GENERAL CERTIFICATE OF EDUCATION BOARD

Technical and Vocational Education Examination

JUNE 2021 **ADVANCED LEVEL**

Specialty Name / Code	**Electrical Power Systems (EPS)**
Subject Title	**Design of Electrical Installations**
Subject Code N°	**7245**
Paper N°	**2**

Three hours

The paper has Two Sections (A and B) and constitutes 35% of the whole subject.

Section A has ONE COMPULSORY QUESTION, carrying **40 marks.**
Section B has FOUR QUESTIONS, each carrying **30 marks. ANSWER ANY TWO QUESTIONS**.

All sketches must be neat and clear.

You are allowed the use of Electronic calculators and mathematical sets.

No programmable calculators are allowed

You are also reminded of the necessity for good English and orderly presentation in your answers.

You are advised to read carefully through the question paper, before you begin your answers.

THEME : **ELECTRICAL INSTALLATIONOF A PRE-PROJECT OF A GOVERNMENT TECHNICAL HIGH SCHOOL.**

We want to realize a preliminary design of electrical installation of a newly created GTHS which will offer three trades for the beginning, consisting of three workshops, an administrative block and twelve (12) class rooms.

I. General Presentation.

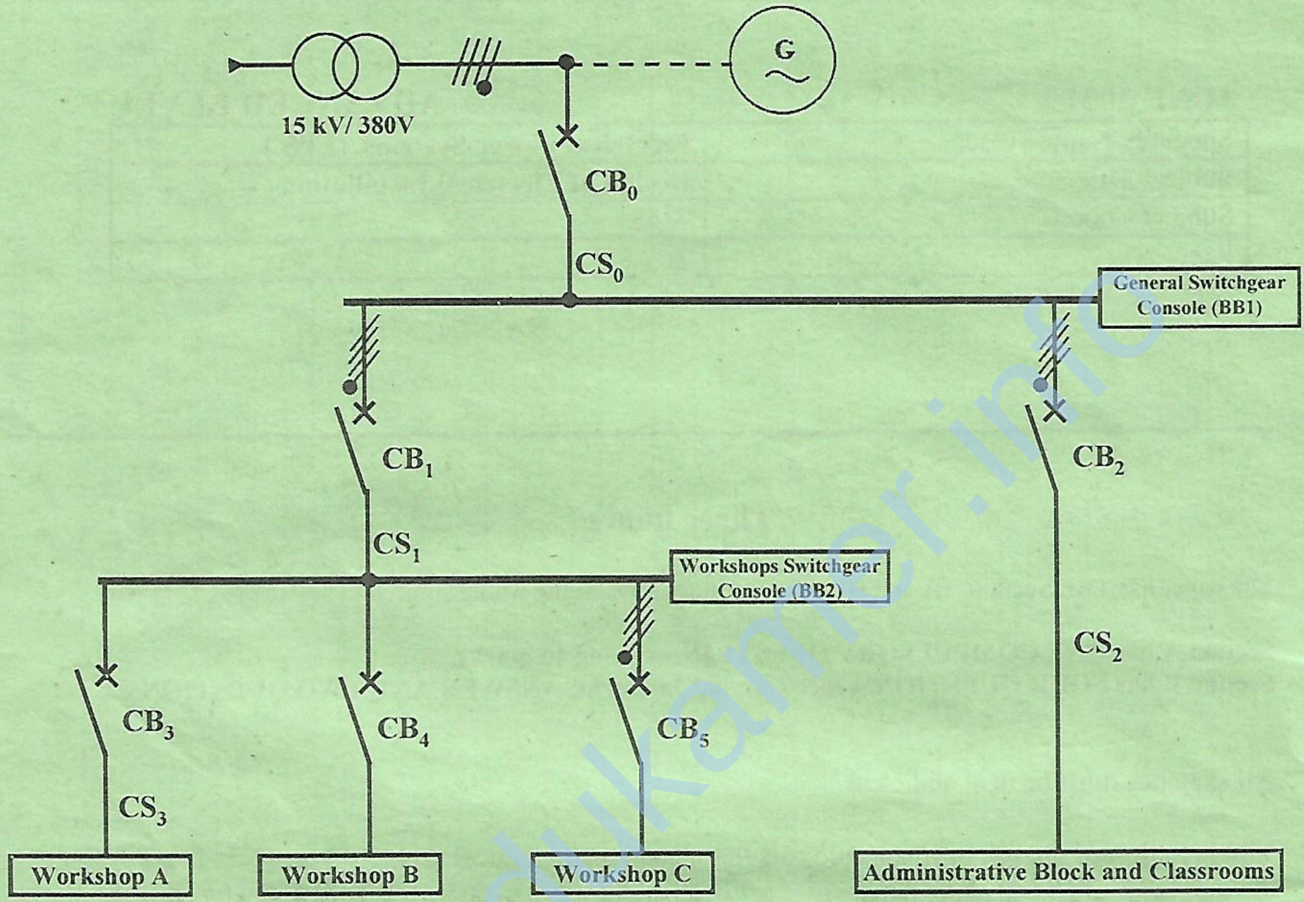


Figure 1: General Line Diagram of the Installation

II. Presentation of the Different Blocks.

Workshop A : Motor mechanics.

- Six (06) 1-ph motors: $P = 1.5kW$; $\cos\varphi = 0.70$; $\eta = 0.7$ each. $K_S = 0.75$; $K_U = 0.8$
- Eight (08) 1-ph socket-outlets of $2P + T$; 16A, 220V each.
- 30 fluorescent tubes of $40W$; $\cos\varphi = 0.86$.
- A 15KW compressor of $\cos\varphi = 0.85$; $\eta = 0.7$; $K_U = 0.8$
- A 15kW lift of $\cos\varphi = 0.75$; $\eta = 0.75$; $K_U = 0.8$

Workshop B: Mechanical manufacturing.

- Twenty (20) compensated fluorescent tubes of $58W$; $\cos\varphi = 0.86$ each.
- Ten (10) 1-ph socket-outlets of $2P + T$; 16A, 220V each.
- Four (04) 1-ph motors of : $P = 2.2kW$; $\cos\varphi = 0.80$; $\eta = 0.75$ $K_S = 0.75$; $K_U = 0.8$
- Three (03) 3-ph motors with power $P = 18.5kW$; $\cos\varphi = 0.90$; $\eta = 0.85$ each. $K_S = 0.75$; $K_U = 0.8$
- A 5kW milling machine of; $\cos\varphi = 0.86$; $\eta = 0.75$; $K_U = 0.8$
- Four (04) 5kW lathes machines, $\cos\varphi = 0.75$; $\eta = 0.85$ each. $K_S = 0.75$; $K_U = 0.8$

Workshop C: Carpentry

- A planer of $P = 10kW$; $\cos\varphi = 0.85$; $\eta = 0.9$; $K_U = 0.8$
- Nine (09) grinders of: $P = 1.6kW$; $\cos\varphi = 0.8$; $\eta = 0.9$ each. $K_S = 0.75$; $K_U = 0.8$
- A jointer of: $P = 7kW$; $\cos\varphi = 0.8$; $\eta = 0.9$; $K_U = 0.8$ = 7KW; cosφ= 0,80 ; η=0,9. KU= 0,8
- Eighteen (18) compensated fluorescent tubes in twin mounting of: $40W$; $\cos\varphi = 0.86$ each
- Two (02) sanders of: $P = 1.5kW$; $\cos\varphi = 0.80$; $\eta = 0.9$ each. $K_S = 0.75$; $K_U = 0.8$
- Two (02) circular saws of: $P = 3kW$; $\cos\varphi = 0.85$; $\eta = 0.75$ each. $K_S = 0.75$; $K_U = 0.8$

Administrative block and Class Room : $K_S = K_U = 1$

- Three (03) air conditioners of: $P = 2.5kW$; $\cos\varphi = 0.85$; $\eta = 0.75$ each.
- Twenty-one (21) lighting fittings carrying two fluorescent tubes of: $P = 10kW$; $\cos\varphi = 0.86$ each.
- Twelve (12) 1-ph socket-outlets of: $2P + T$; 16A,220V each.
- Two (02) refrigerators of $P = 2kW$; $\cos\varphi = 0.86$; $\eta = 0.75$ each.
- Eight (08) 1-ph socket-outlets of: $2P + T$; 16A,220V each, in each class room.
- Five (05) lighting fittings carrying two fluorescent tubes of: $P = 40kW$; $\cos\varphi = 0.86$ each, in each class room.

NB :

- The power lost in the ballast of each fluorescent tube is estimated at 25% of the rated power of the tube.
- The simultaneity factors to be applied to the whole administrative/classrooms and workshops switchgear console are 1 and 1.
- The ambient temperature of the entire structure is 40 °C.
- For sockets $K_S = 0.1 + \frac{0.9}{N}$ (with $N \leq 5$ number of sockets per circuit) and Ku = 1.

Section A. (COMPULSORY)

1. **Power demand and choice of transformer**
   a) Complete appendix 1by calculating the:
      i. active, reactive, apparent powers absorbed , the currents absorbed and power factors in each block. **(5 marks×4)**
      ii. active, reactive, apparent powers absorbed, the total current absorbed in the whole installation and the overall power factor the whole installation **(15 marks)**
   b) Using appendix 2 , choose the appropriate transformer specifying its characteristics, including (S_n, U_{sc}, U_{20}, I_n and I_{sc}) knowing that for reasons of extension of the installation, the power previously calculated as 248 KVA is to be increased by 40%. **(5 marks)**

Section B

2. **Power factor improvement.**
   The power factor of the overall installation is to be improved from 0.88 to 0.93. The overall installation active power is assumed to be 220 kW, the rated apparent power (S_n) of the transformer to be 400 kVA.
   a) Determine the corrected power Qc and the ratio of the correction $\frac{Q_C}{S_n}$ to be installed using appendix 3 and precise the type of compensation. **(15 marks)**
   b) Use appendix 4 to select:
      i. the type of network using appendix 4 for $\frac{G_h}{S_n} = 26\%$ **(8 marks)**
      ii. the type of compensation for $\frac{Q_C}{S_n} \leq 15\%$. **(7 marks)**

Turn Over

3. Selection of cables sizes.

Table 1 gives the characteristics of cables. All the cables are made of copper and placed together, under a temperature of **40 °C**.

Cable labelling	Length (m)	Current absorbed (A) (A)	Nature of the insulator	Laying method
CS_0	6	365	XLPE	Multi-core cable installed alone on perforated cable tray.
CS_1	35	320	XLPE	Multi-core cable placed on perforated tray with 2 other circuits.
CS_2	40	45	PVC	Single-core cable laid with 4 other circuits on un-perforated cable tray.
CS_3	40	130	XLPE	PVC multicore cable laid alone under spaces in buildings.

Table 1: Characteristics of cables

Cable labelling	Insulator	Letter of selection	Correction Factor ($k_1.k_2.k_3$)	Current Absorbed (A)	Current Corrected (A)	C.S.A. (mm^2)
CS_0						
CS_1						
CS_2						
CS_3						

Table 2

Determine, using the manufacturer documents of Appendix 5 and 6, the standard cross sectional area of the cables based on the characteristics provided, by filling in the table 2.

(30 marks)

4. Selection of circuit breakers.

a) Determine, using appendix 7,the length of cables in table 1 and the upstream I_{SC} of the chosen transformer of 14.2kA the downstream short-circuit currents at the following points:

i. **BB1** busbar; **S=185mm²** **(2.5 marks)**

ii. **BB2** busbar; **S=185mm²** **(2.5 marks)**

iii. Administrative block and Class Rooms. CS=25mm² **(2.5 marks)**

b) Choose the circuit breakers (**CB_1, CB_2, CB_3, CB_4** and **CB_5**) using the manufacturer documents of appendix 8a & 8b by filling table 3. **(22.5 marks)**

Labelling	Type (reference)	Calculated current (A)	Nominal Current (A)	Nominal Voltage (V)	Number of poles	Breaking Capacity(kA)
CB_1		350				
CB_2		61				
CB_3		127				
CB_4		130				
CB_5		61				

Table 3

5. Lighting pre-project

You are also entrusted with the study of the lighting project of the multi-purpose hall which is under construction in the complex, whose characteristics are as follows:

- Size of the multi-purpose hall: $50m \times 20m$; working height : 7.20 m ;
- Reflection factor of walls: Ceiling 50%, Wall 30%, Useful plan 30%;
- Average luminance level for general lighting: 300 lux ;
- Light sources: fluorescent mercury vapor lamp or high pressure sodium vapor lamp.

- Lighting fixture: a semi-intensive, bright, anodized aluminum direct reflector capable of using any of the selected sources; $\eta = 0.7$
- Easy maintenance, relatively low total installation cost, low dust level.
- Depreciation factor d=1,25.

According to the specifications above, and using appendix 9:

a. Determine the total luminous flux to be produced. **(10 marks)**

b. Determine the number of devices for each of the proposed sources. **(8 marks)**

c. Choose the most economical solution to determine the number of lamps to install and propose the plan of distribution of the lighting fittings by respecting the standard. **(12marks)**

Appendix 2 (Q1b)

TABLE OF CHARACTERISTICS OF HV/LV TRANSFORMERS.

MAXIMUM SHORT-CIRCUIT CURRENT FROM DOWNSTREAM OF A TRANSFORMER MV/LV

The values indicated in the table below correspond to a three-phase short-circuit bolted at the terminals of a MV/LV transformer connected to a network whose short-circuit power in MV is 500 MVA at 20 kV.

	Ratings of transformers in KVA													
	50	63	80	100	125	160	200	250	315	400	500	630	800	1000
220V														
I_n(A)	120	157	200	250	313	400	500	625	789	1000	1250	1575	2000	2500
I_{sc}(KA)	3.1	3.9	4.8	6.2	7.8	9.9	12.4	15.4	19.4	24.5	31.2	38.2	38.35	44.4
U_{sc}(%)	4	4	4	4	4	4	4	4	4	4	4	4		
Copper losses (kW)	1.1	1.1	1.1	1.8	1.8	2.4	2.85	3.25	3.9	4.81	5.95	6.95	12	13.9
380V														
I_n(A)	72	91	115	140	180	232	290	360	450	580	720	910	1155	1445
I_{sc}(KA)	1.8	2.3	2.9	3.7	4.5	5.7	7.14	8.9	11.2	14.2	17.6	22.1	24.8	27.8
U_{sc}(%)	4	4	4	4	4	4	4	4	4	4	4	4	4.5	5
Copper losses (kW)	1.1	1.1	1.1	1.8	1.8	2.4	2.85	3.25	3.9	4.81	5.5	6.95	10.2	12.1

APPENDIX 9 (Q5)

		Reflection Factors (%)													
Ceiling		70			50			30		70			50		0
Walls		50	30	10	50	30	10	30	10	50	30	10	50	30	0
Useful plan		10								30					
K	0.60	0.42	0.37	0.34	0.41	0.37	0.34	0.37	0.34	0.44	0.38	0.35	0.43	0.38	0.33
	0.80	0.48	0.44	0.41	0.48	0.44	0.41	0.43	0.41	0.51	0.46	0.42	0.50	0.45	0.39
	1.00	0.54	0.50	0.47	0.53	0.49	0.46	0.49	0.46	0.57	0.52	0.48	0.56	0.51	0.45
	1.25	0.58	0.55	0.52	0.57	0.54	0.51	0.53	0.51	0.63	0.58	0.54	0.61	0.56	0.50
	1.50	0.62	0.58	0.56	0.60	0.57	0.55	0.57	0.55	0.67	0.62	0.58	0.64	0.60	0.53
	2.00	0.66	0.64	0.61	0.65	0.63	0.61	0.62	0.60	0.73	0.66	0.65	0.70	0.66	0.59
	2.50	0.69	0.65	0.69	0.68	0.66	0.64	0.65	0.63	0.77	0.73	0.70	0.73	0.70	0.62

Table 4: Utilance Factors

	Mercury vapour lamp with fluorescent balloon	**High pressure sodium lamp**
Life Span	6000 hours	6000 hours
Power	400 W	400 W
Losses due to choke	22 W	22 W
Flux emitted by lamp	22.000 Lm	47.000 Lm
Cost of (fixture +	9000frs CFA	13500frs CFA

Table 5: Characteristics of lamps

APPENDIX 3 (Q2a)

REQUIRED REACTIVE POWER KVAR PER KW TO IMPROVE THE POWER FACTOR

The capacitors improve the power factor only on the part of the installation situated before their point of connection. they shall be placed near appliances consuming reactive energy

Before Improvement		Power of Capacitor in KVAR to be installed per KW of load to improve the power factor													
		tan ϕ	0.75	0.59	0.48	0.46	0.43	0.4	0.36	0.33	0.29	0.25	0.20	0.14	0
tan ϕ	cos ϕ	cos ϕ	0.80	0.86	0.9	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1
2.29	0.4		1.55	1.69	1.80	1.83	1.861	1.89	1.924	1.95	1.99	2.03	2.08	2.146	2.288
2.22	0.41		1.47	1.62	1.74	1.76	1.798	1.83	1.840	1.89	1.93	1.97	2.02	2.082	2.225
2.16	0.42		1.41	1.56	1.68	1.70	1.738	1.77	1.800	1.83	1.87	1.91	1.96	2.022	2.164
2.10	0.43		1.35	1.49	1.62	1.65	1.680	1.71	1.742	1.77	1.81	1.85	1.90	1.964	2.107
2.04	0.44		1.29	1.44	1.55	1.58	1.614	1.64	1.677	1.71	1.75	1.79	1.83	1.899	2.041
1.98	0.45		1.23	1.38	1.50	1.53	1.561	1.59	1.628	1.65	1.69	1.73	1.78	1.846	1.988
1.93	0.46		1.17	1.33	1.44	1.47	1.502	1.53	1.567	1.60	1.63	1.67	1.72	1.786	1.929
1.88	0.47		1.13	1.27	1.39	1.42	1.454	1.48	1.519	1.53	1.58	1.62	1.67	1.758	1.881
1.83	0.48		1.07	1.22	1.34	1.37	1.400	1.43	1.464	1.49	1.53	1.57	1.62	1.684	1.826
1.78	0.49		1.03	1.17	1.29	1.32	1.355	1.38	1.420	1.45	1.48	1.53	1.57	1.639	1.782
1.73	0.50		0.96	1.13	1.24	1.27	1.303	1.33	1.369	1.40	1.44	1.48	1.52	1.590	1.732
1.69	0.51		0.93	1.08	1.20	1.23	1.257	1.29	1.323	1.35	1.39	1.43	1.48	1.544	1.686
1.64	0.52		0.89	1.04	1.16	1.18	1.215	1.24	1.281	1.31	1.35	1.39	1.44	1.502	1.644
1.60	0.53		0.85	1.00	1.11	1.14	1.171	1.20	1.237	1.27	1.30	1.34	1.37	1.458	1.600
1.56	0.54		0.80	0.95	1.07	1.10	1.130	1.16	1.196	1.23	1.26	1.30	1.35	1.417	1.559
1.52	0.55		0.76	0.91	1.03	1.06	1.090	1.12	1.156	1.19	1.22	1.26	1.31	1.377	1.519
1.48	0.56		0.73	0.87	0.99	1.02	1.051	1.08	1.117	1.15	1.18	1.22	1.27	1.338	1.480
1.44	0.57		0.69	0.84	0.95	0.98	1.013	1.04	1.079	1.11	1.15	1.19	1.23	1.300	1.442
1.40	0.58		0.66	0.80	0.92	0.94	0.976	1.01	1.042	1.07	1.11	1.15	1.20	1.263	1.405
1.37	0.59		0.61	0.76	0.88	0.91	0.939	0.97	1.005	1.03	1.07	1.11	1.16	1.226	1.368
1.33	0.60		0.58	0.73	0.84	0.87	0.905	0.93	0.971	1.00	1.04	1.08	1.13	1.192	1.334
1.30	0.61		0.54	0.69	0.81	0.84	0.870	0.90	0.936	0.97	1.00	1.04	1.09	1.157	1.299
1.27	0.62		0.51	0.66	0.78	0.80	0.838	0.87	0.902	0.93	0.97	1.01	1.06	1.123	1.265
1.23	0.63		0.48	0.63	0.74	0.77	0.804	0.83	0.870	0.90	0.94	0.98	1.03	1.091	1.233
1.20	0.64		0.45	0.60	0.71	0.74	0.771	0.80	0.837	0.87	0.90	0.94	0.99	1.058	1.200
1.17	0.65		0.41	0.56	0.68	0.71	0.740	0.77	0.806	0.84	0.87	0.91	0.96	1.007	1.169
1.14	0.66		0.38	0.53	0.65	0.68	0.709	0.74	0.775	0.80	0.84	0.88	0.93	0.996	1.138
1.11	0.67		0.35	0.50	0.62	0.65	0.679	0.71	0.745	0.77	0.81	0.85	0.90	0.966	1.108
1.08	0.68		0.32	0.47	0.59	0.62	0.650	0.68	0.716	0.75	0.78	0.82	0.87	0.937	1.079
1.05	0.69		0.29	0.44	0.56	0.59	0.620	0.65	0.686	0.72	0.75	0.79	0.84	0.907	1.049
1.02	0.70		0.27	0.42	0.53	0.56	0.591	0.62	0.657	0.69	0.72	0.76	0.81	0.878	1.020
0.99	0.71		0.24	0.39	0.50	0.53	0.563	0.59	0.629	0.66	0.70	0.74	0.78	0.850	0.992
0.96	0.72		0.21	0.36	0.47	0.50	0.534	0.56	0.600	0.63	0.67	0.71	0.75	0.821	0.963
0.94	0.73		0.18	0.33	0.45	0.48	0.507	0.54	0.573	0.60	0.64	0.68	0.72	0.794	0.936
0.91	0.74		0.15	0.30	0.42	0.45	0.480	0.51	0.546	0.58	0.61	0.65	0.70	0.767	0.909
0.88	0.75		0.13	0.36	0.39	0.42	0.453	0.48	0.519	0.55	0.59	0.63	0.67	0.740	0.882
0.86	0.76		0.10	0.33	0.37	0.39	0.426	0.46	0.492	0.52	0.56	0.60	0.65	0.713	0.855
0.83	0.77		0.07	0.30	0.34	0.37	0.400	0.43	0.466	0.50	0.53	0.57	0.62	0.687	0.829
0.80	0.78		0.05	0.20	0.31	0.34	0.374	0.40	0.440	0.47	0.51	0.55	0.59	0.661	0.803
0.78	0.79		0.02	0.17	0.29	0.32	0.347	0.38	0.413	0.44	0.48	0.52	0.56	0.634	0.776
0.75	0.80			0.15	0.26	0.29	0.321	0.35	0.387	0.42	0.45	0.49	0.54	0.608	0.750
0.72	0.81			0.12	0.24	0.26	0.295	0.32	0.361	0.39	0.43	0.47	0.51	0.582	0.724
0.70	0.82			0.09	0.21	0.24	0.269	0.30	0.335	0.36	0.40	0.44	0.48	0.556	0.698
0.67	0.83			0.07	0.18	0.21	0.243	0.27	0.309	0.34	0.38	0.42	0.46	0.530	0.672
0.65	0.84			0.04	0.16	0.19	0.217	0.25	0.283	0.31	0.35	0.39	0.43	0.504	0.645
0.62	0.85			0.02	0.13	0.16	0.191	0.22	0.257	0.29	0.32	0.36	0.41	0.478	0.620
0.59	0.86				0.10	0.14	0.167	0.19	0.230	0.26	0.30	0.34	0.39	0.450	0.593
0.57	0.87				0.08	0.11	0.141	0.17	0.204	0.23	0.27	0.31	0.36	0.424	0.567
0.54	0.88				0.05	0.08	0.112	0.14	0.175	0.20	0.24	0.28	0.33	0.395	0.538
0.51	0.89				0.02	0.05	0.086	0.11	0.149	0.18	0.23	0.26	0.30	0.369	0.512
0.48	0.90					0.03	0.058	0.08	0.121	0.15	0.19	0.23	0.28	0.341	0.484

Choice of the mode of reactive energy compensation:Global-Partial-Individual.

Three modes of compensations in function of the location of equipment:

- The global compensation is case 1.
- The partial compensation is case 2.
- The individual compensation is case 3.

Choice of the type of compensation: Fixed or Automatic.

The ratio **Qc/Sn** guides in the choice between a fixe compensation equipment or an automatic compensation equipment in the cases of global or partial compensations.

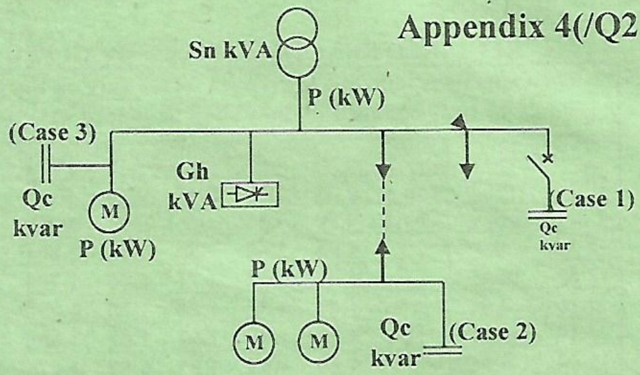
- **Qc/Sn ≤ 15%** : fixed compensation.
- **Qc/Sn > 15%**: automatic compensation.

Selection of the type of reactive energy compensation equipment.

There are three type of compensation equipment based on the level of the harmonic pollution of the network:

- If **Gh/Sn ≤15%**, the equipment to use is the **standard** type.
- If **15% < Gh/Sn ≤ 25%**, the equipment to use is type **H.**
- If **25% < Gh/Sn ≤ 60%**, the equipment to use is type **SAH.**

Appendix 4(/Q2b)



Sn: Apparent power of the transformer.
Gh : Apparent power of equipment producing harmonic.
Qc: Power of the compensation equipment.

Q/S ≤ 15% Fixe improvement		Nature of the Network	Q/S > 15% Automatic improvement	
Standard type		**Standard network**	**Standard type**	
Without protection circuit breaker	With protection circuit breaker		Rectimat	Secomat
Varplus M 10 to 100 kVAR High power Varplus 100 to 140 kVAR	Rectibloc 10 to 120 kVAR	**Gh/Sn ≤ 15%**	22.5 to 720 kVAR	22.5 to 180 kVAR Compensationequipment Prisma 150 to 720 kVAR
TypeH		**Pollutednetwork**	**TypeH**	
Without protection circuit breaker	With protection circuit breaker		Rectimat	Secomat
Varplus M 10 to 100 kVAR High power Varplus 100 to 140 kVAR	Rectibloc 10 to 120 kVAR	**15% <Gh/Sn ≤25%**	22.5 to 720 kVAR	25 to 120 kVAR Compensation equipment Prisma 160 to 540 kVAR
TypeSAH		**Highly Pollutednetwork**	**TypeSAH**	
Without protection circuit breaker	With protection circuit breaker			Secomat and Prisma Cabinets
High power Varplus 12.5 to 150 kVAR	Rectibloc 25 to 150 kVAR	**25% <Gh/Sn ≤60 %**		25 to 200 kVAR Compensation equipment Prisma 150 to 600 kVAR

Appendix 5/ Q3

Go on to the next page

APPENDIX 5 (Q3)

REFERENCE METHOD		
Type of cables	**Laying Method**	**Reference method**
Single or multi-core cables	In visible or embedded conduits and chutes In spaces in buildings, In gutters, mouldings, plinths and frame-linings	B
	Directly on the walls or on the ceilings On unperforated cable paths or trays	C
Multi-core cables	On corbels, ladder supports and perforated paths Directly on the walls, Suspended cables	E
Multi-core cables	On corbels, ladder supports and perforated paths Directly on the walls, Suspended cables	F

CORRECTION FACTOR K1		
Reference method	**Cases of installation**	**K1**
B	Cables embedded directly in a thermal insulated material	**0.70**
	Conduits embedded directly in a thermal insulated material	**0.77**
	Multi-core cables	**0.90**
	Spaces in buildings and gutters	**0.95**
C	Directly fixed on the ceiling	**0.95**
B, C , E, F	Other cases	**1**

CORRECTION FACTOR K2													
Reference method	**Arrangement of joint cables**	**Correction Factor K2** **Number of circuits or multi-core cables**											
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**12**	**16**	**20**
B,C	Embedded inside the walls	1.00	0.80	0.70	0.65	0.60	0.57	0.54	0.52	0.50	0.45	0.41	0.38
C	Single layer on the walls, on the floors or on Unperforated trays	1.00	0.85	0.79	0.75	0.73	0.72	0.72	0.71	0.70	0.70		
	Single layer fixed directly under ceiling	0.95	0.81	0.72	0.68	0.66	0.64	0.63	0.62	0.61	0.61		
E,F	Single layer on perforated horizontal trays or on vertical trays	1.00	0.88	0.82	0.77	0.75	0.73	0.73	0.72	0.72	0.72		
	Single layer on cable ladder supports or cloats	1.00	0.87	0.82	0.80	0.80	0.79	0.79	0.78	0.78	0.78		

CORRECTION FACTOR K3			
Ambient Temperatue (°C)	**Insulator**		
	Rubber	**PVC**	**XLPE**
10	1.29	1.22	1.15
15	1.22	1.17	1.12
20	1.15	1.12	1.08
25	1.07	1.07	1.04
30	1.00	1.00	1.00
35	0.93	0.93	0.96
40	0.82	0.87	0.91
45	0.71	0.79	0.87
50	0.58	0.71	0.82

APPENDIX 6 (/Q3)

RECOMMENDED SIMPLIFIED APPROACH FOR CABLE SIZING

Reference methods	Number of loaded conductors and type of insulation											
A1		2 PVC	3 PVC		3 XLPE	2 XLPE						
A2	3 PVC	2 PVC		3 XLPE	2 XLPE							
B1				3 PVC	2 PVC		3 XLPE		2 XLPE			
B2			3 PVC	2 PVC		3 XLPE	2 XLPE					
C					3 PVC		2 PVC	3 XLPE		2 XLPE		
E						3 PVC		2 PVC	3 XLPE		2 XLPE	
F							3 PVC		2 PVC	3 XLPE		2 XLPE
1	2	3	4	5	6	7	8	9	10	11	12	13
Size (mm²) Copper												
1.5	13	13.5	14.5	15.5	17	18.5	13.5	22	23	24	26	
2.5	17.5	18	19.5	21	23	25	27	30	31	33	36	
4	23	24	26	28	31	34	36	40	42	45	49	
6	29	31	34	36	40	43	46	51	54	58	63	
10	39	42	46	50	54	60	63	70	75	80	86	
16	41	43	48	53	58	61	66	73	77	84	91	
25	68	73	80	89	95	101	110	119	127	135	149	161
35				110	117	126	137	147	158	169	185	200
50				134	141	153	167	179	192	207	225	242
70				171	179	196	213	229	246	268	289	310
95				207	216	238	258	278	298	328	352	377
120				239	249	276	299	322	346	383	410	437
150					285	318	344	371	395	441	473	504
185					324	362	392	424	450	506	542	575
240					380	424	461	500	538	599	641	679
Size (mm²) Aluminium												
2.5	13.5	14	15	16.5	18.5	19.5	21	23	24	26	28	
4	17.5	18.5	20	22	25	26	28	31	32	35	38	
6	23	24	26	28	32	33	36	39	42	45	49	
10	31	32	36	39	44	46	49	54	58	62	67	
16	41	43	48	53	58	61	66	73	77	84	91	
25	53	57	63	70	73	78	83	90	97	101	108	121
35				86	90	96	103	112	120	126	135	150
50				104	110	117	125	136	146	154	164	184
70				133	140	150	160	174	187	198	211	237
95				161	170	183	195	211	227	241	257	289
120				186	197	212	226	245	263	280	300	337
150					226	245	261	283	304	324	346	389
185					256	280	298	323	347	371	397	447

Appendix 7 (/Q4)

DETERMINATION OF SHORT CIRCUIT CURRENT (Isc)

The table below shows Isc at a point downstream, as a function of a known upstream fault-current value and the length and c.s.a. of the intervening conductors, in a 220/380V 3-phase system.

Copper 230 V / 400 V

c.s.a. of phase conductors (mm²)	Length of circuit (in metres)																					
1.5														1.3	1.8	2.6	3.6	5.2	7.3	10.3	14.6	21
2.5												1.1	1.5	2.1	3.0	4.3	6.1	8.6	12.1	17.2	24	34
4											1.2	1.7	2.4	3.4	4.9	6.9	9.7	13.7	19.4	27	39	55
6											1.8	2.6	3.6	5.2	7.3	10.3	14.6	21	29	41	58	82
10										2.2	3.0	4.3	6.1	8.6	12.2	17.2	24	34	49	69	97	137
16								1.7	2.4	3.4	4.9	6.9	9.7	13.8	19.4	27	39	55	78	110	155	220
25						1.3	1.9	2.7	3.8	5.4	7.6	10.8	15.2	21	30	43	61	86	121	172	243	343
35						1.9	2.7	3.8	5.3	7.5	10.6	15.1	21	30	43	60	85	120	170	240	340	480
47.5					1.8	2.6	3.6	5.1	7.2	10.2	14.4	20	29	41	58	82	115	163	231	326	461	
70					2.7	3.8	5.3	7.5	10.7	15.1	21	30	43	60	85	120	170	240	340			
95				2.6	3.6	5.1	7.2	10.2	14.5	20	29	41	58	82	115	163	231	326	461			
120		1.6	2.3	3.2	4.6	6.5	9.1	12.9	18.3	26	37	52.	73	103	146	206	291	412				
150	1.2	1.8	2.5	3.5	5.0	7.0	9.9	14.0	19.8	28	40	56	79	112	159	224	317	448				
185	1.5	2.1	2.9	4.2	5.9	8.3	11.7	16.6	23	33	47	66	94	133	187	265	374	529				
240	1.8	2.6	3.7	5.2	7.3	10.3	14.6	21	29	41	58	83	117	165	233	330	466	659				
300	2.2	3.1	4.4	6.2	8.8	12.4	17.6	25	35	50	70	99	140	198	280	396	561					
2x120	2.3	3.2	4.6	6.5	9.1	12.9	18.3	26	37	52	73	103	146	206	292	412	583					
2x150	2.5	3.5	5.0	7.0	9.9	14.0	20	28	40	56	79	112	159	224	317	448	634					
2x185	2.9	4.2	5.9	8.3	11.7	16.6	23	33	47	66	94	133	187	265	375	530	749					
553x120	3.4	4.9	6.9	9.7	13.7	19.4	27	39	55	77	110	155	219	309	438	619						
3x150	3.7	5.3	7.5	10.5	14.9	21	30	42	60	84	119	168	238	336	476	672						
3x185	4.4	6.2	8.8	12.5	17.6	25	35	50	70	100	141	199	281	398	562							
Isc upstream (in kA)	**Isc downstream (in kA)**																					
100	93	90	87	82	77	70	62	54	45	37	29	22	17.0	12.6	9.3	6.7	4.9	3.5	2.5	1.8	1.3	0.9
90	84	82	79	75	71	65	58	51	43	35	28	22	16.7	12.5	9.2	6.7	4.8	3.5	2.5	1.8	1.3	0.9
80	75	74	71	68	64	59	54	47	40	34	27	21	16.3	12.2	9.1	6.6	4.8	3.5	2.5	1.8	1.3	0.9
70	66	65	63	61	58	54	49	44	38	32	26	20	15.8	12.0	8.9	6.6	4.8	3.4	2.5	1.8	1.3	0.9
60	57	56	55	53	51	48	44	39	35	29	24	20	15.2	11.6	8.7	6.5	4.7	3.4	2.5	1.8	1.3	0.9
50	48	47	46	45	43	41	38	35	31	27	22	18.3	14.5	11.2	8.5	6.3	4.6	3.4	2.4	1.7	1.2	0.9
40	39	38	38	37	36	34	32	30	27	24	20	16.8	13.5	10.6	8.1	6.1	4.5	3.3	2.4	1.7	1.2	0.9
35	34	34	33	33	32	30	29	27	24	22	18.8	15.8	12.9	10.2	7.9	6.0	4.5	3.3	2.4	1.7	1.2	0.9
30	29	29	29	28	27	27	25	24	22	20	17.3	14.7	12.2	9.8	7.6	5.8	4.4	3.2	2.4	1.7	1.2	0.9
25	25	24	24	24	23	23	22	21	19.1	17.4	15.5	13.4	11.2	9.2	7.3	5.6	4.2	3.2	2.3	1.7	1.2	0.9
20	20	20	19.4	19.2	18.8	18.4	17.8	17.0	16.1	14.9	13.4	11.8	10.1	8.4	6.8	5.3	4.1	3.1	2.3	1.7	1.2	0.9
15	14.8	14.8	14.7	14.5	14.3	14.1	13.7	13.3	12.7	11.9	11.0	9.9	8.7	7.4	6.1	4.9	3.8	2.9	2.2	1.6	1.2	0.9
10	9.9	9.9	9.8	9.8	9.7	9.6	9.4	9.2	8.9	8.5	8.0	7.4	6.7	5.9	5.1	4.2	3.4	2.7	2.0	1.5	1.1	0.8
7	7.0	6.9	6.9	6.9	6.9	6.8	6.7	6.6	6.4	6.2	6.0	5.6	5.2	4.7	4.2	3.6	3.0	2.4	1.9	1.4	1.1	0.8
5	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.8	4.7	4.6	4.5	4.3	4.0	3.7	3.4	3.0	2.5	2.1	1.7	1.3	1.0	0.8
4	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.8	3.7	3.6	3.5	3.3	3.1	2.9	2.6	2.2	1.9	1.6	1.2	1.0	0.7
3	3.0	3.0	3.0	3.0	3.0	3.0	2.9	2.9	2.9	2.9	2.8	2.7	2.6	2.5	2.3	2.1	1.9	1.6	1.4	1.1	0.9	0.7
2	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.9	1.9	1.9	1.8	1.8	1.7	1.6	1.4	1.3	1.1	1.0	0.8	0.6
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.8	0.7	0.6	0.6	0.5

Aluminium 230 V / 400 V

c.s.a. of phase conductors (mm²)	Length of circuit (in metres)																					
2.5														1.4	1.9	2.7	3.8	5.4	7.6	10.8	15.3	22
4												1.1	1.5	2.2	3.1	4.3	6.1	8.6	12.2	17.3	24	35
6												1.6	2.3	3.2	4.6	6.5	9.2	13.0	18.3	26	37	52
10											1.9	2.7	3.8	5.4	7.7	10.8	15.3	22	31	43	61	86
16										2.2	3.1	4.3	6.1	8.7	12.2	17.3	24	35	49	69	98	138
25								1.7	2.4	3.4	4.8	6.8	9.6	13.5	19.1	27	38	54	76	108	153	216
35							1.7	2.4	3.4	4.7	6.7	9.5	13.4	18.9	27	38	54	76	107	151	214	302
47.5						1.6	2.3	3.2	4.6	6.4	9.1	12.9	18.2	26	36	51	73	103	145	205	290	410
70						2.4	3.4	4.7	6.7	9.5	13.4	19.0	27	38	54	76	107	151	214	303	428	
95					2.3	3.2	4.6	6.4	9.1	12.9	18.2	26	36	51	73	103	145	205	290	411		
120					2.9	4.1	5.8	8.1	11.5	16.3	23	32	46	65	92	130	184	259	367			
150					3.1	4.4	6.3	8.8	12.5	17.7	25	35	50	71	100	141	199	282	399			
185				2.6	3.7	5.2	7.4	10.4	14.8	21	30	42	59	83	118	167	236	333	471			
240	1.2	1.6	2.3	3.3	4.6	6.5	9.2	13.0	18.4	26	37	52	73	104	147	208	294	415				
300	1.4	2.0	2.8	3.9	5.5	7.8	11.1	15.6	22	31	44	62	88	125	177	250	353	499				
2x120	1.4	2.0	2.9	4.1	5.8	8.1	11.5	16.3	23	33	46	65	92	130	184	260	367	519				
2x150	1.6	2.2	3.1	4.4	6.3	8.8	12.5	17.7	25	35	50	71	100	141	200	282	399					
2x185	1.9	2.6	3.7	5.2	7.4	10.5	14.8	21	30	42	59	83	118	167	236	334	472					
2x240	2.3	3.3	4.6	6.5	9.2	13.0	18.4	26	37	52	74	104	147	208	294	415	587					
3x120	2.2	3.1	4.3	6.1	8.6	12.2	17.3	24	34	49	69	97	138	195	275	389	551					
3x150	2.3	3.3	4.7	6.6	9.4	13.3	18.8	27	37	53	75	106	150	212	299	423	598					
3x185	2.8	3.9	5.5	7.8	11.1	15.7	22	31	44	63	89	125	177	250	354	500	707					
3x240	3.5	4.9	6.9	9.8	13.8	19.5	28	39	55	78	110	156	220	312	441	623						

Note: for a 3-phase system having 230 V between phases, divide the above lengths by $\sqrt{3}$

APPENDIX 8a (Q4b)

Selection of Multi 9 circuit breakers

Type of circuit breakers			TC16	TC16P	DPN(1)	DPN N	C32H DC	Reflex XC40	C60a	C60N	C60H	C60L ≤25A	C60L 32-40A	C60L 50- 63A	NC100H	NC6100LH
Ratedcurrent I_r (A)			16 at 30°C	16 at 30°C	40 at 30°C	40 at 30°C	40 at 30°C	38 at 20°C	40 at 30°C	63 at 30°C	63 at40°C	25 at 40°C	40 at 40°C	63 at 40°C	100 at 40°C	63at 40°C
Rated voltage U_r (V)	ac 50/60 Hz		240	240	240	240	Special Direct Current	440	440	440	440	440	440	440	440	440
	dc				60	60		250	250	250	250	250	250	250	250	250
Insulation voltage U_i (V)			500	500	500	500			500	500	500	500	500	500	500	500
Maximum withstand (kV) Uimp rated voltage			6	6	4	4	6	6	6	6	6	6	6	6	6	6
number of poles			1-1 + N	1-1 + N	1 + N	1 + N		2--3-4	1 2--3-4	1 2--3-4	1 2--3-4	1 2--3-4	1 2--3-4	1 2--3-4	1 2--3-4	1 2--3-4
Breakingcapacity																
NF C61410 EN 60898 (A eff.)	Icn	230V	3000	3000	4500	6000			3000 3000	6000 6000	10000 10000					
		400V							3000 3000	6000 6000	10000					
	Ics	230V/400V							3000 3000	6000 6000	7500 7500					
NF C63120 CEI 947.2 (kA eff.)	Icu	130V							10	20		50	50	50		100
		240V	4,5	4,5	6	7,5			5 10	10 20	15 30	25 50	20 40	15 30	20	40 80
		415V			2 (400V)	2 (400V)						6 25	5 20	4 15	4 10	10 40
		440V										20	15	10	6	30
	Ics															

Selection of NS Compact circuit breakers

APPENDIX 8b (Q4b)

Type of circuit breakers			NS80	NS125E	NSA160	NS100			NS160			NS250			NS400	
number of poles			3	3,4	3,4	2,3,4			2,3,4			2,3,4			,3,4	
Electrical characteristics according to CEI947-2 and EN60947-2																
Rated current I_r (A) at 40°C			80	125	160	100			160			250			150/250	400
Insulation voltage U_i (V)			750	750	500	750			750			750			750	750
Maximum withstand (kV) Uimp rated voltage			8	8	8	8			8			8			8	8
Rated voltage U_r (V)	ac 50/60 Hz		690	500	500	690			690			690			690	690
	dc				250	500			500			500			500	500
			H	E	N	N	H	L	N	H	L	N	H	L	L	N
Ultimate breaking capacity Icu ($kA_{eff.}$)	ac 50/60Hz	220V/240V	10	25	50	85	100	150	85	100	150	85	100	150	150	85
		380V/415V	70	16	30	25	70	150	36	70	150	36	70	150	150	45
		440V	65	10	15	25	65	130	35	65	130	35	65	130	130	42
		500V	25	6		18	50	100	30	50	70	30	50	70	100	30
		525V	25			18	35	100	22	35	50	22	35	50	100	22
		660/690V	6			8	10	75	8	10	20	8	10	20	75	10
	dc	250V				50	85	100	50	85	100	50	85	100	100	50
		500V				50	85	100	50	85	100	50	85	100	100	50