1+R_2 for this circuit at full operating temperature.

~~OSG Appendix I Pg 217~~

Line conductor = 10.00 mm²
CPC is the SWA armour = **?? mm²**

$$R_1 + R_2 = \frac{m\Omega/m \ x \ Multiplier \ x \ Length}{1000}$$

Values for mΩ/m for SWA: **ANIXSTER cable data = 3.1 (DRAKA link changed/unusable)**

Armour_Resistance_Values.pdf

Nominal Conductor Area	Max Resistance per Km of Cable @ 20°C					
	Copper Conductor (plain)	Steel Wire Armour Cables with Stranded Copper Conductors				
		Two Core 600/1000V	Three Core 600/1000V	Three Core 1900/3300V	Four Core 600/1000V	Five-core 600/1000V
mm²	ohms/km	ohms/km	ohms/km	ohms/km	ohms/km	ohms/km
1.5	12.1	10.2	9.5	-	8.8	8.2
2.5	7.41	8.8	8.2	-	7.7	6.8
4.0	4.61	7.9	7.5	-	6.8	6.2
6.0	3.08	7.0	6.7	-	4.3	3.9
10	1.83	6.0	4.0	-	3.7	3.4
16	1.15	3.7	3.5	1.9	3.1	3.2
25	0.727	3.7	2.5	1.7	2.3	1.8

Temperature multiplier values: **OSG** Table I3 Pg 220 = 1.28

(90°C Thermoplastic cable bunched with live conductors)

$$R_1 + R_2 = \frac{1.15+3.1 \ m\Omega/m \ x \ 1.28 \ x \ 83 \ m}{1000} = 0.45 \ \Omega$$

$R_1 + R_2 = 0.45 \ \Omega$ ✓

Question 6)

a) Determine Zs

$Z_s = Z_e + (R_1 + R_2)$

$Z_s = 33\ \Omega + 0.45\ \Omega =$ **33.45 Ω** ✓

b) Max Zs

BS 7671 (2022) Table 41.3 Pg 68 max Zs for 50A Type B BS EN 60898-1 MCB = **0.87 Ω** ✓

Our **calculated Zs value** is **more than the maximum allowed!**

TABLE 41.3 –
Maximum earth fault loop impedance (Z_s) for circuit-breakers with U_0 of 230 V, for operation giving compliance with the 0.4 s disconnection time of Regulation 411.3.2.2 and 5 s disconnection time of Regulation 411.3.2.3 (for RCBOs see also Regulation 411.4.204)

(a) Type B circuit-breakers to BS EN 60898 and the overcurrent characteristics of RCBOs to BS EN 61009-1

Rating (amperes)	3	6	10	16	20	25	32	40	50	63	80	100	125	I_n
Z_s (ohms)	14.57	7.28	4.37	2.73	2.19	1.75	1.37	1.09	0.87	0.69	0.55	0.44	0.35	230 x 0.95/(5I_n)

That's where an RCD device comes in; as this installation's earthing arrangement is a TT type supply, an RCD is utilised for **FAULT PROTECTION.**

A 300mA RCD should have been selected in accordance with section 705 (pg 260)

705.411.1 General

In circuits, whatever the type of earthing system, the following disconnection devices shall be provided:

(i) In final circuits supplying socket-outlets with rated current not exceeding 32 A, an RCD having the characteristics specified in Regulation 415.1.1

(ii) In final circuits supplying socket-outlets with rated current more than 32 A, an RCD with a rated residual operating current not exceeding 100 mA

(iii) In all other circuits, RCDs with a rated residual operating current not exceeding 300 mA.

To verify fault protection, the following regulation shall be met:

411.5.3 Where an RCD is used for fault protection, the following conditions shall be fulfilled:

(i) The disconnection time shall be that required by Regulation 411.3.2.2 or 411.3.2.4, and

(ii) $R_A \times I_{\Delta n} \leq 50$ V

where:

R_A is the sum of the resistances of the earth electrode and the protective conductor connecting it to the exposed-conductive-parts (in ohms)

$I_{\Delta n}$ is the rated residual operating current of the RCD.

The requirements of this regulation are met if the earth fault loop impedance of the circuit protected by the RCD meets the requirements of Table 41.5.

NOTE 1: Where selectivity between RCDs is necessary refer also to Regulation 536.4.1.4.

NOTE 2: Where R_A is not known, it may be replaced by Z_s.

TABLE 41.5 –
Maximum earth fault loop impedance (Z_s) for non-delayed and time delayed 'S' Type RCDs to BS EN 61008-1 and BS EN 61009-1 for U_0 of 230 V (see Regulation 411.5.3)

Rated residual operating current (mA)	Maximum earth fault loop impedance Z_s (ohms)
30	1667*
100	500*
300	167
500	100

Ra x I△n ≤ 50v

33 x 0.3 (300mA) = 9.9V.

9.9V is less than 50V and therefore complies with requirements for fault protection ✓

c) **Determine the Fault current.** (Ipf)

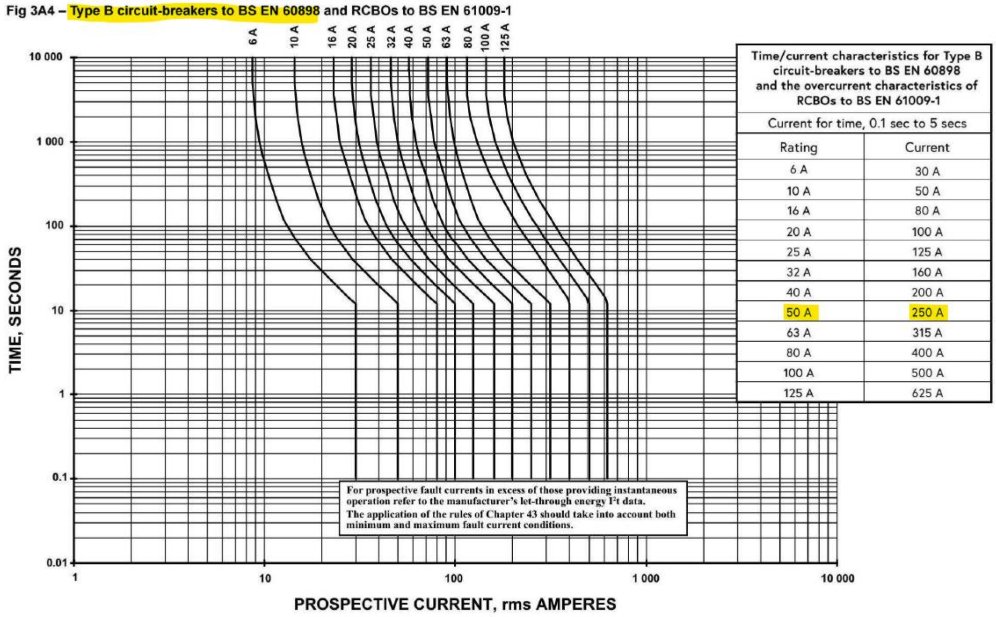
Prospective Earth Fault Current. **(PEFC)**

OSG Appendix I Pg 217

Ipf = $\frac{Uo}{Zs} = \frac{230V}{33.45\Omega}$ = **6.87 A** Ipf = **6.87 Amps**

A **minimum of 250 A** is required to disconnect the **32 A Type C MCB** between 0.1s to 5 seconds, **THERFORE THIS WILL NEVER DISCONNECT IN EARTH FAULT CONDITIONS!**

Fig 3A4 – Type B circuit-breakers to BS EN 60898 and RCBOs to BS EN 61009-1



What about Prospective Short Circuit Current - PSCC?

R1 + Rn values used = 16mm line + 16mm neutral (from anixster data sheet)

$$R_1 + Rn = \frac{1.15+1.15\ m\Omega/m\ x\ 83\ m}{1000} = 0.19\ \Omega$$

$R_1 + R_n = 0.19\ \Omega$

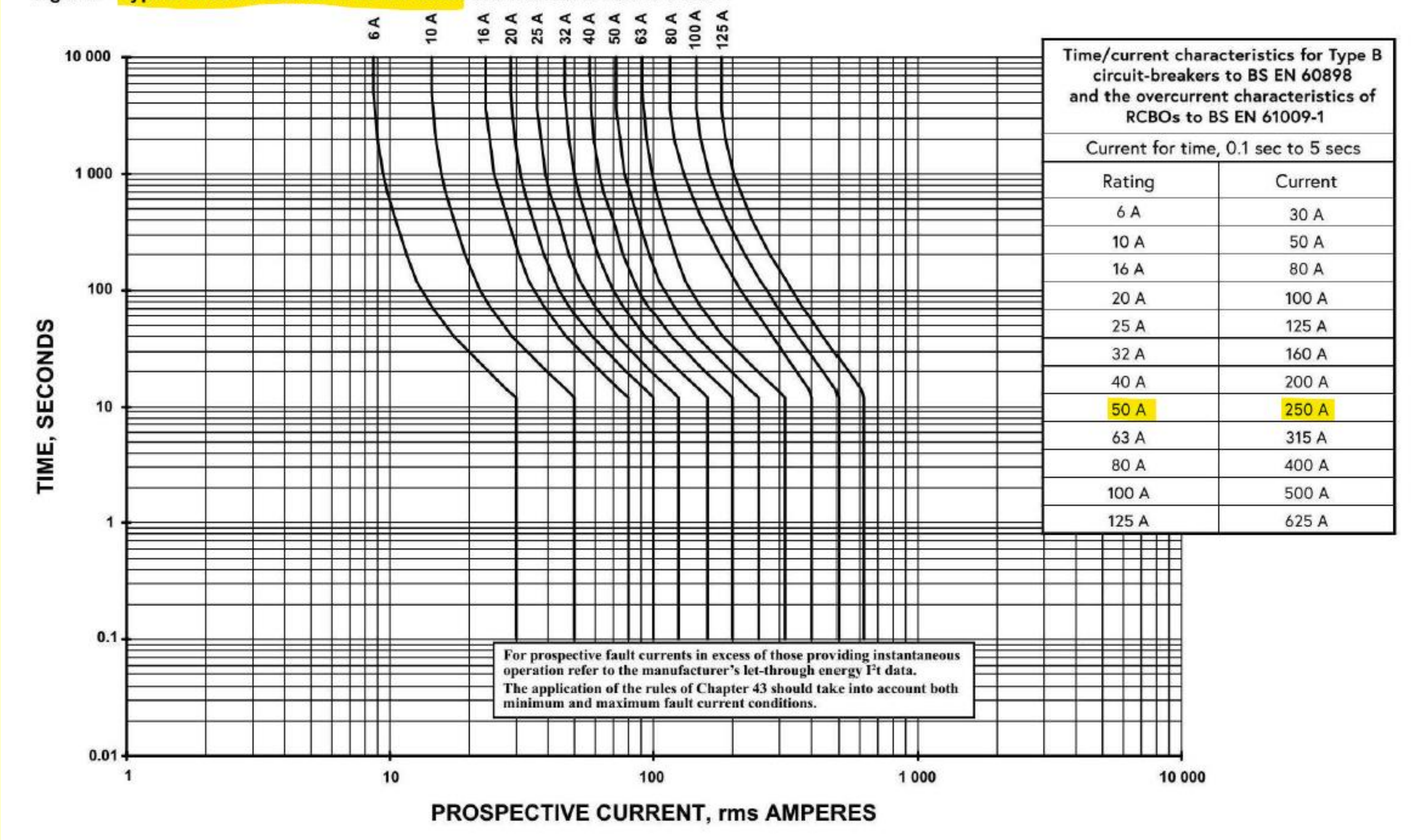
$$Ipf = \frac{Uo}{R} = \frac{230V}{0.19\Omega} = \mathbf{1210\ A}$$

PSCC = 1,210 Amps ✓

*REMINDER: A **minimum of 250 A** is required to disconnect the **50 A Type B MCB** between 0.1s to 5 seconds*

Therefore, 1210 A is more than enough current for the protective device to operate in the event of a short-circuit fault!

Fig 3A4 – Type B circuit-breakers to BS EN 60898 and RCBOs to BS EN 61009-1



Rating	Current
6 A	30 A
10 A	50 A
16 A	80 A
20 A	100 A
25 A	125 A
32 A	160 A
40 A	200 A
50 A	250 A
63 A	315 A
80 A	400 A
100 A	500 A
125 A	625 A

d) Determine the required CPC size – does the SWA comply?

16.0mm^2 Line and Neutral conductors + SWA as the CPC

BS 7671 (2022) Pg 199

Regulation 543.1.3 states to calculate minimum CSA of the CPC required:

$$S = \frac{\sqrt{I^2 t}}{k}$$

I = **6.87 A** (calculated in answer C above)

t = Table 3A5 Appendix 3 **BS 7671 (2022)** Pg 418 = **6.87A**

THIS IS NOT ENOUGH CURRENT TO OPERATE THE MCB UNDER FAULT CONDITIONS!

SO WHAT CAN WE DO INSTEAD?

Page 199 BS 7671

543 PROTECTIVE CONDUCTORS

543.1 Cross-sectional areas

543.1.1 The cross-sectional area of every protective conductor, other than a protective bonding conductor, shall be:

(i) calculated in accordance with Regulation 543.1.3, or

(ii) selected in accordance with Regulation 543.1.4.

Page 201 BS 7671

543.1.4 Where it is desired not to calculate the minimum cross-sectional area of a protective conductor in accordance with Regulation 543.1.3, the cross-sectional area may be determined in accordance with Table 54.7. Where the application of Table 54.7 produces a non-standard size, a conductor having a larger standard cross-sectional area shall be used.

TABLE 54.7 –
Minimum cross-sectional area of protective conductor in relation to the cross-sectional area of associated line conductor

Cross-sectional area of line conductor S	Minimum cross-sectional area of the corresponding protective conductor	
	If the protective conductor is of the same material as the line conductor	If the protective conductor is not of the same material as the line conductor
(mm^2)	(mm^2)	(mm^2)
$S \leq 16$	S	$\frac{k_1}{k_2} \times S$
$16 < S \leq 35$	16	$\frac{k_1}{k_2} \times 16$
$S > 35$	$\frac{S}{2}$	$\frac{k_1}{k_2} \times \frac{S}{2}$

where:

k_1 is the value of k for the line conductor, selected from Table 43.1 in Chapter 43 according to the materials of both conductor and insulation.

k_2 is the value of k for the protective conductor, selected from Tables 54.2 to 54.6, as applicable.

$$\frac{k_1}{k_2} \times S$$

We already know S = 16mm as that is our cable size.

*For **K1** we are referring to page 99 of BS 7671:*

TABLE 43.1 –
Values of k for common materials, for calculation of the effects of fault current for disconnection times up to 5 seconds

	Conductor insulation							
	Thermoplastic				**Thermosetting**		**Mineral insulated**	
	90 °C		70 °C		90 °C	60 °C	Thermoplastic sheath	Bare (unsheathed)
Conductor cross-sectional area	≤ 300 mm²	> 300 mm²	≤ 300 mm²	> 300 mm²				
Initial temperature	90 °C		70 °C		90 °C	60 °C	70 °C	105 °C
Final temperature	160 °C	140 °C	160 °C	140 °C	250 °C	200 °C	160 °C	250 °C
Copper conductor	k = 100	k = 86	k = 115	k = 103	k = 143	k = 141	k = 115	k = 135/115[a]
Aluminium conductor	k = 66	k = 57	k = 76	k = 68	k = 94	k = 93		
Tin soldered joints in copper conductors	k = 100	k = 86	k = 115	k = 103	k = 100	k = 122		

K1 = 143 ✓

*For **K2** we are referring to page 200 of BS 7671:*

TABLE 54.4 –
Values of k for the sheath or armour of a cable as the protective conductor

Material of conductor	Insulation material		
	70 °C thermoplastic	90 °C thermoplastic	90 °C thermosetting
Aluminium	93	85	85
Steel	51	46	46
Lead	26	23	23
Assumed initial temperature	60 °C	80 °C	80 °C
Final temperature	200 °C	200 °C	200 °C

K2 = 46 ✓

$$\frac{143}{46} \text{ X } 16 = \underline{49.74 \text{ mm}^2}$$ ✓

WHAT NEXT?......

Refer back to the cable manufacturers data:

Table 1: XPLE 90°C CABLES TO BS 5467 OR BS 6724 (COPPER CONDUCTORS) STEEL ARMOURING

csa of phase conductor (mm²)	Table 54G formula	Required csa armouring (mm²)	Actual csa of armouring (mm²)			
			2 core	3 core	4 core	5 core
1.5	k1S/k2	4.66	15	16	17	19
2.5	"	7.77	17	19	20	22
4	"	12.43	19	20	22	25
6	"	18.65	22	23	36	40
10	"	31.09	26	39	42	46
16	"	49.74	42	45	50	72
25	16 k1/k2	49.74	42	62	70	88
35	"	49.74	60	68	78	100
50	k1S/2k2	77.72	68	78	90	144
70	"	108.8	80	90	131	166
95	"	147.7	113	128	147	
120	"	186.5	125	141	206	
150	"	233.2	138	201	230	
185	"	287.6	191	220	255	
240	"	373.1	215	250	289	
300	"	466.3	235	269	319	
400	"	621.7	265	304	452	

k1=143 Table 43A copper conductor with 90°C insulation
k2=46 Table 54 D steel conductor with 90°C insulation

Area of SWA = 50mm² ✓ **THEREFORE, IT COMPLIES!**

7. Explain if the new circuit complies with the requirements of the current edition of BS 7671.

- **The 16mm 4-core cable selected can carry up to 83A, so is more than adequate (Ib 45A),**
- **The combined volt-drop at 14.96V complies (max 20V),**
- **Fault protection is afforded by the selection of a 300mA RCD device, with a calculated touch voltage of 9.9V,**
- **The overcurrent device will disconnect under short-circuit fault conditions within 0.1s,**
- **The 300mA RCD will disconnect in the event of an earth-fault,**
- **The SWA armouring as the CPC has been calculated and meets the requirements of 543.1.4**

8. State what *additional* considerations need to be made with regards to the installation being on a farm.

From page 260 of BS 7671…..

- 300mA RCD required at the origin for fault protection.
- The array may need to be suitably fenced-off due to the presence of livestock (External Influences) ***705.513:***

705.513 Accessibility

705.513.2 Accessibility by livestock

Electrical equipment generally shall be inaccessible to livestock. Equipment that is unavoidably accessible to livestock such as equipment for feeding and basins for watering, shall be adequately constructed and installed to avoid damage by, and to minimize the risk of injury to, livestock.

- The SWA cable supports may require suitably-spaced metal cable ties.

705.514.9.3 The following documentation shall be provided to the user of the installation:
(i) A plan indicating the location of all electrical equipment
(ii) The routing of all concealed cables
(iii) A single-line distribution diagram
(iv) An equipotential bonding diagram indicating locations of bonding connections.

- The SWA cable supports may require suitably-spaced metal cable ties.

PLUS, ANY OTHER ITEMS/RELEVANT REGULATIONS YOU HAVE SELECTED

9. State any other design considerations to be made to the solar PV system (AC only).

Section 712 of BS 7671 page 291….

- **712.433.104 – Protection of PV AC supply cable (covered earlier)**
- **712.511.103 – Assemblies and enclosures**
- **712.514.101 – Identification & notices**

712.531.3.5.1 Residual Current Devices

Where an RCD is used for protection of the PV AC supply circuit, the RCD shall be of Type B according to BS EN 62423 or BS EN 60947-2, unless:
(i) the inverter provides at least simple separation between the AC side and the DC side, or
(ii) the installation provides at least simple separation between the inverter and the RCD by means of separate windings of a transformer, or
(iii) the inverter does not require a Type B RCD as stated by the manufacturer of the inverter.

NOTE: In some circumstances other types of RCD may need to be selected based on inverter manufacturer's instructions. See also Regulation 531.3.3.

So, what does the manufacturer recommend?

consequently towards the photovoltaic modules). The leakage currents that can occur in the AC section between the draw/feed in point and the inverter are not detected and require an external protection device.
For protection of the AC line, on the basis of the aforesaid with regard to the differential protection integrated in ABB inverters, **it is not necessary to install a type B ground fault interrupter**.

In accordance with article 712.413.1.1.1.2 of Section 712 of IEC Standard 64-8/7, we hereby declare that, because of their construction, ABB inverters do not inject ground fault direct currents.

The use of an AC type circuit breaker with differential thermal magnetic protection with tripping current of 300 mA is advisable so as to prevent false tripping, due to the normal capacitive leakage current of photovoltaic modules.

10. If the installation method was changed to the new circuits being buried direct in the ground (instead of on a catenary wire), what would the requirements be?

Page 262 BS 7671

705.52 Selection and erection of equipment: Wiring systems

705.522 Selection and erection of wiring systems in relation to external influences

In locations accessible to, and enclosing, livestock, wiring systems shall be erected so that they are inaccessible to livestock or suitably protected against mechanical damage.

Overhead lines shall be insulated.

In areas of agricultural premises where vehicles and mobile agricultural machines are operated, the following methods of installation shall be applied:

(i) Cables shall be buried in the ground at a depth of at least 0.6 m with added mechanical protection

(ii) Cables in arable or cultivated ground shall be buried at a depth of at least 1 m

(iii) Self-supporting suspension cables shall be installed at a height of at least 6 m.

11. BONUS QUESTION: Investigate/determine if separate DC isolators are required for each of the DC strings (6x strings on Inverter 3 and 4x on Inverter 4).

Page 298 BS 7671

712.537.2 Isolation

712.537.2.101 To allow maintenance and replacement of the inverter, means of isolating the inverter from the DC side and the AC side shall be provided.

NOTE: Further requirements with regard to the isolation of a PV installation operating in parallel with the public supply system are given in Regulation 551.7.

712.537.2.2 Devices for isolation

712.537.2.2.101 A switch disconnector or a circuit-breaker suitable for isolation shall be provided on the DC side of the inverter.

Could this circuit be designed differently?