University of Exeter

Centre for Smart Grid

L3
HV and LV Distribution Networks

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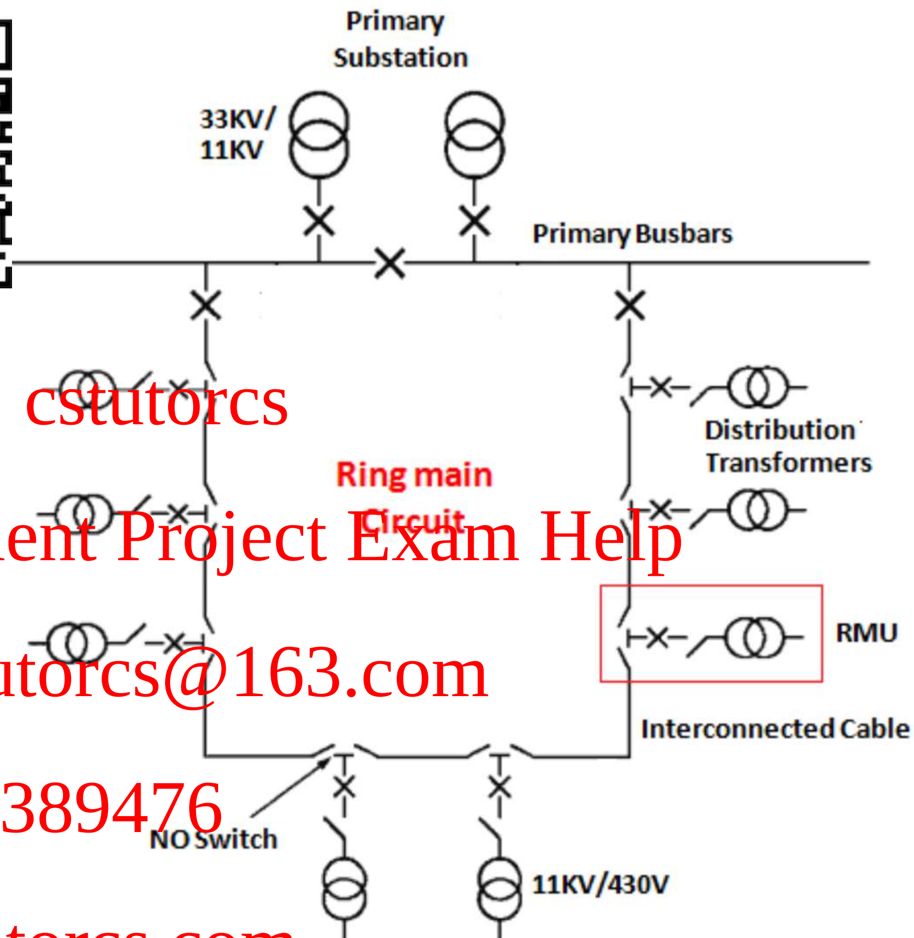
HV open ring, supplying LV radial feeders

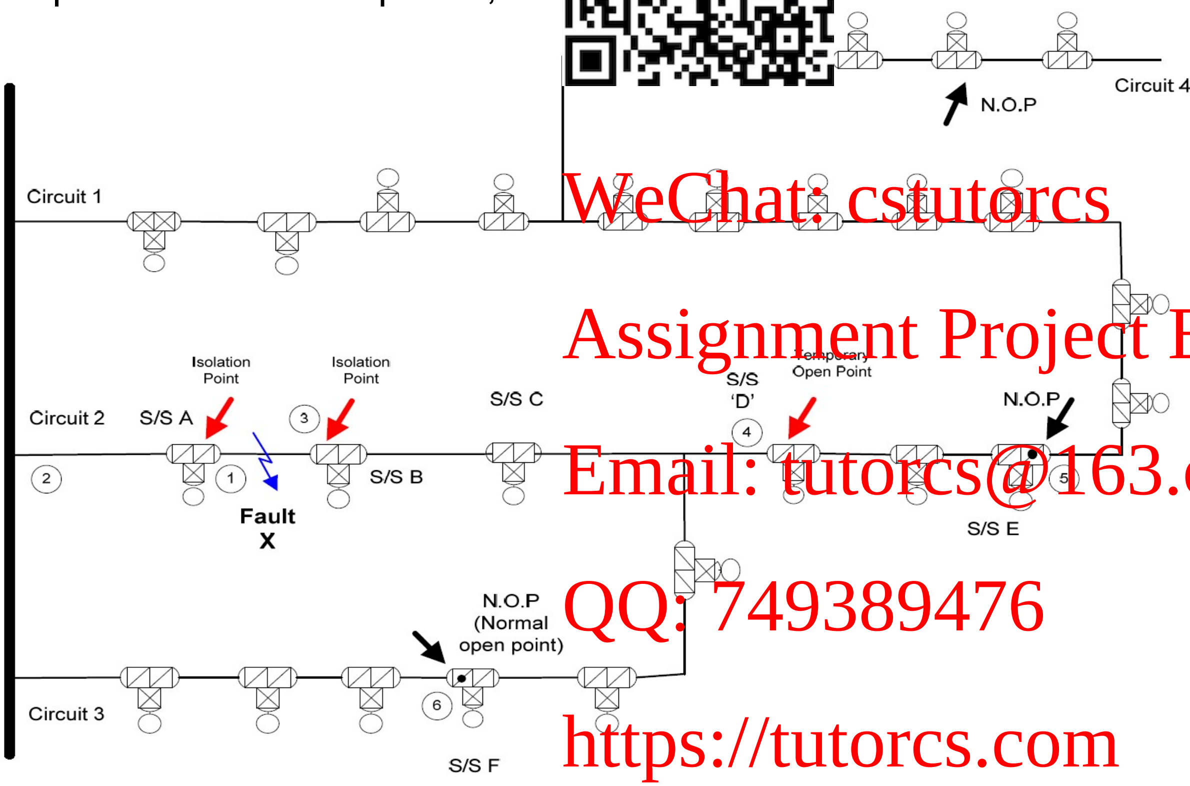
- Normal method of 11kV or 6.6 distribution is an open ring cir feeding from the primary subs to normal open points.

- Load on any teed section or group of teed substations between switching points is usually restricted to 1MVA.



Supply restoration after fault.

- For 11kV fault outage, alternat normally restored to healthy sections of network by single load transfer plus restoration fr uit breaker (4 switching operations).
- On established networks with bles this may not be possible, hence 6 switching operations are acceptable; see



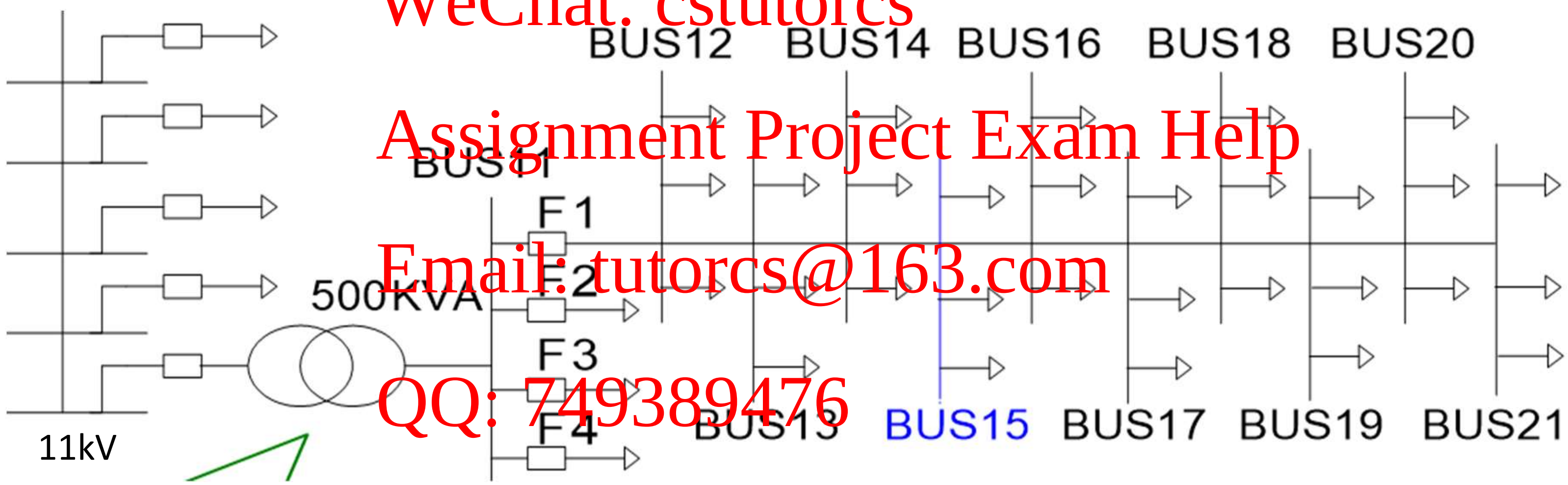
For a fault at 'X'

Following trip of feeder circuit breaker and confirmation that the fault is between substations A & B it should only be necessary to carry out a maximum of six switching operations to restore customer supplies

1. At substation A -.Open substation B Gas switch
2. At primary substation - Close circuit 2 circuit breaker.
3. At substation B – Open S/S A Gas Switch
4. At substation D - Open S/S C and Tee Gas Switch } Additional Load Transfer
5 At substation E - Close N. O. P.
6 At substation F – Close N. O. P.

LV NETWORK DESIGN

- LV networks are normally design[illegible]d from the secondary substation via fuses to open points in network link boxes.
  - An exception is central Lon[illegible] demand in the area of the West End to the City.
  - In this area the LV network i[illegible]nnected together via fuses across HV feeders to support the high LV load density by prov[illegible]nfeeds and to maintain supply to LV loads in the event of an HV fault.
- Supplies to loads of less than 800kVA will generally be made at LV.



11kV:430V transformer
(200kVA – 800kVA)

LV Network = 4 feeders protected by fuses
Example: Feeder F1 is 300m and it supplies, via 10 load connection points (LCP), 96 customers, evenly distributed across the phases

Calculation of domestic LV Demand

- Calculation of demand is deper[illegible]mber of connections and designer's estimate of annual unit consumption of each conne[illegible]ble below indicates the classifications of properties and typical unit consumptions used [illegible] Networks.

ADMDs (kW)

Type	Day	Night
1/2 Bed Gas C/h	1.2	0.3
3 Bed Gas C/h	1.5	0.3
4 Bed Gas C/h	1.8	0.5
5+ Bed Gas C/h	2.4	0.5
1/2 Bed Other C/h	1.5	2
3 Bed Other C/h	1.9	2.5
4 Bed Other C/h	2.1	3
5+ Bed Other C/h	3.1	3.5
E7 1 Heater / W/h	2.2	5.13
E7 2 Heater / W/h	2.5	7.56
E7 3 Heater / W/h	2.8	9.99
E7 4 Heater / W/h	3.4	12.42
15kW Boiler	4.5	16.2
19kW Boiler	5.7	19.8

- [illegible]diversity maximum demand (ADMD) is used in the design of [illegible]ution networks and assumes demand is aggregated over large number of customers.
- ADMD accounts for the coincident peak load a network is likely to experience over its lifetime and as such is an over-estimation of typical demand.
  - If you live in a 3 bed Gas c/h house your energy use (kWh) per year based on ADMD and 8 hour nights is almost 10MWh = £1700 for kWh + standing charges (£70). In reality, kWh part of your electricity bill is probably about £400 - £500, hence annual kWh demand is 2.2 – 2.7MWh, which translates to average kW use of 250W – 300W.
  - Problem is the time we all want to use electricity.
- Would time-of-day pricing change when you use your kWh's?
  - Is 5p – 50p per kWh, enough to shift the demand peaks?

- What happens to LV networks, when we all stop using Methane Gas for Central Heating and switch to electricity powered heat pumps.
- Similarly, what happens when domestic consumers switch to EVs and decide to charge at home.

Calculation of LV Demand:

Calculation of ADMD and site maximum demand for a new housing development:

The site maximum demand shall [illegible]ng the following formula:

$$Site\ M\text{[illegible]} = (ADMD_w\ x\ N) + 8\ kW$$

Where:

- $ADMD_w$ is the weigh[illegible]D per household within the site.
- N is the total number of houses.

To arrive at the weighted average of the After Diversity Maximum Demand the following rule applies:

$$ADMD_W = \frac{(N_a\ x\ ADMD_a) + (N_b\ x\ ADMD_b) + \ldots + (N_z\ x\ ADMD_z)}{N_a + N_b + \ldots + N_z}$$

For example, if it is planned to connect 20 houses with an $ADMD$ of 5 kW and 60 houses with an $ADMD$ of 3 kW, the weighted average $ADMD_w$ would be 3.5 kW, as below:

$$ADMD_w = \frac{(20\ x\ 5) + (60\ x\ 3)}{20 + 60} = \frac{280}{80} = 3.5\ kW$$

Therefore: $$Site\ Maximum\ Demand = (3.5\ x\ 80) + 8 = 288\ kW$$

The specific ADMD figures for each household will vary depending on the size of the house, the type of heating system installed and the presence of low carbon technologies. Given the ongoing and forecast uptake of low carbon technologies, ADMD values must reflect the electrification of heat and transport. This ensures adequate supply capacity is provided at the time of construction and avoids future network issues arising from thermal or voltage constraints.

LV Demand: challenges on networks for a low carbon future

Baseline ADMD values:

Type of Heating	Type of House	Estimated Annual Consumption (kWh)	*ADMD* (kW)
Gas Hot Water and Central Heating and/ 3kW Immersion Heat	om property	5000	2.0
	property, or tached property	4250	1.5
	om property, or detached property	3500	1.0

ADMD modifier for electrically heated homes:

Type of Heating Scheme	H (kW)	ADMD (kW)
Water and Space Heating (Property EPC* Rating A-C)	Total heating load including water heating, storage and panel heaters	+ 0.5H
Water and Space Heating (Property EPC* Rating D-G)	Total heating load including water heating, storage and panel heaters	+ 0.6H
Electric Central Heating Boilers	Total value of installed storage space heating only	+ H
Heat Pump (air/ground source)	Total Installed Heat Pump capacity	+ H

*EPC – Energy Performance Certificate; typically A-C for a new build property. Where no data is provided assume D-G.

ADMD modifier for EVSE/EV charging:

CT Status	EVSE Installation	EVSE Rating (kW)	ADMD (kW)
EVSE or EV charge point to be installed for domestic EV charging	Slow Charging	3.68kW (16A)	+ 1.5
	Fast Charging	7.36 (32A)	+ 2.5
EVSE not installed but off-street parking is available	Not installed at time of construction	-	+ 1.5

*Only applied if no other charge point equipment is specified.

Tables illustrate the challenges networks will face in the future.

SP ENERGY NETWORKS FRAMEWORK FOR DESIGN & PLANNING OF LV HOUSING DEVELOPMENTS, INCLUDING U/G NETWORKS AND ASSOCIATED HV/LV S/S ESDD-02-012 Issue No 7

Calculation of LV Demand:

Examples

A. A 3 bedroom detached p[illegible] street parking, 4.8 kW of installed panel heaters, an EPC rating of A and ava[illegible] property specific ADMD of 5.5 kW:

$$1.[illegible].5 = 5.4kW = 5.5\ kW$$

B. A 5 bedroom property, 7.2kW of installed panel heaters, an EPC rating of A, and an installed Fast Charging EVSE will have a property specific ADMD of 9.0 kW:

$$2.0 + 0.5(7.2) + 2.5 = 8.6\ kW = 9\ kW$$

C. The weighted $ADMD_w$, for the above two properties is found as follows:

$$\frac{(1\ x\ 5.5) + (1\ x\ 7.5)}{2} = 6.5kW$$

D. The *Site Maximum Demand*, for the above two properties is found as follows:

$$(6.5\ kW\ x\ 2) + 8 = 21\ kW$$

Impact of EVs & Heat Pumps:

Heating | PUHZ-(H)W50-140VHA(2)/YHA2(-BS)
Ecodan Monobloc Air Source Heat Pumps

Mitsubishi range of Ecodan monobloc air source heat pumps includes 5, 8.5, 11.2 and 14kW sizes, designed to cascade up to 6-units.

- ...eter lives on a road with 86 houses, each connected to overhead 3Φ LV line ...upplied by 300kVA transformer.
- ...l houses large & detached, most built in 1950's and later extended.
- ...021 guess: all heated by gas & small number with EVs, PV & solar thermal ...anels or Heat Pumps.

- Guess "mean" ADMD for each home today is 2kW.
- Hence 86 homes = 172kW (OK for 300kVA transformer)
- If we assume everyone switches to fast charging EVs and large Heat Pumps (14kW capacity)
- ADMD for each house ≈ 2.0 + 4.8 + 2.5 = 9.3kW
- Hence 86 homes ≈ 800kW (300kVA transformer & line overheats).
- **What are the solutions, other than new transformer & higher rated line ?**

OUTDOOR UNIT		PUHZ-W50VHA2(-BS)	PUHZ-W85VHA2(-BS)	PUHZ-W112VHA(-BS)	PUHZ-HW140VHA2(-BS)
HEATING*2 (A-3/W35)	Capacity (kW)	4.8	8.3	11.0	14.0
	Power Input (kW)	1.63	2.96	3.65	4.81
	COP	2.95	2.80	3.01	2.91
ELECTRICAL DATA	Electrical Supply	220-240v, 50Hz	220-240v, 50Hz	220-240v, 50Hz	220-240v, 50Hz
	Phase	Single	Single	Single	Single
	Nominal Running Current [MAX] (A)	5.4 [13]	10.3 [23]	11.2 [29.5]	14.9 [35]
	Fuse Rating - MCB Sizes (A)*	16	25	32	40

Voltage Regulation:

- At LV, the supply volta[illegible]ain within the declared voltage range of 230 volts +10% and – [illegible] normal running and outage conditions.
- Maximum Voltage on L[illegible]on feeders shall **not** exceed 253V;
- Minimum Voltage at the distribution system Exit Point shall **not** be less than 216V;

- Maximum voltage regulation from LV busbars of HV/LV substation to the end of each main feeder shall not exceed 5%. Assuming no generation on feeder:
  - if LV at substation is 253V, then minimum voltage at end of longest "heavily loaded" feeder > 240V.
  - If LV at substation is 227V, then minimum voltage at end of longest "heavily loaded" feeder > 216V.
- Maximum voltage regulation in any service to customer from main feeder shall not exceed 2%.

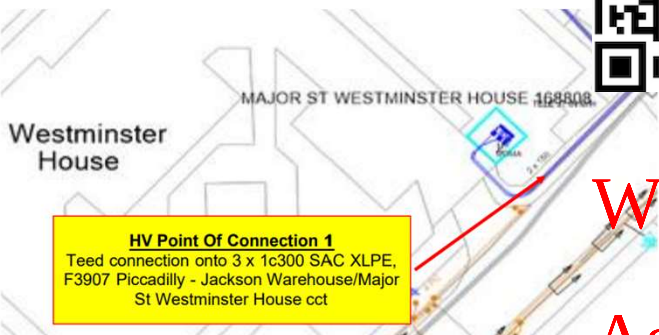
Substations:

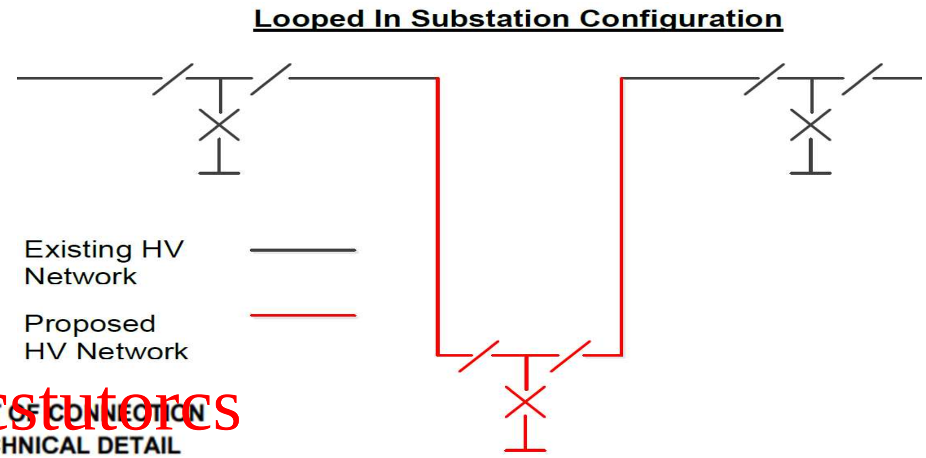
- Substations must be sited a practical to the major load centre(s) and must allow 24 hour unimpeded a
- Designs incorporating subs b-optimal locations cause increased system losses and will NOT be approved.

- Substations in areas below ground will not generally be accepted.
- Choice of enclosure will be influenced by an assessment of the likely risks to arise from interference, vandalism or unauthorised access.
- Other security measures may also be required.

Housing Development, underground supplies and HV/LV substations:

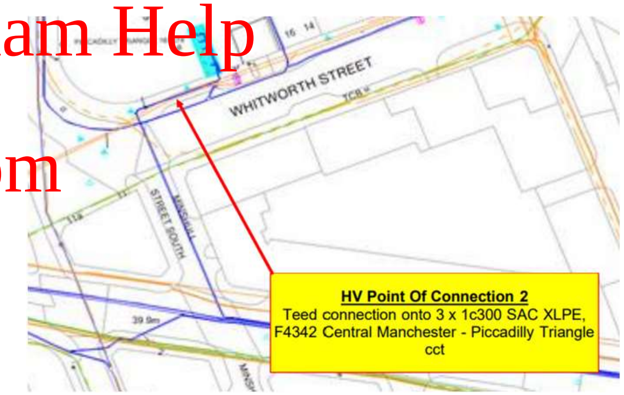
New substation to be looped in between HV Point of connections 1 & 2





POINT OF CONNECTION TECHNICAL DETAIL

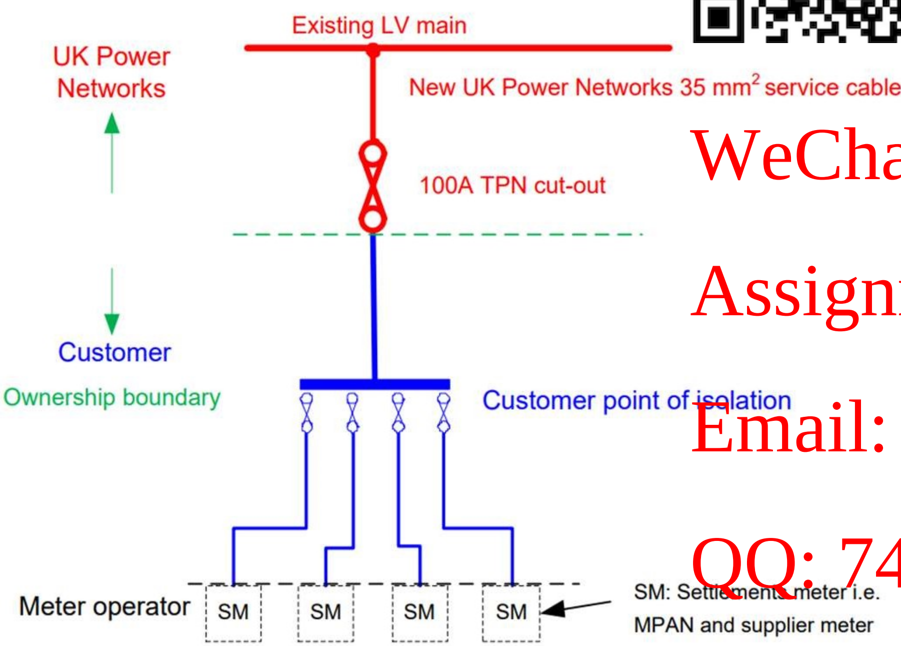
Cable Size @ P.O.C :	see drawing	
Voltage :	6600	volts
Minimum Cable Size :		
Loop or Teed (HV only)	Looped	
Feeder Name / No :	Jackson Warehouse/Major St	
Transformer Size :		kVA
Fuse Size :		Amps
Earth Loop Impedance :		ohms
% Voltage Drop		
1) Including site load		%
2) excluding site Load		%



EDS 08-2100 LV CUSTOMER SUPPLIES

- Guidance on provision of LV s… en 100A & 2165A (23kVA to 1.5MVA).
  - Supplies of > 1.5MVA to a single cust… ed at HV.

A 100A three-phas… TPN) supply shall be provided via 35mm2 three-phase service cable termin… phase 100A cut-out. Maximum ratings of fuses = 100A.



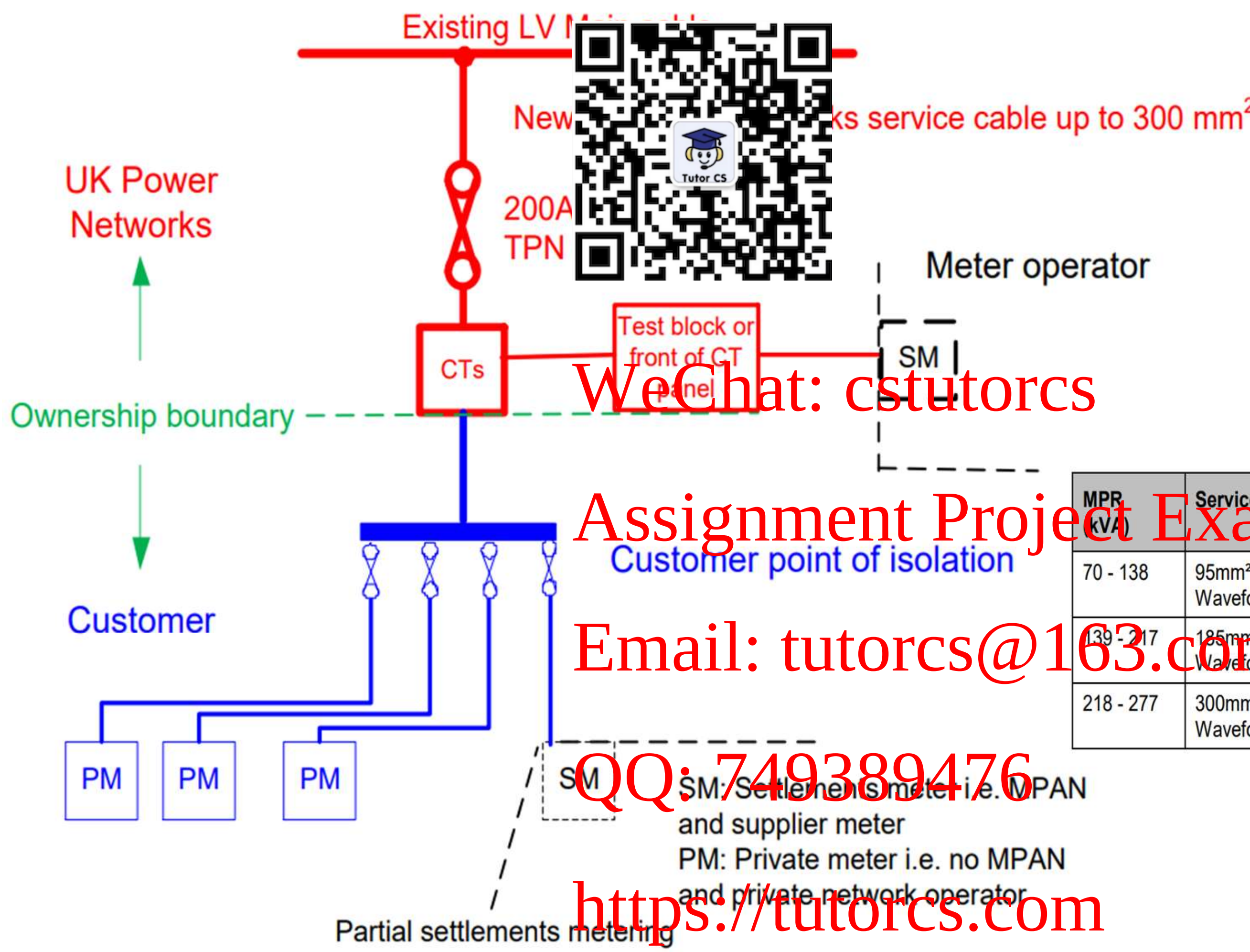
Service length limited to 43m to ensure maximum voltage drop of 6% at customer supply terminals.

Comment: if your home is located at the remote end of longest main cable, the minimum “acceptable” voltage is 216V.
Slide 11, quoted 5% drop from start to end main cable. This slide, quotes 6% for customer tee.
Note: minimum LV voltage at HV:LV transformer is 241V.

Hence, if minimum LV transformer voltage is 241V, and maximum 5% drop for main feeder and 6% for customer tee, then voltage at most remote customer is 215V. Is this acceptable??

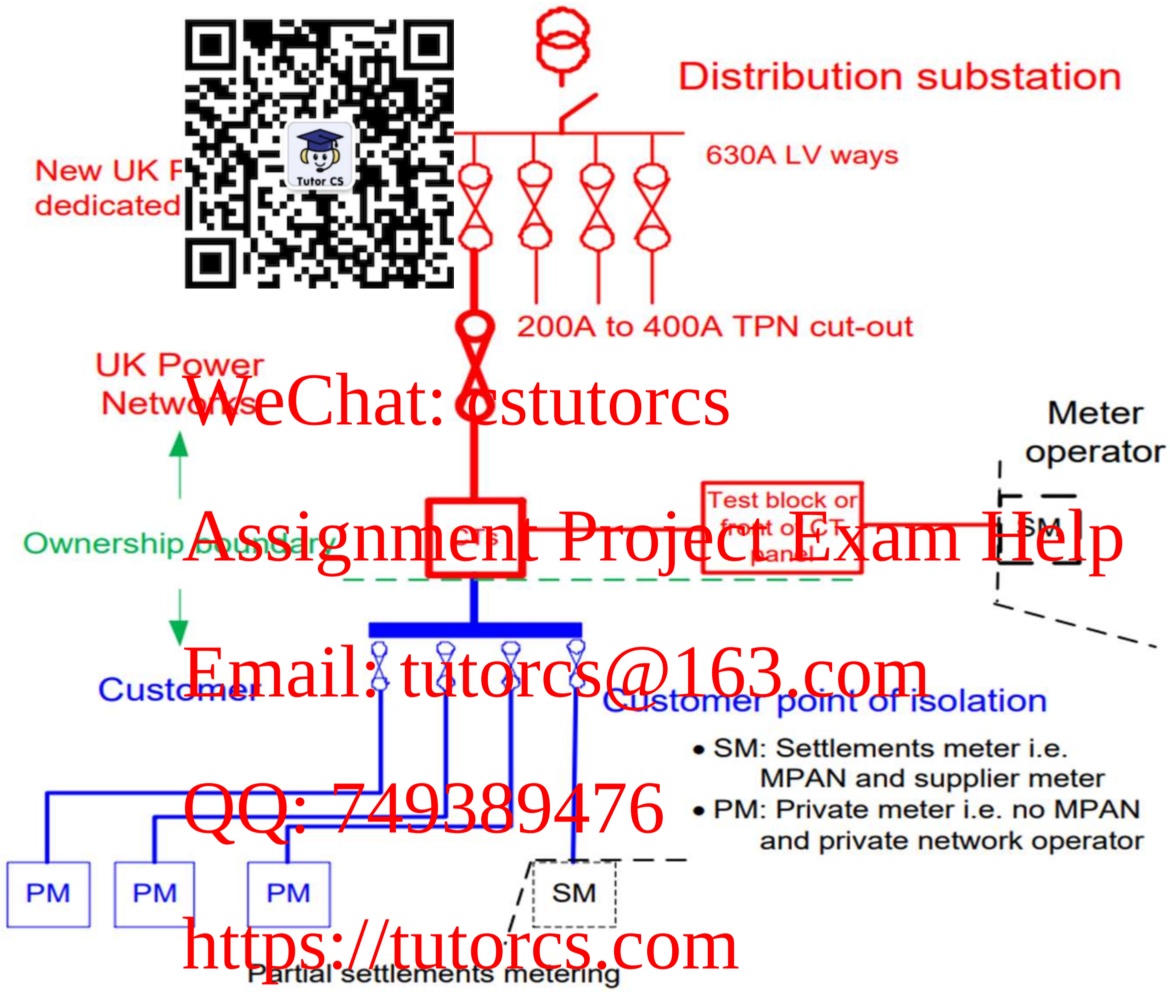
Assume highest acceptable LV transformer voltage 254V (assumes no load on transformer)

EDS 08-2100 LV CUSTOMER SUPPLIES (200A – 400A 3Φ supplies)



MPR (kVA)	Service Cable	Rating and Termination	Max. Fuse Rating (A)
70 - 138	95mm² Three-phase Aluminium Waveform	200A Three-phase cut-out	200
139 - 217	185mm² Three-phase Aluminium Waveform	400A Three-phase cut-out	315
218 - 277	300mm² Three-phase Aluminium Waveform	400A Three-phase cut-out	400

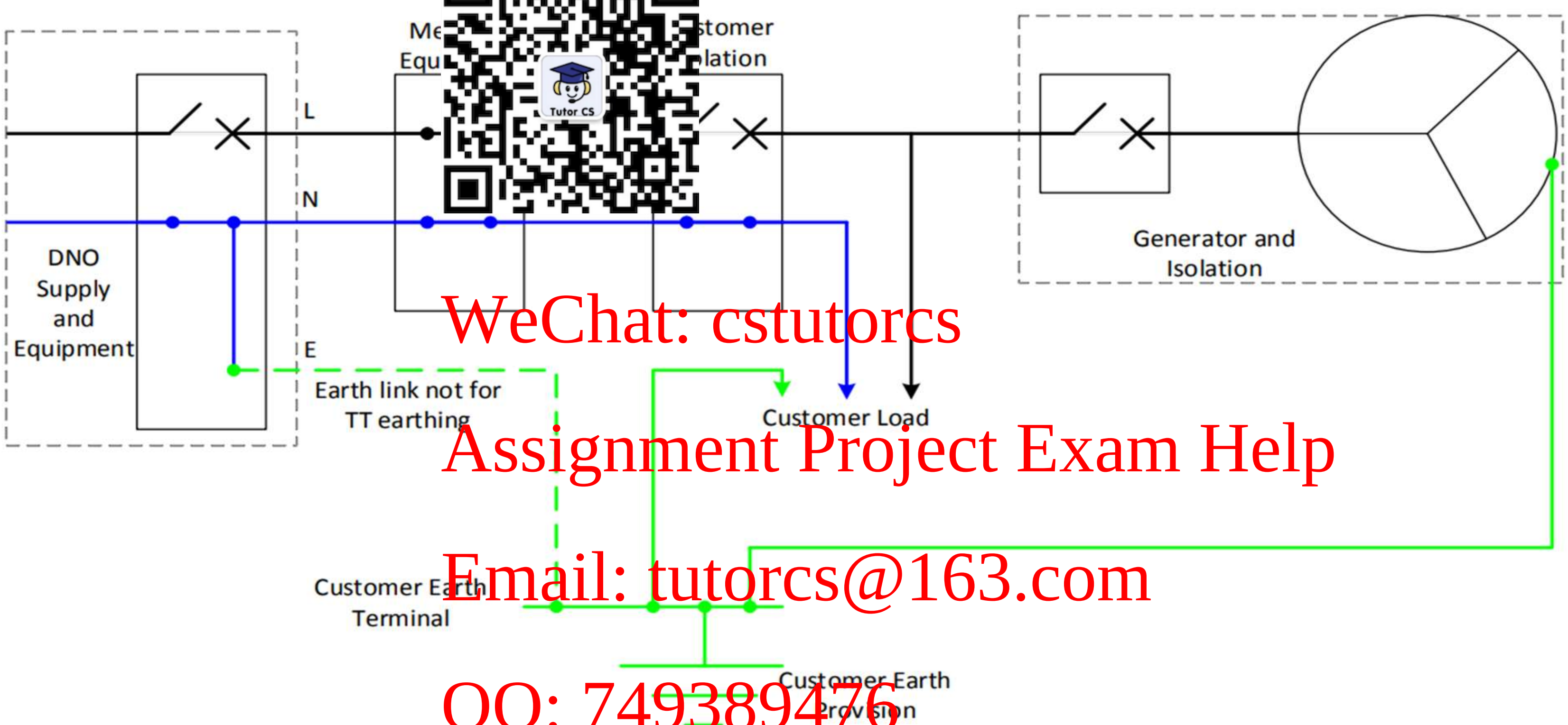
EDS 08-2100 LV CUSTOMER SUPPLIES: new supply from substation



EDS 08-2100 LV CUSTOMER SUPPLIES (800A – 1440A 3Φ supplies)

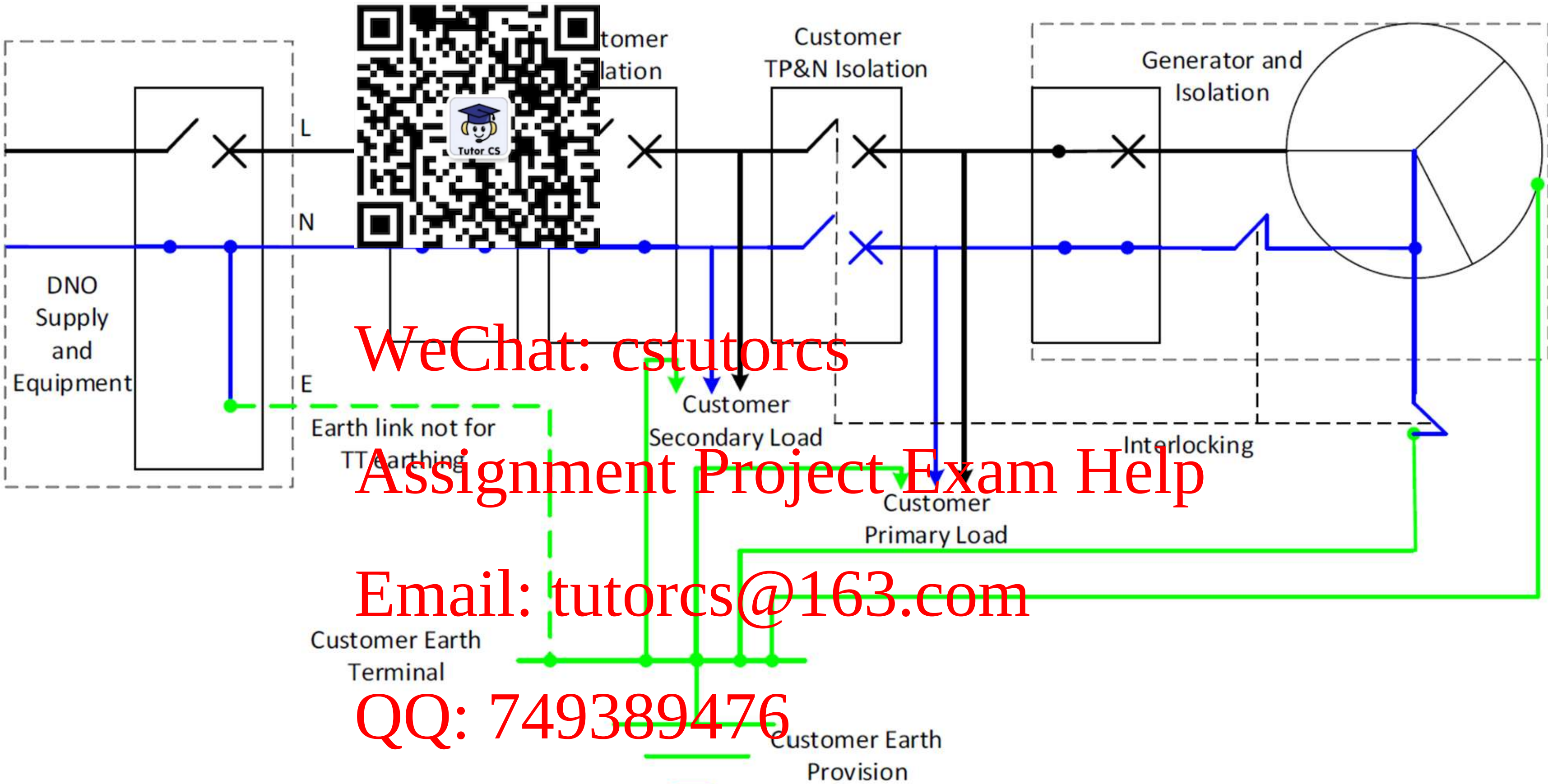
- A 800A to 1440A three-phase and ne pply shall be provided via an air-circuit-breaker (ACB) in a 5-way Transformer Mounted Fuse Cab th a spare 630A way and equipped with integral metering current transformers (CTs) on the ou de

LV Generation for Parallel Operation Only



- Earthing for an LV generator designed for parallel operation only shall be installed in accordance with ENA EREC G99 noting that independent neutral earthing for the generator is not a requirement where there is no application for standby generation.

LV Generation for Parallel and Standby Operation



Earthing for an LV generator designed for both parallel and standby operation shall be installed in accordance with G99.

Q & A

- I specifically wanted to discuss the issues a DNO faces as the UK moves to a lower carbon economy and restricts the use of natural gas and petroleum
- Later in the course we will discuss m… Heat Pumps and other low carbon technologies and their impact on transmission and distributi…
- Most experts expect domestic custom… …ntly increase their annual use of electrical energy.
- Main issue for networks is when people want to use the Energy.

- My personal view is a “smart” home will install an “Energy Computer” that talks with the Smart Meter, calculating your bill based on time of day pricing. Your computer will then decide based on a “cost & flexibility” optimisation algorithm when to charge the EV or when to operate home heating or cooling. Obviously the decision will also be based on the availability of PV energy and the capacity of your battery “electricity” storage systems and thermal heat/cold storage systems
  - Significant reduction in domestic energy costs is “easily” achievable with new build homes, but major challenges exist with many existing properties.
  - Situation is even worse in the rental sector, but can we imagine a situation where a landlord cannot rent-out a property unless its “Energy Performance Certificate” is an A or B rating.
  - Perhaps something similar is required when you sell your home, i.e. an Estate Agent cannot advertise it, unless the EPC rating is high.
- UK government commitments/promises/words about a low carbon energy future are impressive, but what will we achieve in the next 5, 10 or 20 years.