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VICTORIA UNIVERSITY OF TECHNOLOGY

ELECTRICAL POWER SYSTEMS 2

VAA3001

ASSIGNMENT No. 1

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1. Electrical Wiring Line Diagram



Figure 1 Electrical wiring Diagram

Single line electrical wiring diagram for the hospital is shown in the Error! Reference source not found.. Important dimensions are shown in meters and each distribution box is marked with kVA ratings.

1.1. Loads on submains

Lighting and power load on each hospital floor are calculated from given data as follows:

Lighting and power non essential load = 28 VA / m2

Lighting and power non essential load per floor = 1650 * 28 / 1000 = 46.2 kVA

Lighting and power essential load = 24 VA / m2

Lighting and power essential load per floor = 1650 * 24 / 1000 = 39.6 kVA

There are some additional essential and non essential load as per given in the problem. Details of load in kVA are given in Error! Reference source not found.. We calculate here maximum demand current for each floor as per kVA loads.

1.1.1. Essential Loads

Roof

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Total kVA load on the Roof = 295 kVA
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Total current required per phase for a 3 phase supply = $\frac{222 \times 2222}{\sqrt{2} \times 222}$ = 222.22 A

Similar calculation for other floors can be done.

L5

Total kVA load = 39.6 kVA

Total current demand per phase = 57.15 A

L4

Total kVA load = 39.6 kVA

Total current demand per phase = 57.15 A

L3

Total kVA load = 39.6 kVA

Total current demand per phase = 57.15 A

L2

Total kVA load = 39.6 kVA

Total current demand per phase = 57.15 A

L1

Total kVA load = 39.6 kVA

Total current demand per phase = 57.15 A

B1

Total kVA load = 3.96 kVA

Total current demand per phase = 5.71 A

B2

Total kVA load = 78.96 kVA

Total current demand per phase = 113.96 A

B3

Total kVA load = 3.96 kVA

Total current demand per phase = 5.71 A

1.1.2. Non Essential Load

Roof

Total kVA load = 500 kVA

Total current demand per phase = 721.68 A

L5

Total kVA load = 166 kVA

Total current demand per phase = 239.88 A

L4

Total kVA load = 46.2 kVA

Total current demand per phase = 66.68 A

L3

Total kVA load = 46.2 kVA

Total current demand per phase = 66.68 A

L2

Total kVA load = 46.2 kVA

Total current demand per phase = 66.68 A

L1

Total kVA load = 46.2 kVA

Total current demand per phase = 66.68 A

B1

Total kVA load = 9.24 kVA

Total current demand per phase = 13.33 A

B2

Total kVA load = 9.24 kVA

Total current demand per phase = 13.33 A

B3

Total kVA load = 9.24 kVA

Total current demand per phase = 13.33 A

2. Sizing of Cables

Sizing is required for three cables i.e.

I. Mains

Total current for the essential & non-essential loads is 2157.70A (from section 1)

Derating factor for circuit of multi core cables insulated in perforated air = 0.98 (from Table-24 AS /NZS 3008.1)

Derating factor of ambient air temperature = 0.88 (from Table-27 AS/NZS 3008.1)

So the total derating factor = $0.98 \times 0.88 = 0.8624$

Let's select 4 cables in parallel in each phase, then,

Current in a single conductor cable in each phase = 2157.70/4 = 539.425

Tabulated current capacity required = 539.425/0.8624 = 625.49Amp

Hence the cable conductor size for the mains will be 500 mm2 (from Table-10 AS /NZS 3008.1)

Conductor Size as per Voltage Drop across its length (which should not be more than 2.5 %)

Resistance of 500mm2 circular conductor multi-core cable at 45 0 C temperature R= 0.0486 Ω /km (as per AS/NZS 3008.1)

Reactance of 500mm2 circular conductor multi-core cable X= 0.0666 Ω /km

Cable length L = 20m (as per given data)

Let us assume that load power factor = 0.8

Then, Voltage drop

$$V = \frac{\sqrt{3} * I * (R * cos \Phi + X * sin \Phi)}{1000} * L$$
$$V = \frac{\sqrt{3} * 539.425 * (0.0486 * 0.8 + 0.0666 * sin (cos^{-1}(0.8)))}{1000} * 20$$

V= 1.473V

For a 400V system, the voltage drop is = (1.473/400)*100 = 0.36 %, which is less than 2.5 % and acceptable.

II. Lift cable size

Lift power = 120 kVA (given)

Required current of the lift = $1000x\frac{120}{\sqrt{3}x400}$ = 173.21A

Derating factor for circuit of single core cables insulated in perforated trays or air = 0.97 (from Table-23 AS /NZS 3008.1)

Derating factor of ambient air temperature = 0.88 (from Table-27 AS/NZS 3008.1)

Total derating factor = $0.97 \times 0.88 = 0.8536$

Let's select single cables in parallel in each phase, then,

Current in a single conductor cable in each phase = 173.21A

Tabulated current capacity required = 173.21/0.8536 = 202.92Amp

So the conductor size for the mains will be 95 mm2 (From Table-20 AS /NZS 3008.1)

Conductor Size as per Voltage Drop across its length (which should not be more than 2.5 %)

As per AS/NZS 3008.1

Resistance of 95 sq-mm circular conductor multi-core cable at 45 $^{\rm 0}{\rm C}$ temperature R= 0.214 Ω / km

AC Reactance of 95 sq-mm circular conductor multi-core cable X= 0.0904 Ω / km

Cable length L = 45.2 m

Let us assume that load power factor = 0.8

Then, Voltage drop,

$$V = \frac{\sqrt{3} * I * (R * \cos \Phi + X * \sin \Phi)}{1000} * L$$
$$V = \frac{\sqrt{3} * 202.92 * (0.214 * 0.8 + 0.0904 * \sin(\cos^{-1}(0.8)))}{1000} * 45.2 = 3.58V$$

For a 400 V system the voltage drop = 3.58/400*100 = 0.89 %, which is under 2.5 %

III. Carpark B2

In section1, I have already derived total current for essential load for park level B2 = 117.72A

Derating factor for circuit of single core cables insulated in perforated trays or air = 0.97 (from Table-23 AS /NZS 3008.1)

Derating factor of ambient air temperature = 0.88 (from Table-27 AS/NZS 3008.1)

Total derating factor = $0.97 \times 0.88 = 0.8536$

Let's select single cables in parallel in each phase, then,

Current in a single conductor cable in each phase = 117.72A

Tabulated current capacity required = 117.72/0.8536 = 137.91A

So the conductor size for the carpark level B2 will be 50 mm2 (From Table-20 AS /NZS 3008.1)

Conductor Size as per Voltage Drop across its length (which should not be more than 2.5 %)

As per AS/NZS 3008.1

50 sq-mm circular conductor multi-core cable at 45 0 C temperature

R= 0.426 Ω / km

X= 0.0829 Ω / km

Slab to slab height of each floor = 4.2m (given)

Cable length L for the lift will be = 4.2 * 6 + 20 = 24.2 m

Let us assume that load power factor = 0.8

Then, Voltage drop,

$$V = \frac{\sqrt{3} * I * (R * \cos \Phi + X * \sin \Phi)}{1000} * L$$
$$V = \frac{\sqrt{3} * 117.72 * (0.426 * 0.8 + 0.0829 * \sin(\cos^{-1}(0.8)))}{1000} * 24.2 = 1.927 V$$

For a 400 V system the drop is 1.927/400*100 = 0.481 %, which is less than 2.5 %

3. Maximum demand calculation and fault level in parking area

Following calculations are required:

Maximum demand in parking area

Fault level at B2

3.1. Maximum demand calculations for the Car park level

Parking area has major loads of lighting and typical load is 3-10 VA/m² depending on selection of illumination level and types of light used.

Let's assume power consumption in parking area = $8.0 \text{ VA}/m^2$ Total power consumption in parking area = $8.0 \times 1650 = 13.2 \times 14.6 \text{ kVA}$ Total power consumption for parking area = $13.2 \times 3 + 75 = 114.6 \text{ kVA}$

Let's assume parking area have 30% essential and 70% non essential load, Then non-essential power consumption = $13.2 \times 70 / 100 = 9.24$ kVA And, essential power consumption = $13.2 \times 30 / 100 = 3.96$ kVA

3.2. Fault level at DB B2



Figure 2 Electrical Diagram for Fault at parking level B2

Length of the cable from **MSB** to **DB** = 4.2 + 20 = 24.2meter

For a 3 phase system fault level current in each phase If = $\frac{V phase}{Z}$

Where,

 V_{phase} = Phase Voltage Z = Line Impedance $V_{\text{phase}} = \frac{400}{\sqrt{3}} = 230.94 \text{ V}$ Z = $\sqrt{R^2 + X^2}$

Lets assign conductor temperature = 75 DegC (maximum operating temperature)

For 6 square mm copper conductor,

Resistance Rs = $3.75 \ \Omega/km \&$

Reactance Xs = $0.104 \ \Omega/km$

Then

$$R = Rs \times \frac{24.2}{1000} = 3.75 \times 0.0242 = 0.09075 = 90.75 \text{ m}\Omega \text{ and}$$
$$X = 0.104 \times \frac{24.2}{1000} = 0.104 \times 0.0242 = 0.00251 = 2.51 \text{ m}\Omega$$

Z =
$$\sqrt{(0.09075)^2 + (0.00251)^2} = 90.74 m$$
Ω

Fault Current in each Phase $I_f = \frac{230.94}{90.74 \times 10^{-3}} = 2.54 \times KAmp$

4. Battery sizing calculation

UPS load rating kVA = 120 kVA

Backup time = 4 hour

Let's assume load power factor on UPS p.f. = 0.9

Let's assume efficiency of inverter part in UPS = 0.96

And total UPS efficiency η = 0.93

Now, real power required from battery during backup time,

$$P = \frac{kVA * PF}{efficiency} = \frac{120kVA * 0.9}{0.96} = 112.5 \, kW$$

Total discharged energy from batteries = 112.5 * 4 = 450 kWh

Therefore, Total energy required to charge the battery = 450 kWh

Let us assume that as per the load shading conditions in hospital, total time available to charge the batteries = 15 hours

Power required for charging the batteries = 450 / 15 = 30 kW

Let's assume 16 block of 12V batteries in series are used for storage.

Total battery voltage for series combination = 16*12 = 192V

For a AVR45-33 battery from Deka East Penn Manuf,

Watt per cell when discharging the battery in 4 hours = 299 W

Power from the battery = 299 * 6 = 1794 W

Number of strings required to provide total 450 kWh = $\frac{450*1000}{4*1794*16}$ = 3.91

Therefore, total 4 strings of 16 no of AVR45-33 (12V) batteries in each string can be used.