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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2018/2019

COURSE NAME	:	INDUSTRIAL POWER SYSTEMS
COURSE CODE	:	BEF 44903
PROGRAMME CODE	:	BEV
EXAMINATION DATE	:	DECEMBER 2018/ JANUARY 2019
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **FIFTEEN (15)** PAGES

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Q1 (a) (i) Name **TWO (2)** functions of Motor Control Centre (MCC) in a factory.
(2 marks)

(ii) Tap changer is usually placed on the primary windings of distribution transformer. Explain this statement in brief.
(1 mark)

(b) (i) Cooling method in a distribution transformer is designated by its internal and external cooling medium and mechanism. Classify the cooling method for the oil immersed distribution transformer as depicted in **Figure Q1(b)(i)**.
(2 marks)

(ii) A fault current of 30kA is flowing in a power cable energised by 50 Hz supply. The conductor and the insulation material of the cable is aluminium and Butyl Rubber, respectively. Refer to **Appendix C** for the boundary conditions of the cable. By applying the short circuit current withstand capacity criteria, plot the graph of cross sectional area (A in mm^2) versus the duration of fault (t in second) for the fault clearing time of 2, 4, 6 and 8 cycles.
(4 marks)

(c) A simplified industrial electrical diagram for a factory is depicted in **Figure Q1(c)**. Cable 1 is laid between Distribution Transformer 1 and Main Distribution. The cable used in this installation is 3-core copper, XLPE power cables. The cables are laid 150 cm underground in horizontal formation with 30 cm spacing to each other. The number of cables in a group is 6 Nos. The ground ambient temperature is 50°C and the thermal resistivity of soil is 250 °C cm/ Watt. **Appendix A** shows the standard cable size with its ampacity and **Appendix B** gives the rating factors for power cable.

(i) Analyse the initial size of Distribution Transformer 1 if the total maximum demand of the industrial loadings must less than or equal to 65% of the transformer full-load size.
(4 marks)

(ii) Investigate again the size of Distribution Transformer 1 if the voltage drop due to largest motor starting at secondary must less than 10%.
(5 marks)

(iii) Point out the initial size of the cable based on the short circuit current withstand capacity criteria.
(2 marks)

(iv) Analyse again the cable size as identified in **Q1(c)(iii)** by considering the continuous current carrying capacity criteria.
(3 marks)

(v) Recommend the standard size of Distribution Transformer 1 and Cable 1 after considered all criteria from **Q1(i)** to **Q1(iv)**.
(2 marks)

Q2 (a) Name **TWO (2)** types of batteries typically used in industrial plant.

(2 marks)

(b) **Table Q2(b)** depicts the average monthly power consumption for a single-phase feeder which is energised by three-phase 415 V, 50 Hz supply. A XLPE cable with resistance of 0.25 Ω/ km is laid from the feeder to the load point with the cable length of 0.75 km. The loss constant, *k* is assumed as 0.15 and the average power factor is 0.80 lagging.

(i) By applying the estimated losses calculation approach, determine the Load Loss Factor (LLF) for the feeder.

(4 marks)

(ii) Solve for yearly technical energy loss for this feeder in kWh.

(2 marks)

(c) The critical loads for an industrial packaging plant that to be supplied by Uninterruptible Power Supplies (UPS) during power outage period is given in **Table Q2(c)(i)**. The block diagram of the proposed UPS and its main configurations is shown in **Figure Q2(c)**. The characteristics of the proposed UPS is given in **Table Q2(c)(ii)**.

(i) Investigate the load profile (kVA versus period in hour) of the UPS loading.

(4 marks)

(ii) Analyse the peak design load (in kVA) and design energy demand (kVAh) if the future load growth and design margin are both been considered as 10%.

(4 marks)

(iii) Analyse the UPS system that consists of battery bank, rectifier, static switch and inverter systems if the desired AC voltage output is 415 V.

(6 marks)

(iv) Rewrite the inverter and static switch sizing for the UPS system in the plant with a new suitable current rating.

(3 marks)

Q3 (a) Summarise **THREE (3)** technical benefits gained by industry with proper load monitoring system in place.

(3 marks)

(b) Illustrate the process flow that outlining important parameters and considerations use to sizing the capacitor banks as power factor compensator for the industrial-scale non-linear load system.

(6 marks)

(c) A 5 MVA, 11 kV/ 415 V, Y-connected step-down transformer has been installed to serve an industrial plant in Parit Raja town as depicted in the diagram shown in **Figure Q3(c)**. The transformer is having a resistance, $R_{pu} = 0.5$ % and reactance, $X_{pu} = 7.5$ %.

(i) Classify the total resistance, R_{tot} and inductance L_{tot} to be observed in the single phase equivalent circuit for harmonic study purpose as depicted in **Figure Q3(c)(i)**.

(10 marks)

(ii) Investigate the parallel resonant frequency when the installed power factor correction is rated at 400 kVAr and 650 kVAr.

(4 marks)

(iii) Recommend the appropriate type of tune filter to treat the harmonic problem encountered in the plant and its suitable location in the single line circuit shown in **Figure Q3(c)(i)**.

(2 marks)

Q4 (a) The overload protection of industrial distribution transformer is usually done by monitoring a specified parameter. Explain in brief about this specified parameter on oil immersed type and dry type of distribution transformer.

(2 marks)

(b) Capacitor bank energisation causes current and voltage transient operating states. Thus, the maximum inrush peak current due to the switching of capacitor bank should be carefully determined. A fixed 300 kVAr capacitor bank with line-to-line voltage of 6.6 kV is fed by a 50 Hz network with short circuit capacity of 200 MVA.

(i) Determine the maximum inrush peak current ratio as compared to its nominal current

(4 marks)

(ii) Discover also the natural frequency of the inrush peak current

(2 marks)

(c) An industrial motor is to be protected against overload. Its nameplate details are three-phase 3.3 kV, 300 kW, 68% efficiency and 0.8 power factor. The motor can withstand 10% 0verload continuously. The time constant of heat withstand characteristic is 10 minutes. A thermal relay is connected across a C.T. of 120/1 ratio. The time constant of the relay is also 10 minutes. The range of settings is 70% to 130% of 1 A in steps of 5%. Suggest the proper relay setting for this application.

(3 marks)

(d) An 11 kV three-phase 5 MVA, star-connected generator is protected by an earth-fault relay having 10% setting. The C.T. ratio is 200/ 1 A.

(i) If the neutral resistance limits the maximum earth-fault current to 40% of full-load value, analyse the percentage of the protected winding

(9 marks)

(ii) Investigate the maximum earth-fault current if only 9.5% of the winding is to be left unprotected

(5 marks)

– END OF QUESTIONS –

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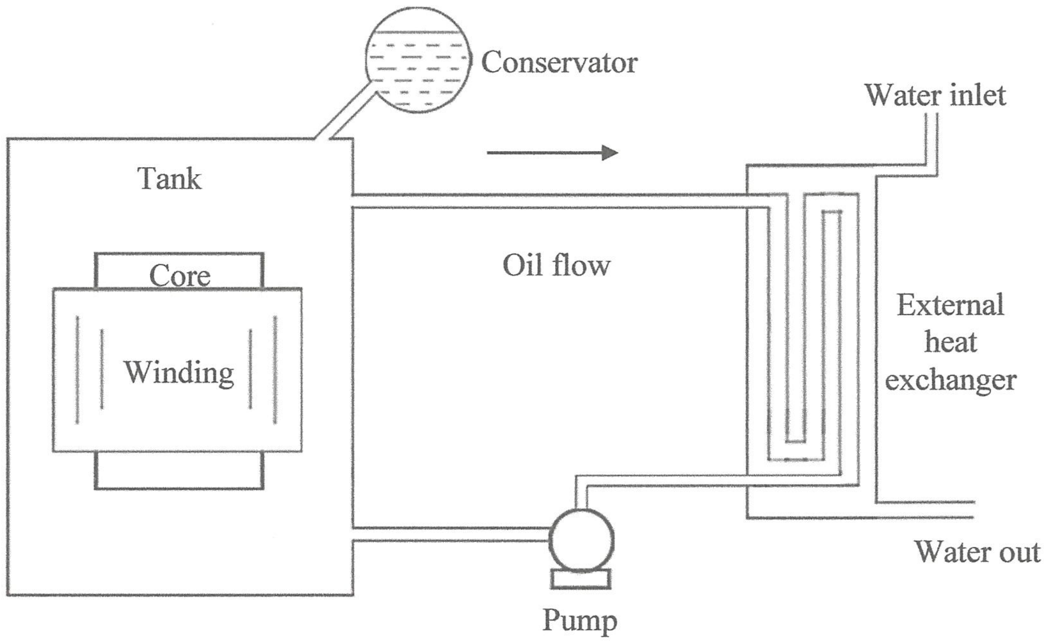

Figure Q1(b)(i)

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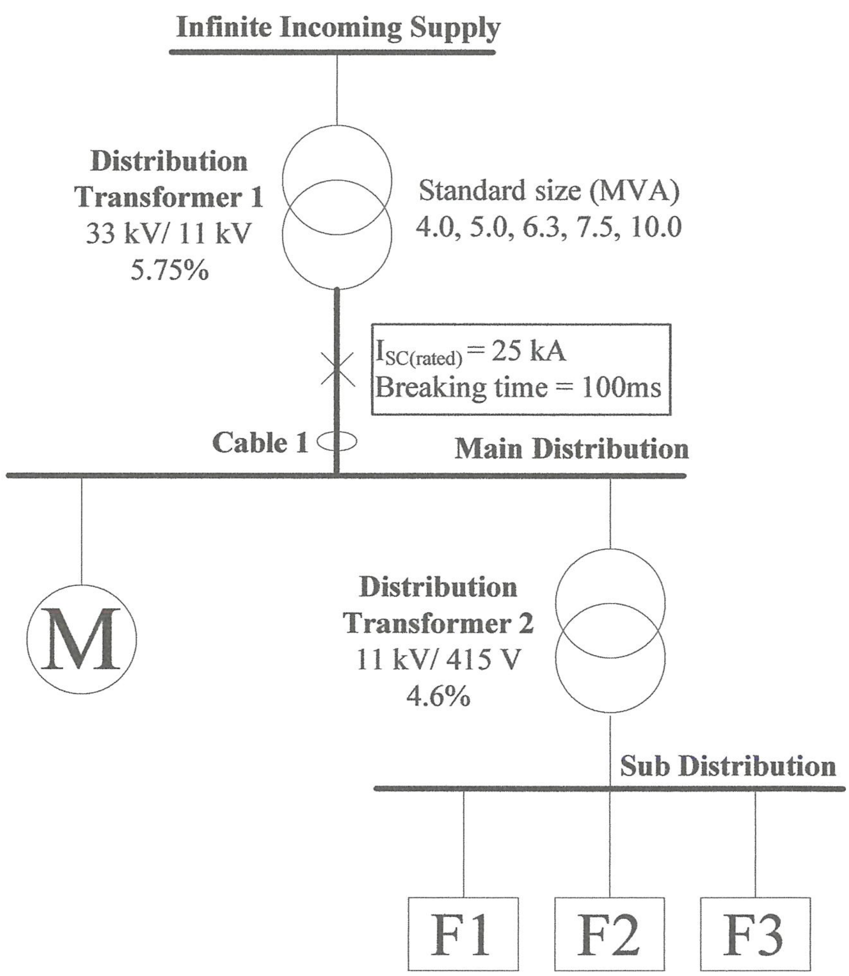

Note:
F = Feeder

M	Rated power (kW)	Speed (r/min)	Efficiency (%)	Power factor (cos Θ)	Locked rated current
	500	495	93.2	0.73	6.0

LOAD	DESCRIPTIONS
F1	240 kVA ventilation and heating loads
F2	280 kW motor loads, η = 70%, PF = 0.80 lagging
F3	80 kVA general power loads

Figure Q1(c)

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Table Q2(b)

Month	Monthly Average Consumption (kW)
January	70
February	45
March	45
April	48
May	60
June	52
July	72
August	65
September	68
October	80
November	75
December	60

Table Q2(c)(i)

Load Description	Ratings (VA)	Nos (Unit)	Autonomy Time (Hours)
Distributed Control System Cabinet	400	10	5
Electrostatic Discharge	450	10	6
Telecommunications Cabinet	200	4	8
Computer Console	120	6	3
HMI Units	200	10	5

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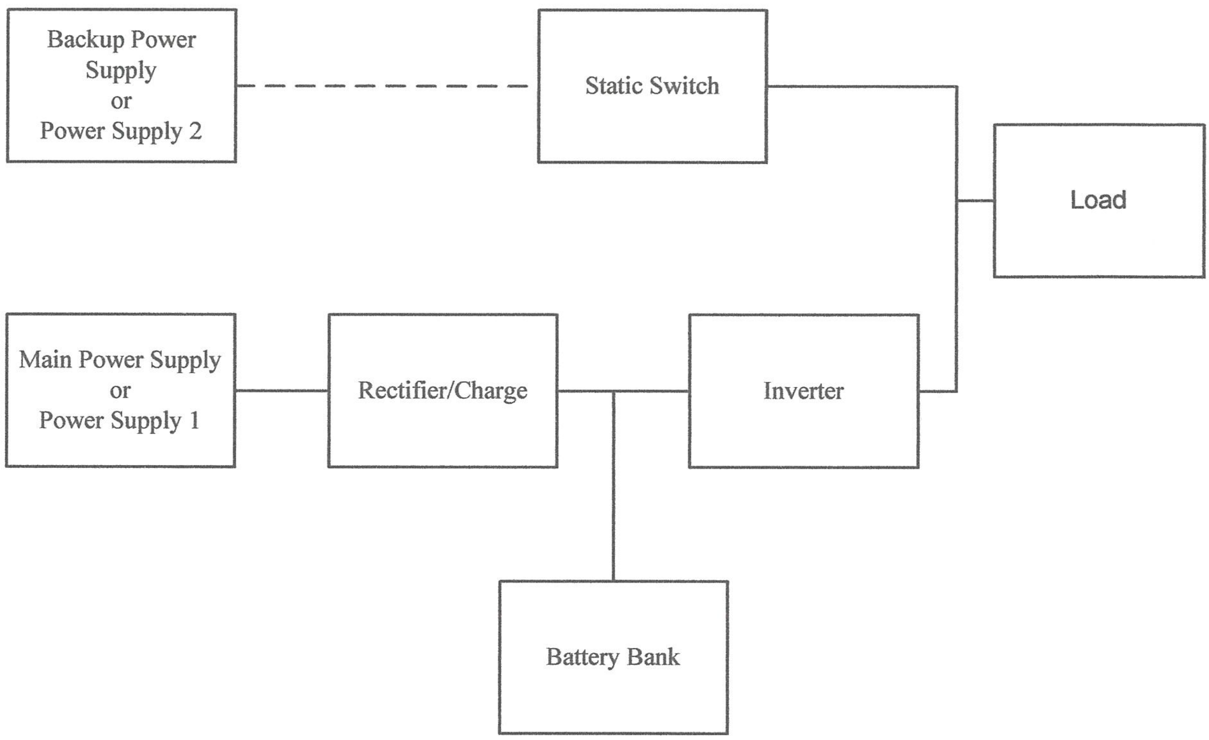

Figure Q2(c)

Table Q2(c)(ii)

Item	**Value**
Output Voltage	120 V_{dc}
Depth of discharger	85%
Battery ageing factor	25%
Temperature correction factor for vented cell at 35°C	0.93
Capacity rating factor	8%
Recharge efficiency factor	1.1
Minimum recharge time	3 hours

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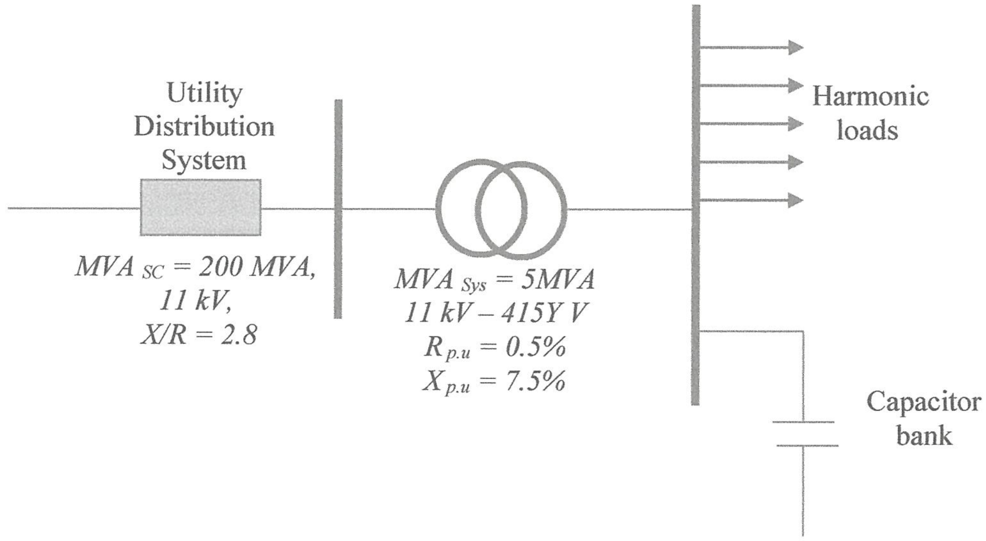

Figure Q3(c)

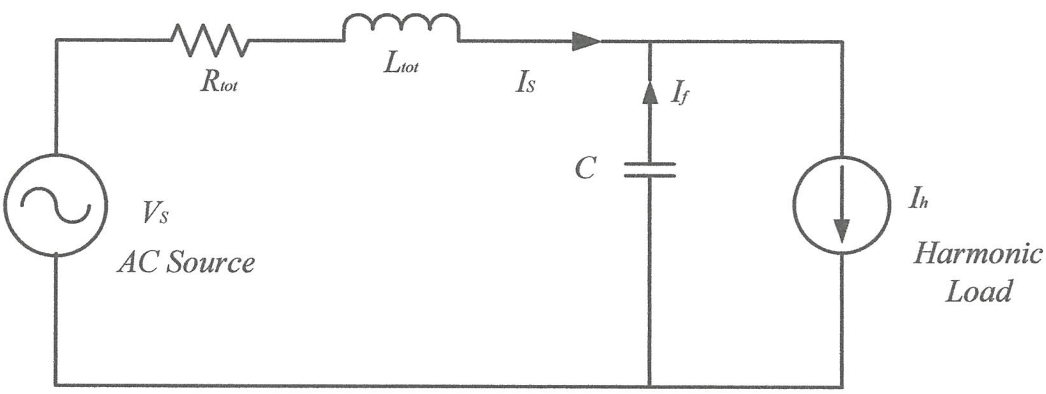

Figure Q3(c)(i)

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Appendix A

TABLE 4E4A – Multicore 90 °C armoured thermosetting insulated cables (COPPER CONDUCTORS)

Air ambient temperature: 30 °C
Ground ambient temperature: 20 °C
Conductor operating temperature: 90 °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 a.c. or d.c.	1 three- or 1 four-core cable, three-phase a.c.	1 two-core cable, single-phase a.c. or d.c.	1 three- or 1 four-core cable, three-phase a.c.	1 two-core cable, single-phase a.c. or d.c.	1 three- or 1 four-core cable, three-phase a.c.
1	2	3	4	5	6	7
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)
1.5	27	23	29	25	25	21
2.5	36	31	39	33	33	28
4	49	42	52	44	43	36
6	62	53	66	56	53	44
10	85	73	90	78	71	58
16	110	94	115	99	91	75
25	146	124	152	131	116	96
35	180	154	188	162	139	115
50	219	187	228	197	164	135
70	279	238	291	251	203	167
95	338	289	354	304	239	197
120	392	335	410	353	271	223
150	451	386	472	406	306	251
185	515	441	539	463	343	281
240	607	520	636	546	395	324
300	698	599	732	628	446	365
400	787	673	847	728	-	-

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Appendix B

Ground Temp. (°C)	20	25	30	35	40	45	50
Rating Factor	1.12	1.08	1.04	0.96	0.91	0.87	0.82

Spacing	No. of cables in group				
	2	3	4	6	8
Touching	0.79	0.69	0.62	0.54	0.50
15 cm	0.82	0.75	0.69	0.61	0.57
30 cm	0.87	0.79	0.74	0.69	0.66
45 cm	0.90	0.83	0.79	0.75	0.72
60 cm	0.91	0.86	0.82	0.78	0.76

Cable size	Depth of laying (cm)					
	75	90	105	120	150	180 ≥
up to 25 sq. mm.	1.00	0.99	0.98	0.97	0.96	0.95
25 to 300 sq. mm	1.00	0.98	0.97	0.96	0.94	0.93
above 300 sq. mm.	1.00	0.97	0.96	0.95	0.92	0.91

Nominal area of conductor in sq. mm	Rating factors for value of Thermal Resistivity of Soil in °C cm / Watt					
	100	120	150	200	250	300
25	1.24	1.08	1.00	0.91	0.84	0.78
35	1.15	1.08	1.00	0.91	0.84	0.77
50	1.15	1.08	1.00	0.91	0.84	0.77
70	1.15	1.08	1.00	0.90	0.83	0.76

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Appendix C

The temperature rise constant (*K*) according to IEC 60364-5-54:

$$K = 148\sqrt{In\left(1+\frac{T_2 - T_1}{228.1+T_1}\right)} \text{.....(for aluminium conductors)}$$

$$K = 226\sqrt{In\left(1+\frac{T_2 - T_1}{234.5+T_1}\right)} \text{.....(for copper conductors)} \quad (1)$$

where,
T_1 = initial conductor temperature in °C
T_2 = final conductor temperature in °C

Insulation material	Final temperature, T_2 (°C)	Initial temperature, T_1 (°C)
PVC	160	70
Butyl Rubber	220	85
XLPE/ EPR	250	90

The minimum cable size due to short circuit temperature rise:

$$A = \frac{\sqrt{I_{SC}^2 t}}{K} \quad (2)$$

where,
A = minimum required cross section area in mm^2
t = the duration of the short circuit in second
K = short circuit temperature rise constant

Load Loss Factor:

$$LLF = k * LF + (1-k) * LF^2 \quad (3)$$

where,
LF = Load Factor
k = loss constant

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Number of cells:

$$N_{\max} = \frac{V_{DC}\left(1 + V_{l,\max}\right)}{V_c} \quad (4)$$

$$N_{\min} = \frac{V_{DC}\left(1 - V_{l,\min}\right)}{V_{eod}} \quad (5)$$

where,

N_{max}/ N_{min}	=	maximum or minimum of cells
V_{DC}	=	nominal battery voltage
$V_{l,max}$	=	maximum load voltage tolerance (%)
$V_{l,min}$	=	minimum load voltage tolerance (%)
V_c	=	cell charging voltage (charge cycle)
V_{eod}	=	cell end of discharge voltage

Frequency variation:

$$f = \frac{1 + \frac{d-1}{d}\Delta P}{1 + \Delta P} \quad (6)$$

where,

d	=	load reduction factor
ΔP	=	relative overload
f	=	frequency variation
f_0	=	system frequency

Minimum battery capacity:

$$C_{\min} = \frac{E_d \times (1 + k_a) \times (1 + k_c) \times k_t}{V_{DC} \times k_{dod}} \quad (7)$$

where,

C_{min}	=	minimum battery capacity (Ah)
E_d	=	design energy over autonomy time (VAh)
V_{DC}	=	nominal battery voltage
k_a	=	battery ageing factor (%) (25%)
k_c	=	capacity rating factor (%) (10%)
k_t	=	temperature correction factor
k_{dod}	=	maximum depth of discharge (%) (80%)

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DC current rating of the battery charger:

$$A = \left[\frac{1.1 \times AH}{T} + L\right] \times \frac{1}{C1} \times \frac{1}{C2} \qquad (8)$$

where,

AH	=	recharge in ampere-hours
T	=	recharge time [T]
L	=	DC continuous load current [amperes]
$C1$	=	temperature correction (from manufacturer)
$C2$	=	altitude correction factor (from manufacturer)

Capacitor bank protection:

$$C = \frac{Q_{CAP}}{(V_{LL})^2 \times 2\pi f} \qquad (9)$$

$$L = \frac{(V_{LL})^2}{2\pi f \times S_{SC}} \qquad (10)$$

$$\frac{I_{rush}}{I_{ncap}} = \sqrt{2}\left(\frac{1}{2\pi f \times \sqrt{C \times L}}\right) \qquad (11)$$