Electric Distribution Comparison – USA, Middle East, Europe

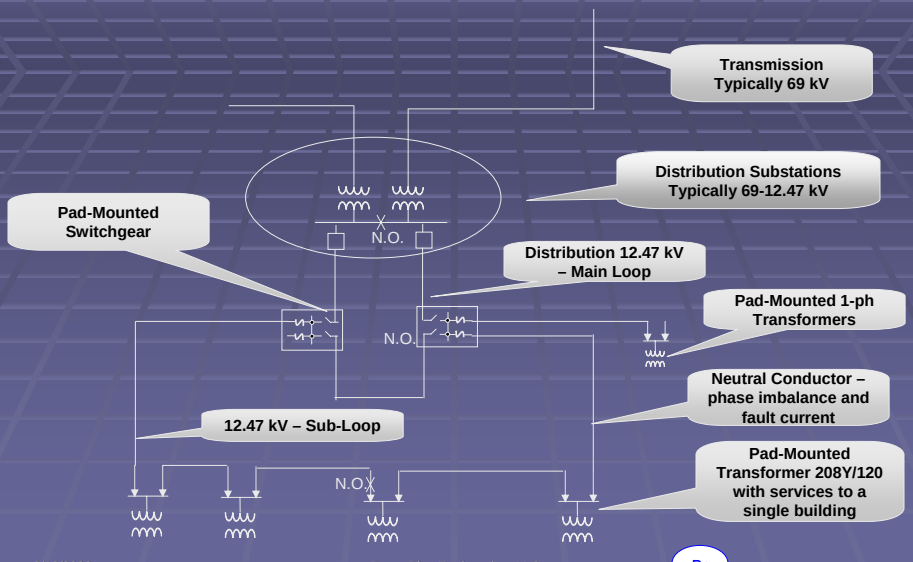
Comparison Areas

- USA – Midwest
- Middle East – United Arab Emirates
- Europe – Scotland and Germany

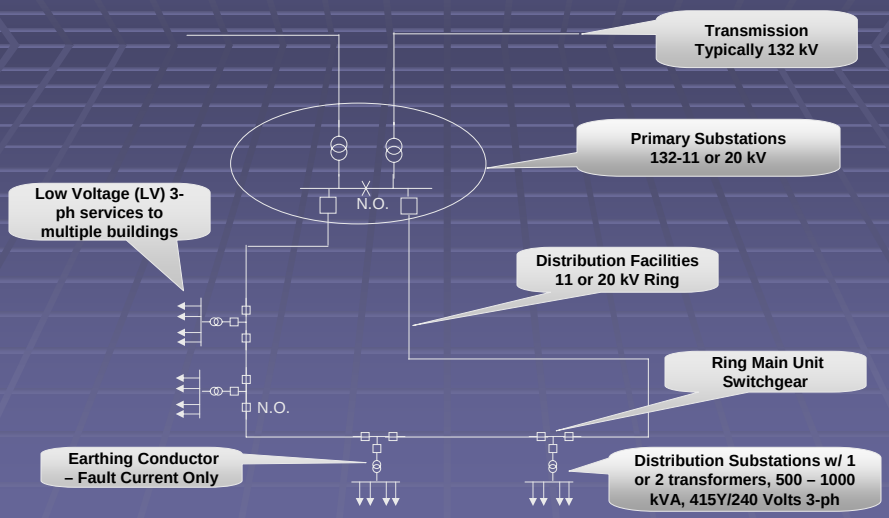
Distribution Comparison

- Substations
- Primary Feeders
- Secondary and Services
- Grounding and Neutrals
- Protection
- Reliability

USA – Electric Distribution



Europe and Middle East – Electric Distribution



Substations

	Urban		Rural	
Area	QTY	MVA	QTY	MVA
USA	2, 3	15, 30	1	5, 7.5, 10
Middle East	3, 4	40	2	15, 20
Scotland	3-5	7.5	1	7.5
Germany	3	40, 50		

Transformer Loading - % of Rated Capacity

Operation	USA	Europe	Middle East
Normal	80% to 100%	50 to 67%	50 to 80%
Emergency	120 to 150%	130%	100%

Primary Voltages

- USA – 12.47, 13.8, 25 kV
- Middle East – 11, 33 kV
- Europe – 11 and 20 kV (Some 6.0 or 6.6 kV that is planned for conversion to a higher voltage)

Europe and Middle East– Feeder Layout

- Underground feeders - loop feeds with open points, switching substations
- Overhead - radial for loads 1.5 MW or less and loop for loads greater than 1.5 MW
- Sensitive loads – primary selective, mesh primary and mesh secondary
- Underground areas with more than 1000 customers- mid-point circuit breakers with auto-sectionalizing

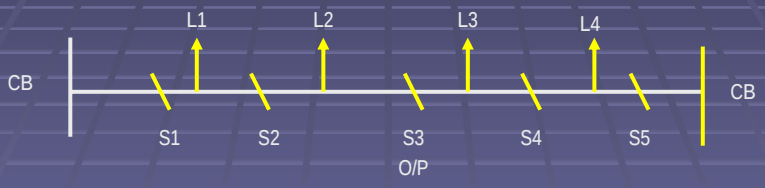
Feeder Configuration or Network Structure Options

USA	Europe/Middle East
Radial	Radial
Loop	Ring, Switching Subs
Automatic Sectionalizing	Automatic Sectionalizing
Primary Selective	Primary Selective
Primary Network	Primary Mesh
Secondary Network	Secondary Mesh

Radial Feeders – USA, Middle East and Europe

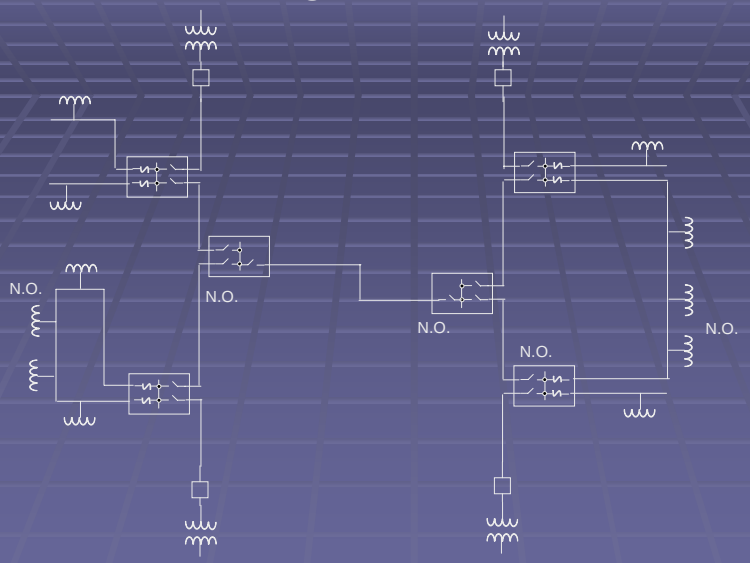
CB = Circuit Breaker L = Loads
S = Switches

Open-Loop (Ring) Feeder - USA, Middle East and Europe

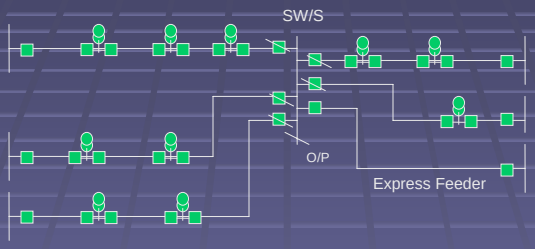


CB = Circuit Breaker O/P = Open Point
L = Loads S = Switches

USA – Underground Electric Distribution



Middle East – Downtown Areas with Switching Centers



Legend

SW/S – Switching Substation

Distribution Substations – Indoor with circuit breakers

O/P – Open Point

Substation Feeder circuit breaker

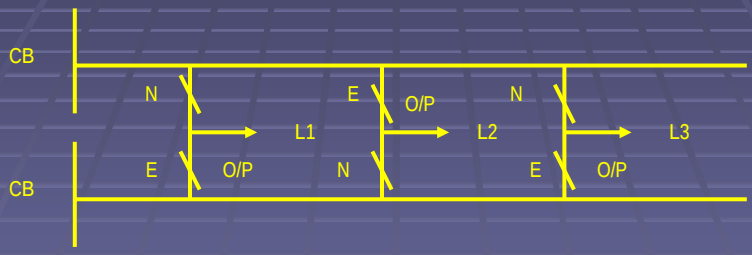
Automatic-Sectionalizing – USA and Scotland

- Three or more automatic switches between feeders

CB = Circuit Breaker	O/P = Open Point
S = Switches	
L = Loads	S-AS = Automatic Switch

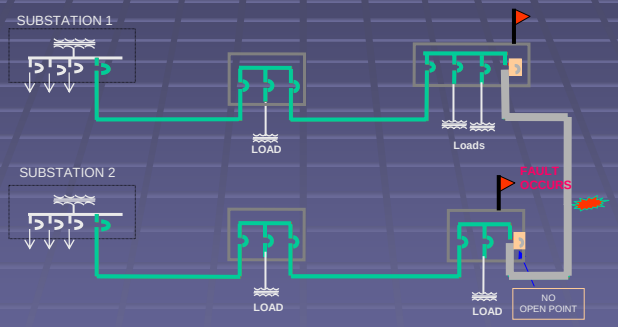
Primary Selective – USA and Middle East

- Normal and emergency source

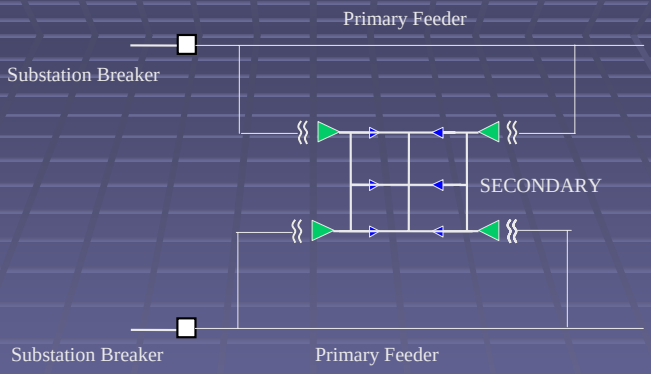


CB = Circuit Breaker	O/P = Open Point
E = Emergency Switch	L = Loads
N = Normal Switch	

Primary Network (Mesh) – USA and Scotland



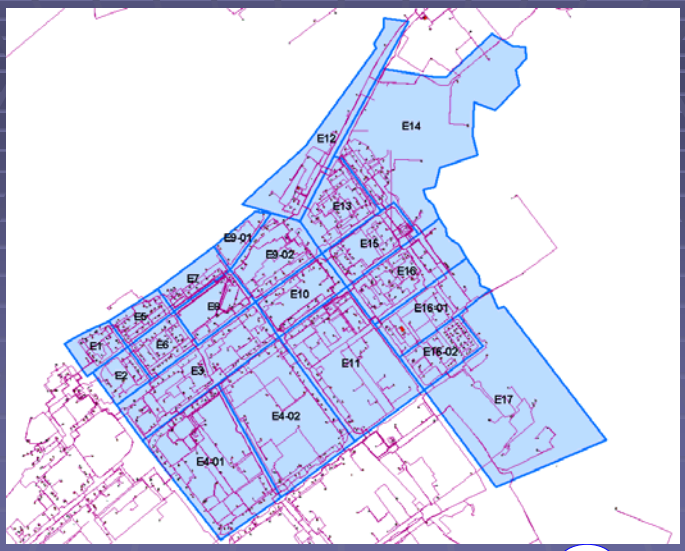
Secondary Network (Mesh) - USA



= Network transformer

= Network protector

Load Density Review



Configuration Based on Load Density

Area	Region	kVA/km²	kV	Configuration
Seattle, WA	Downtown	82,800	20	Secondary Mesh
Middle East	Downtown	74,000	11	Loop
Atlanta, GA	Olympic Village	31,000	20	Secondary Mesh
Philadelphia	Commercial	15,000	13	Primary Network
Middle East	Commercial	14,000	11	Loop
Urban - USA	Retail	10,800	14	Loop
Middle East	Retail	5,800	11	Loop
Middle East	Residential	3,7005	11	Loop
USA Midwest	Residential	2,900	14	Loop
Midwest	Rural	8	13	Loop/Radial

Overhead – Europe and Middle East – 3-Wire

Overhead - USA

Primary Cable and Conductor

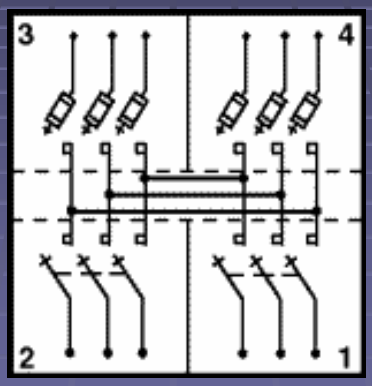
Type	USA	Europe	Middle East
OH	ACSR	ACSR or AA	Copper and some AA
UG	Jacketed Single Cable AL	Three-core cable - AL	Three-core cable - CU

Underground Primary Cables

- USA – Single jacketed cable, duct bank and conduits used in high load density areas
- Middle East – 3-core copper cables, limited use of conduit
- Europe – 3-core aluminum cables, limited use of conduit

USA - Switchgear

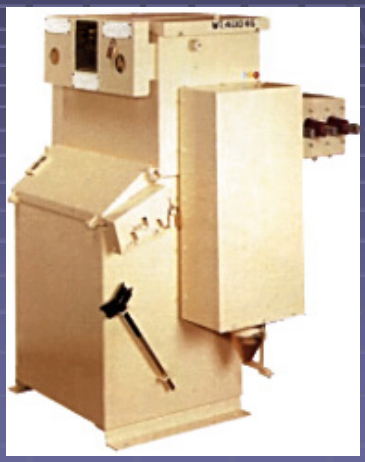
S&C PMH-9



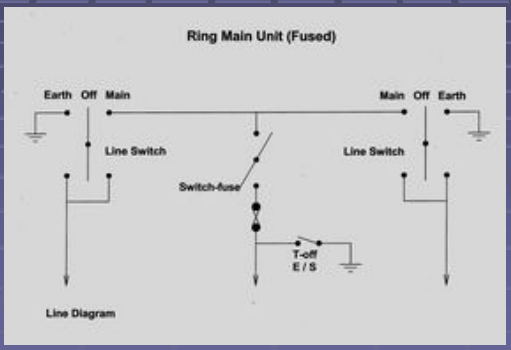
Ring Main Unit (RMU)

- Switchgear – Europe and Middle East
- Switches or circuit breaker on both sides of the T-off
- Tap – fuse or circuit breaker typically connecting to a transformer

Ring Main Unit Switchgear



Ring Main Unit



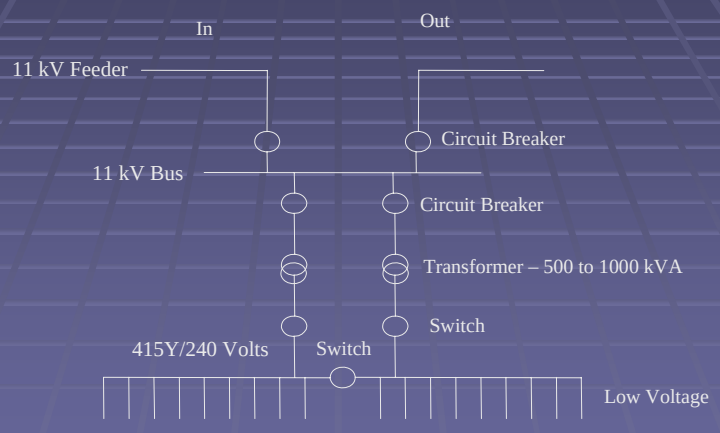
Transformers - Distribution

Type	USA	Europe	Middle East
OH	1-phase units, connected phase to neutral	1-phase connected ph-ph and 3-phase units	Three-phase units only
UG	1-phase and 3-phase units, various sizes	500 and 1000 kVA, 3-phase only	500, 750 and 1500 kVA, 3-ph only

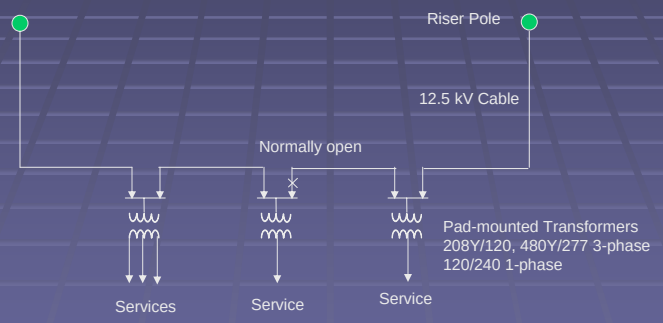
Europe and ME Distribution Substations

- Same function as overhead and pad-mounted transformers in USA
- 11 kV to 415Y/240 volts
- Equipment installed in buildings or within fenced area
- Typically 1 or 2 transformers
- Extensive secondary (low voltage)

Distribution Substation - Europe and Middle East



USA – Pad-mounted Transformers and Services



Secondary/Service Voltages

- USA – 120/240, 208Y/120, 480Y/277 volts
- Middle East – 415Y/240 volts (delta primary connected transformer)
- Europe – 415Y/240 volts (400Y/230) – delta primary connected transformer

Europe and Middle East - Low-Voltage Equipment

- Extensive secondary system (Low voltage or LV)
- Typical Service Lengths – 50 Meters
- Typical secondary length - 250 Meters
- Separate substation for buildings with demands of 500 kW and Above
- Voltage Drop on LV Cable – 5%

Services – Europe and Middle East

- Residential - 4 wire 3-phase service to the majority of houses
- 400 or 415 volts 3-phase, 230 or 240 volts 1-phase
- Household power outlet connection uses one phase and neutral
- Three phase is used for high power loads such as ovens, air-conditioners, dryers and water heaters

Service Voltages (volts)

Area	Residential	Small Commercial	Commercial and Industrial
USA	120/240 3-wire, 1-ph	120/240 1-ph and 208Y/120	208Y/120, 480Y/277, primary
Middle East and Europe	415Y/240 3-ph	415Y/240 3-ph	415Y/240, primary

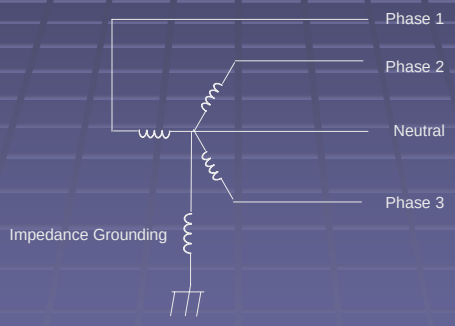
Primary Substation Transformer Grounding

- USA – Solid grounded
- Middle East – Impedance grounded
- Europe – Impedance or solid grounded

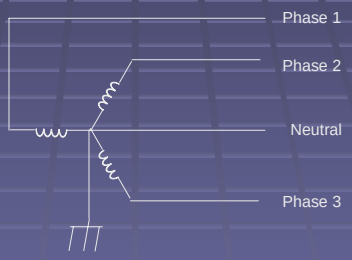
Grounding Practices

Area	Pri-UG	Pri-OH	Secondary
USA	4-wire grd Y	4-wire grd Y	3 and 4-wire grd
Middle East	4-wire grd Y	3-wire grd Y	4-wire grd Y
Europe	4-wire grd Y	4-wire grd Y	4 and 5 -wire grd Y

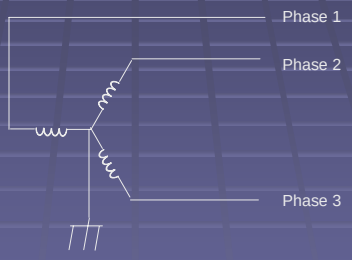
4 –wire impedance grounded neutral (ME and Europe)



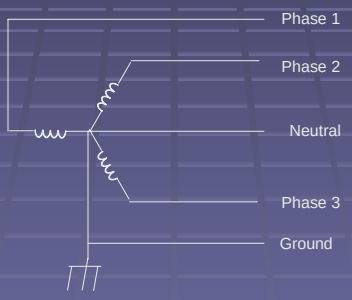
4 – wire solid grounded neutral (USA and Europe)



3 – wire solid grounded neutral Europe and Middle East Overhead



5 – wire service with separate neutral and ground - solidly grounded (some areas of Europe)



3 and 4 wire Wye Comparison

Factor	4-wire Y	3-wire Y
Fault Current	High	Low
Coordination	Better	Difficult
SEF (sensitive earth fault)	Can't use	Can be used
Transformer connections	1-ph and 3-ph	3-ph and ph-ph
Other	Neutral protects - contacts	SEF can detect ph-grd faults

Protection

Type	USA	Europe and Middle East
Underground	Phase and ground overcurrent	Phase and earth overcurrent
Overhead	Phase and ground overcurrent	Phase and earth overcurrent, Sensitive Earth Fault (SEF) – 1 - 20 amps setting
Field Reclosers	Used in rural overhead areas	Europe – rural overhead Middle East - none
Reclose Operations	2 - 4 – overhead 0, 1 or 2 - underground	Europe - 2 or 3 Middle East - none

Reliability - USA

- SAIDI - System Average Interruption Duration Index
- SAIFI - System Average Interruption Frequency Index
- N-1 for transmission and some distribution facilities - one component can fail without causing a sustained outage

Security Standards – Europe and Middle East

- CML - Customer Minutes Lost (SAIDI)
- CI - Interruptions/100 customers (SAIFI)
- Security Standards – repair time based on group demand of outage

Reliability

Description	USA	Europe and Middle East
Reliability	N-1	Repair time for group demand
Duration	SAIDI	CML
Frequency	SAIFI	CI
Regulation	Varies	Government

Security Standards – Europe and Middle East

Class of Supply	Range of Group Demand	Minimum Demand to be Met After First Circuit Outage
A	Up to 1.5 MVA	Group Demand within repair time
B	1.5 to 6 MVA	Group Demand within 3 hours
C	6 to 30 MVA	(a) 1/3rd of the Group Demand within 30 minutes (b) Group Demand within 3 hours

Reliability Metrics - USA

- Transmission – N-1 or higher
- Substation Transformers – N-1 in urban areas
- Distribution Feeders – N-1 in urban, radial feeders in rural
- N-1 for distribution may not be feasible during peak loading periods

Reliability Targets - Scotland

Index	Utility	Target	Actual
CML - minutes	SPD	87.7	74.5
CML - minutes	SPM	65.5	58.2
CI (per 100 cust)	SPD	66.4	65.8
CI (per 100 cust)	SPM	47.2	43.3

SAIDI Comparison (hours/year)

Service Area	SAIDI
Rural - Midwest	2.0
Rural/Urban - Midwest	1.4
Rural/Urban - Midwest	0.8
Rural - Midwest	2.1
Urban - Middle East	0.9
Rural - Middle East	3.6
Scotland – Urban and Rural	0.9
Singapore	0.1

Conclusion

- Distribution voltages are similar
- USA - phase to neutral connected transformers
- Europe and Middle East - 3-phase and some phase-phase connected transformers
- USA - primary laterals with transformers of various sizes
- Europe and Middle East – larger transformers and an extensive secondary serving many customers

Sources

- Cooper Power Systems, System Grounding – A Brief Tutorial, 2002
- Distribution System Performance Evaluation, Tabors Caramanis & Associates Inc. and EMA Inc., December 2003