APPENDIX A
QUESTIONNAIRE ABOUT DISTRIBUTION NETWORKS
SUMMARY OF RESULTS

1. Scope of this summary

This is the final summary of the questionnaire about distribution networks. It have been fulfilled by most of the members before the meeting of September in Dresden. During the meeting members have elaborated / updated / corrected their answers, and decided to add some items of interest for the scope of the WG. A complementary questionnaire has been sent.This summary includes all answers and constitute the basis for the first three chapters of our final report.

It must be noted that answers are sometimes related to the company of the member, sometimes to all companies in his country. Some figures are issued from complete statistics of the company or the country, others are issued from a sample. This heterogeneous nature of the figures must be kept in mind when reading this summary.

<u>List of answers :</u>

AU : OKA - Oberösterreichs Kraftwerke AG (Austria), organisation responsible for the majority of the distribution network of Upper Austria, one of the nine states of Austria.
B : ELECTRABEL (Belgium), integrated utility, covering 80% of the electricity distribution in Belgium
CH : ENSA - Swiss electric utility.
D : ESAG - Energieversorgung Sachsen Ost Aktiengesellschaft (Germany), electricity provider for urban power suppliers and 430000 customers.
E : IBERDROLA (Spain), servicing 57.000.000 Mwh per year to 8.160.000 customers
F : EDF - Electricité de France, integrated utility serving 320 000 MV and 28 600 000 LV customers.
I : ENEL (Italy) - Integrated utility serving more than 28 million of HV, MV and LV customers.

P : EDP - Electricidade de Portugal (Portugal), holding of 24 generation, transmission, distribution and selling companies ; the four distribution companies serve over 4.5 million customers

SF : Finland - figures from VTT - average for Finnish distribution companies (over 115 at the moment).

2. Network structure

2.1 MV networks

2.1.1 Urban / rural

Each of the distribution companies operates from 1 to 150 distribution networks. The urban or rural nature of the network is one of the major issues that differentiates them. Urban networks are generally short and underground, rural networks are usually long overhead (except in Germany and Belgium). Many characteristics of networks can be explained when considering the urban or rural feature.

2.1.2 Operation

All MV networks are always operated radially (AUSTRIA : 2% meshed).

2.1.3 Network structure

	AUSTRIA	ELECTRABEL	ENSA	GERMANY	EDF	ENEL	EDP	FINLAND	IBERDROLA
Meshable	~70%	10%	50%	75%	U: 100% R: 70%	90% of main feeders 10% of laterals	Urban and semiurban areas	50%	U:100% R:60-80%

The structure of the MV network is largely meshable (feeders can be backfeed by adjacent lines) in urban areas, a bit less in rural areas by problem of cost

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2.1.4 Current voltage levels

	AUSTRIA	ELECTRABEL	ENSA	GERMANY	EDF	ENEL	EDP	FINLAND	IBERDROLA
MV	U:10 kV R:30 kV	15 kV (35%) 11 kV (26%)	17 kV	10 kV (51%) 20 kV (43%)	20 kV (83%)	15 kV (40%) 20 kV (52%)	R : 30/15 kV U : 15/10 kV	20 kV (90%)	15kV(50%) 20 kV (50%)

As it could be expected, the most common MV voltage levels are 10, 15, 20 and 30 kV. No value is dominant thorough those utilities.

2.2 LV networks

All LV networks are operated radially. Some LV networks are also meshable :

	AUSTRIA	ELECTRABEL	ENSA	GERMANY	EDF	ENEL	EDP	FINLAND	IBERDROLA
Meshable	~10%	0%	1-2%		some urban areas	10% (urban areas)	urban areas	30%	

3. Primary substation

3.1 Transformers

Primary substations have generally from 1 to 4 HV/MV transformers. 1-2 transformers are the most typical values.

3.2 Information transmitted to the Distribution Control Centre (DCC)

3.2.1 Remote signals

	AUSTRIA	ELECTRABEL	ENSA	GERMANY	EDF	ENEL	EDP	FINLAND	IBERDROLA
Switch position (close/open)	yes	yes	yes	yes	yes	yes	yes	yes	yes
Circuit breaker position	yes	yes	yes	yes	yes	yes	yes	yes	yes
Fault detection	yes	yes	yes	yes	yes	yes		yes	10%
Relay operation	yes	yes	yes	yes	yes	yes	yes	yes	yes
Cause of the event	yes	yes				yes		yes	
Recloser information	yes	yes	no	yes	no	yes	no	yes	no
Type of fault	yes	some	yes		some	yes	some	yes	50%

Fault detection : a fault current has been detected
Relay operation : the opening order has been sent by the relay.

+ The remote signals sent to the DCC form the set of events to be interpreted by operators or by alarm processing software. Differences from one country to another may explain the need or the difficulty for alarm processing software.

3.2.2 Remote measurements

Remote measurements can be obtained by different ways : cyclic polling, polling on demand, threshold surpassing, ...

	AUSTRIA	ELECTRABEL	ENSA	GERMANY	EDF	ENEL[1]	EDP	FINLAND	IBERDROLA
HV-feeder	U, I, some P, Q			P, Q, U, I (110 kV only)	U	U, I			P,Q
HV/MV transformer (secondary)	petersen coil, U, I, P, Q	P, Q, S	P, Q, I	I , temperature, petersen coil	P, Q, I	P, Q	P, Q	P, Q, I	P,Q,I
Busbar (MV)		U	U	U	U	U	U	U	U
MV-feeder	U, I	I	U, I	I	I	I	I	I	I
Fault current	fault reactance	no	no	yes (value)	no	no		yes (value)	no
Position of load tap changers	yes			yes	no	yes	yes	yes	yes

+ It seems that measurements are quite similar from one company to another. The main (and important) difference concerns fault current measurement that may allow fault distance calculation.

3.3 Number of feeders by substation

	AUSTRIA	ELECTRABEL	ENSA	GERMANY	EDF	ENEL	EDP	FINLAND	IBERDROLA
Average		11		13		13.4			6
Urban	4		10-20		7		15-20	10	15-25
Rural	5		5-10		10		5-10	7	3-10

+ No obvious conclusion. More feeders in urban substation than in rural substation in some countries (ENSA, EDP, FINLAND). The opposite in some others (AUSTRIA, EDF).

4. Feeder profile

	AUSTRIA	ELECTRABEL	ENSA	GERMANY	EDF	ENEL	EDP	FINLAND	IBERDROLA
Length (km)	U: 4 R: 33	U: 10 R: 17	U: 3-10 R:15-20	13	U: 7 R : 35	U: 5.1 R: 16.4	U: 4-8 R: 5-10	U: 9 R: 32	U:7 R: 30
Load (MVA)	U: 2-3 R: 5-8	U: 5-6 R: 2	U: 5-10 R: 0.5-5	1-1.5	U : 2-5 R :1-1.5	U : 3.7 R : 3.5	R: 1 U: 2-3	U: 2 R: 1	U: 2 R: 3
Remotely cont. sw(1)	U: 0 R: 1-2	1.2	0-3	0	0-3 (1.3 av.)	0 – 3.5	not generalised	U: 0.2 R : 1.2	U:0 R:0,3
Remotely cont. Fault det(1)	U : 0 R : 1-2	U : 1-2 R : 0	0-3	0	idem sw	0 – 3.5	rarely used	U : 0.1 R : 0.2	U:0,1 R:0,3
Total fault detectors	U : 0 R : 10-12				U : 15 R : 10				U:250 R:800
Types of fault detectors	Current detectors	Current detectors	Fault current, directional det.		Fault current	Fault current		SC : overcurrent EF : sum current	Current detectors
MV/LV stations per MV feeder	U: 7 R: 35	18	U:10-15 R:30-50	22	U : 15 R : 40	U: 8.9 R: 15,5	U: 5-10 R: 20-40	U: 15 R: 30	15
Nb of cust per MV/LV station	U : 40 R : 150	76	1-500	<400	44 average	84 average	U :250-500 R : 50-100	U : 100 R : 25	125
automatisation of secondary substations	reclosers, automatic switching (not RC)				reclosers, sectionalisers	sectionalisers	reclosers and sectionalisers		10 under test
Ratio of remotely controlled MV/LV substations	1 %	0	only in some cases	0		it will be 12.5 – 17.5	very low (but increasing)	~ 0	2%

	AUSTRIA	ELECTRABEL	ENSA	GERMANY	EDF	ENEL	EDP	FINLAND	IBERDROLA
Power quality moniting	no	no	static recorders	no	static recorders systematicl. Installed	no	data management trough quality service application	some portable analysers	50 recorders rotating and several portable

U : Urban / R : Rural (exact definition may change a bit from one country to another one)
SC : Short Circuits / EF : Earth faults
(1) : outside the primary substation

4.1 Comments

a) Rural feeders are longer than urban feeders, but in some utilities they supply more load (in average).
b) LV connection to the MV network is always 3-phased.
c) Some utilities begin to have an interest in power quality monitoring.

4.2 Remotely controlled devices (switches and fault detectors)

a) Level of equipment in remotely controlled devices varies a lot from one utility to another or for rural region versus urban area.
b) Networks with sustained operation have less faults seen by the customers, so a lesser motivation for remotely controlled devices on MV network (GERMANY, AUSTRIA, ENSA).
c) The common transmission mode for remotely controlled devices is radio or telephone by a cyclic connection or when events occur. In Italy, an important use of dlc (distribution line carrier) should be noted – other technologies are also considered.

+ Consequences for fault location and restoration software are important. Fault location may be based on remotely controlled fault detectors. Power restoration will use, for the automatic step, remotely controlled switch devices.

4.3 Others devices and automatism (outside the primary substation)

The following equipment may be found on MV network (outside the primary substation).

- Reclosers (ENSA, GERMANY, ELECTRABEL, AUSTRIA, EDF, EDP, IBERDROLA)
- Sectionaliser (AUSTRIA, EDF, EDP, ENEL, IBERDROLA), co-ordinated with the substation reclosers.
- Automatic switching of MV/LV substation to unfaulted feeders (AUSTRIA, EDF).

4.4 Medium voltage customers

FINLAND : I, U, EDP, Q remote metered for some of the MV customers.

5. Protection scheme

5.1 Types of MV neutral grounding

	AUSTRIA	ELECTRABEL	ENSA	GERMANY	EDF	ENEL	EDP	FINLAND	IBERDROLA
Isolated	4%	3%	yes			**100%**		**80%**	
Directly grounded									**70%**
Impedant grounding		**95%**			**~100 %**		**100%**		30%
compensated grounding	**91%**	2%	yes	**yes**	4 networks and increasing	Study		20%	
compensated + short term grounding	5%			yes					

The four main types of neutral grounding are used in at least one of the utilities : isolated (ENEL, FINLAND), rigid (IBERDROLA), impedant (ELECTRABEL, EDF, EDP) and compensated (AUSTRIA, GERMANY). This have important consequences over the protection scheme and the types of faults encountered by each company. We see a trend (EDF, ENEL) to evolve towards compensated grounding.

5.2 Main feeders protections

	AUSTRIA	ELECTRABEL	ENSA	GERMANY	EDF	ENEL	EDP	FINLAND	IBERDROLA
Definite time current relays	yes	yes	yes	yes	yes	yes	yes	yes	yes
Inverse time current relays		yes			yes		yes		yes
Fuses									
Distance protection	yes		yes	yes					
Zero-sequence relay		yes		yes	yes	yes	yes	yes	yes
Shunt					yes	Yes (in some situations)			
Reclosers at substation	yes (rural)	yes (overhead)	yes (overhead)	yes	yes (rural)	yes (always)		yes (overhead)	yes
Reclosers on MV networks	few	Yes (overhead)	yes		yes (rural)	no	yes	no	yes
automatic sectionalizers	yes	Yes (overhead)	no		yes (rural)	yes	yes	no	yes

All countries use definite time current relays. AUSTRIA, ENSA, GERMANY use distance protections.
It seems that the " shunt " technique to eliminate ground faults is only used by EDF, ENEL. All countries use reclosers to eliminate selectively non permanent faults in rural networks.

5.3 Protection of MV/LV transformers

	AUSTRIA	ELECTRABEL	ENSA	GERMANY	EDF	ENEL	EDP	FINLAND	IBERDROLA
Circuit Breakers	yes		yes		yes		yes		
MV Fuses	yes	yes	yes		some	cabin		cabin	yes
LV Fuses	yes, > 400 kV	yes	yes	yes	yes	cabin	yes	yes	yes
None			yes			Pole mounted		Pole mounted	

6. Power producers

Size of power producers connected to MV lines, and types of information transmitted to the DCC :

	AUSTRIA	ELECTRABEL	ENSA	GERMANY	EDF	ENEL	EDP	FINLAND	IBERDROLA
Size (MW)	0.5–4	0.5–15	0.025–10	0.05–2	0.4–10	0.1–6	no standard	<= 1	1-5
Connected to DCC ?	no	yes	yes	no	Soon		exceptionnaly	yes	Soon
Information transmitted		control	P, I, switch		P, Q, U, Switch		P, U, I	P, U, I, Switch	P, Q, U (soon),
Order to trip									yes

There is a great variability of sizes of power producers connected to MV lines. It seems that the limit are the physical ones (thermal limits of lines and transformers, etc.). Few companies link power producers to DCCs, but we see a trend in several countries to link them in the near future. Several fault management functions need to know the state of the power producer in order to react optimally in case of fault.

+ How to compute load-flow without measurements from power producers ? How to perform restoration without accurate load-flow ?

7. Fault statistics

	AUSTRIA	ELECTRABEL	ENSA	GERMANY	EDF	ENEL	EDP	FINLAND	IBERDROLA
Definition of permanent fault	>0,5 s. > 3 min (if autoreclosure)	Fault not cleared	not cleared after restoring voltage	>2.5 s.	Fault not cleared	> 3 minutes	not temporary	not cleared by reclosers	> 3min
Non permanent faults	70/80% (short circuits only)	Not available	90%	53% (self-extinguished not included)	95%	88.7%	62%	60%	70-90%
Earth faults	permanent 10% (rural)	Not available	75%	25%	75%	62.2%		50%	75%
Frequency of faults	U: <1 R: 1-20 (rarely)	0.97			U: 0-1 R: <25	U: 2.7 SU: 3.3 R: 6		U : 0.1 R:2.5/4.0	42 per 100 km
Duration of Interruptions	U : <30 min R: 15m - some hours	44 m	4h (MV) 2h (LV)		20m to several hours	U: 44 m SU: 47 m R: 59 m	U: 150m R: 180m	U: 0.5-1h R: 1-3h	U:90 % <2h R:90% < 2,5h

Frequency of faults is given in faults per customer per year, except in France that are given per year and per 100 km of network.
U : urban, SU : semi-urban, R : rural.
P : permanent, T : temporary
EF : earth faults, SC : short circuits

- In countries with compensated grounding (AUSTRIA, GERMANY) earth faults are not the majority, but in countries with others types of grounding earth faults represent the majority of faults, specially in ENSA, EDF.
- Frequency of faults : we see a great variability between countries, and within each country between urban and rural areas.
- Duration of faults : no obvious conclusion, it ranges from some seconds to several hours. The average value seems to be somewhere around one hour. This leaves way to improvements from new fault management functions.
- Big differencies between rural and urban areas

+ How reduce the duration of faults ? Detection, telecontroled devices, fault management crews on field ? What is expected ?

8. Quality and cost supply

	AUSTRIA	ELECTRABEL	ENSA	GERMANY	EDF	ENEL	EDP	FINLAND	IBERDROLA
outage costs are hard or soft ?	Hard	Hard	Soft	Soft	Hard	Hard	Hard	Hard	Soft
Compensation / penalties ?	No	Very limited trend (but can change)	Rarely (but changing)	No	Yes, for most MV customers	No	In exceptional cases	No (probably coming)	Rarely (but changing)
Quality agreements ?	No	Only some local arrangements (but can change)	Not yet	No	Yes, for most MV customers	No	Yes	Very uncommon	Rarely

Hard costs = outage costs are real costs when deciding investments.

Today there is few compensation for faults and few quality agreements with customers (except in EDF). Some countries have indicated a trend towards some compensation, but is far from common.

9. SCADA and DCC

9.1 DCC

	AUSTRIA	ELECTRABEL	ENSA	GERMANY	EDF	ENEL	EDP	FINLAND	IBERDROLA
Number of DCC	5 (one company)	9 (trends : 5)	400-600	3	~ 100 (trends : ~30)	24 (trends : 14)	20	115	20
Size of the MV network [(1)]	8 PS - 110 RCS	50-100 PS 500-1500 MVA			~ 20	50 PS	U: 10-15 PS R: 2-5 PS	2-30 PS <100 RCS.	35
Control part of the HV network ?	no	Yes (trends : no)	sometimes	No	no	The HV/MV SCADA controls HV busbars	yes, at the substation	yes	no

(1) : load (MVA), primary substations (PS) and remotely controlled switches (RCS)

9.2 Fault management software

	AUSTRIA	ELECTRABEL	ENSA	GERMANY	EDF	ENEL	EDP	FINLAND	IBERDROLA
Fault location software	fault reactance, detection of faulted segments	No	no	Yes	In trial	Yes	Planned	distance computation, fault detectors	Planned
Automatic switching system	Not in SCADA	No	no	no	In trial	Yes	Planned	3 systems in trial use	Planned
Field crew management	No	Not on SCADA	no	no	no	Development, outside SCADA	Planned	In trial use	Planned
Trouble call handling	No	Not on SCADA	no	no	Planned	Development, outside SCADA	Not linked to SCADA	In trial use	Planned
Customer information software	No	Not on SCADA	no	no	no	Development, outside SCADA	Planned	In trial use	Not on Scada
Dispatcher training software	No	Yes	no	Yes	no	Yes	No	No	Yes