Quality of Electricity Supply in Market Driven Environment

Prof. Jovica V. Milanović

(*e-mail:* milanovic@manchester.ac.uk)

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The University of Manchester

School of Electrical & Electronic Engineering

Manchester M60 1QD, United Kingdom

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Overview of the presentation

- Power Quality definitions
- Consequences (financial) of inadequate Power Quality
- Performance Objectives
- PQ contracts

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"Quality of Electricity Supply"

- Voltage quality (power quality)
  - Covers mainly disturbances in power system
  - Principally deals with the quality of supply voltage waveform
  - Complex physical interaction between electricity supply a end-user's equipment
- Commercial quality (generally relates to individual agreements between the utility and end-use customers)
  - Conditions for (re)connection of individual customers
  - Installation of measurement equipment
  - Regular (billing and meter reading) and Occasional (response to problems and complaints) transactions
- Reliability (measure of the ability of the network to meet continuously changes in customer demand)
  - Adequacy – the availability of sufficient network capacity to guarantee supply of electricity to customers on longer run (no interruptions under normal operating and demand conditions)
  - Security – the ability of (adequately designed) network to withstand disturbances, i.e., customers continue to be supplied

What is "Power Quality" ?

- Power Quality is a collection of various subjects which utilities have traditionally dealt with individually:

Interruptions	Harmonics
Sags (Dips)	Capacitor switching
Flicker	Lightning Surges
Voltage Regulation	(Reliability)

- It covers all areas from the generation plant to the last customer in the chain of electricity supply
- It is a measure of how the elements affect the system as a whole and vice versa.

Power Quality requires looking at the whole picture!

Why are we interested in Power Quality?

Electricity is a *PRODUCT*,

so what are the quality requirements for that product?

- Deregulation of electrical utility industry.
  - Regulatory pressure on utilities.
- Increased awareness of power quality issues by the end users.
  - Load equipment is/becoming more sensitive to power quality variations than in the past.
    - ➢ Increasing penetration of nonlinear loads (harmonics).
    - ➢ Growth in application of high-efficiency variable speed drives (VSD) and shunt capacitors for power factor correction.
  - Efficiency concerns and power factor correction considerations.
- Increased penetration of "non-conventional" types of electricity generators
- Interconnections of networks and highly automated industrial processes.

What is "Good Power Quality"?

- If the voltage:
  - Has a constant sine wave shape with fundamental frequency only
  - Is supplied at constant frequency
  - Forms a symmetrical three-phase power system
  - Has a constant RMS value, unchanged over time
  - Is unaffected by load changes
  - Is reliable, i.e., energy available when required

Business interruption costs

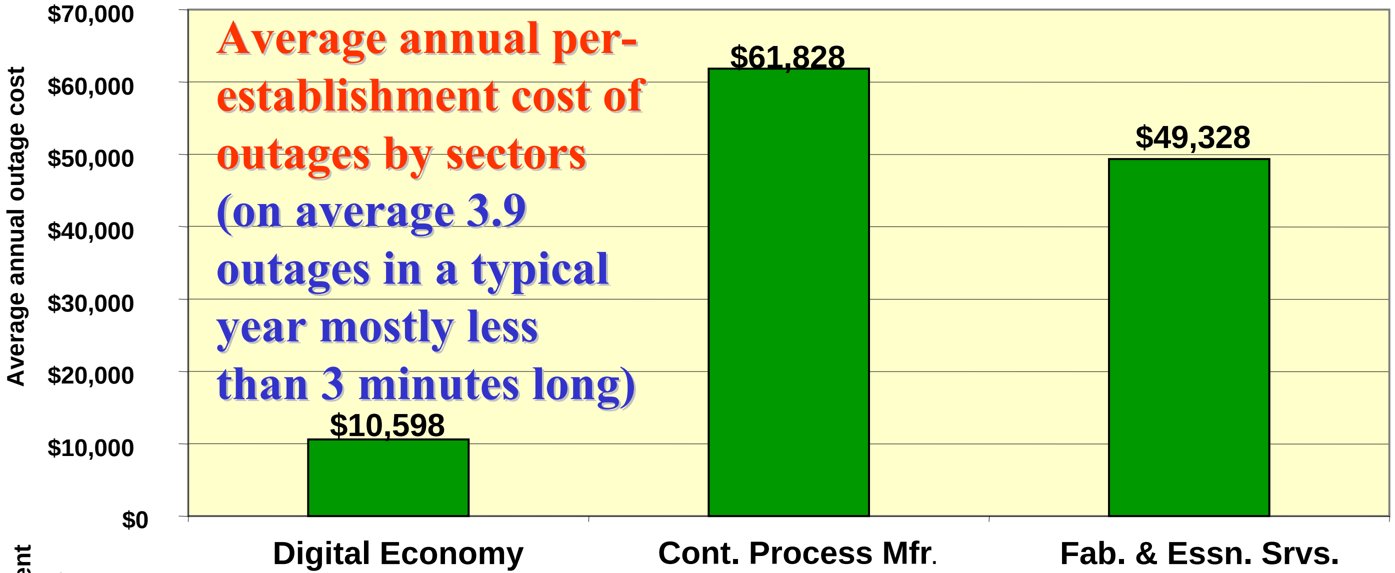
Industry Sector	£ Revenue/Hour	£ Revenue/ Employee/Hour
Energy	£ 1,601,048	£ 334
Telecommunications	£ 1,174,002	£ 106
Manufacturing	£ 915,144	£ 76
Financial Institutions	£ 849,507	£ 613
Information Technology	£ 763,898	£ 104
Insurance	£ 688,888	£ 210
Retail (Headquarters)	£ 629,132	£ 138
Pharmaceuticals	£ 614,915	£ 95
Banking	£ 566,364	£ 74
Food/Beverage Processing	£ 456,927	£ 86
Consumer Products	£ 446,431	£ 72
Chemicals	£ 400,057	£ 110
Transportation	£ 379,878	£ 61
Utilities	£ 365,482	£ 216
Health Care	£ 361,380	£ 81
Metals/Natural Resources	£ 329,879	£ 86
Professional Services	£ 302,562	£ 56
Electronics	£ 271,230	£ 42
Construction & Engineering	£ 221,364	£ 122
Media	£ 193,427	£ 68
Hospitality & Travel	£ 187,871	£ 22
Average	**£ 558,066**	**£ 131**

Revenue/Hour
£0.2M - £1.6M

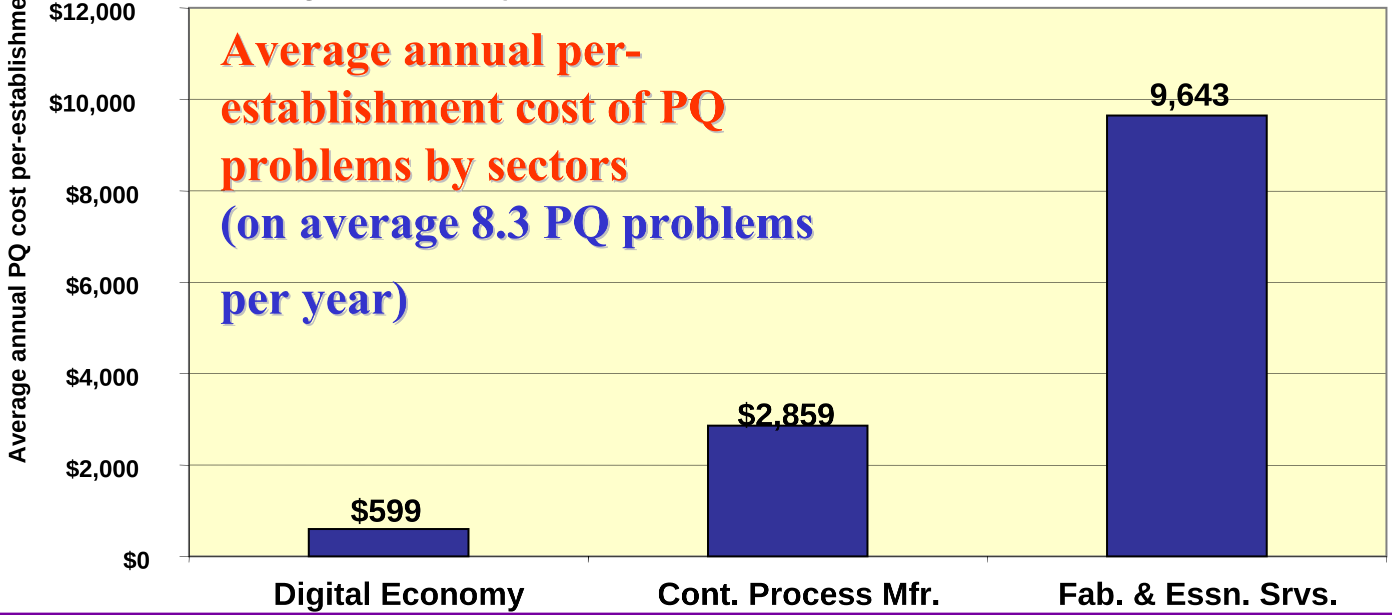
Revenue/
Employee/
Hour
£22 - £613

Source: META Group (www.metagroup.com), 2003; Converted to £, 2005

Annual outages and PQ costs



Total losses due to outages are about **$45.7B/yr** ($23K/plant/yr)
US economy loses **$104 - $164B/yr**



Total losses due to PQ are about **$6.7B/yr** ($3,406/plant/yr)
US economy loses **$15 - $24B/yr**

(9%-23% of costs of outages)

Source: EPRI's CEIDS Report – 2001

Most affected industries

- **The digital economy (DE):**
  - Firms that rely heavily upon data storage and retrieval, data processing, or research and development operations (telecommunications, data storage and retrieval services (including collocation facilities or Internet hotels), biotechnology, electronics manufacturing and the financial industry)
- **Continuous process manufacturing (CPM):**
  - Manufacturing facilities that continuously feed raw materials, often at high temperatures, through an industrial process (paper, chemicals, petroleum, rubber and plastic, stone, clay, glass and metals)
- **Fabrication and essential services (F&ES):**
  - Other manufacturing industries, plus utilities and transportation (railroads and mass transit, water and wastewater treatment, and gas utilities and pipelines)

These three sectors account for roughly 2 million business establishments in US which are about 17% of all US business establishments but contribute about 40% of US GDP.

Source: EPRI's Consortium for Electric Infrastructure for a Digital Society Report – 2001

PQ Legislation

- Minimum set of standards introduced in most EU countries based on EN50160
    - ➢ Strictly valid for V<35kV
    - ➢ Mandatory requirements for limited number of indicators
    - ➢ Indicative values for the others
    - ➢ Standards apply only for 95% of the time
  - – Some countries (Norway, France, Portugal, The Netherlands) adopted or improved EN50160
  - – Network operators in many other countries are obliged to verify PQ complains of individual customers
    - ➢ At customers expense if the PQ meets the standard
    - ➢ There is no penalty yet, only obligation that network operator improves PQ to fulfill minimum standard requirement
  - – There are complaints procedures in many countries (UK, Norway, Hungary, Latvia, Ireland, etc.) that include maximum response time (e.g., to visit customer within 7 days in the UK).
    - ➢ Otherwise some payment to the customer follows £20 - 75 euros.
    - ➢ Corrections sometimes have to be done within 12 months.

Incentives?

- There is NO incentive regulation for PQ as there is for reliability (interruptions)
- There are special PQ contracts in some countries

Survey in Norway established that costs of short interruptions (<3min) are comparable to costs of long interruptions (>3min) which are considered in reliability regulation!

	VOLTAGE QUALITY STANDARDS DIFFERENT FROM EN 50160
Supply voltage variations	ES, FR*, HU, NO, PT (only for EHV-HV customers)
Rapid voltage changes	NO
Flicker severity	NO, PT (only for EHV-HV customers)
Voltage dips	FR* (customised engagement on request only for MV and HV customers)
Temporary or transient overvoltages	FR*
Voltage unbalance	FR*, NO
Harmonic distortion of voltage waveform	FR*, NO, PT
Interharmonic voltage	None
Mains signalling voltage	None

(*) In France the voltage quality limits are set in the contracts between the customer and the distribution/transmission operator; the regulator surveys the contracts but does not set standards.

Source: Third benchmarking report on quality of electricity supply, Council of European Energy Regulators ASBL, RPM 0861.035.445

Summary of Harmonic Objectives

HARMONIC VOLTAGE OBJECTIVES			International standards or guidelines		Regional or national standards or guidelines						
Standard / Document			IEC 61000-2-12: 2003 [11]	IEC 61000-3-6: 1996 [1]	CENELEC EN50160:1999 [5]	ANSI/IEEE 519:1992 [7]		NRS048-2:2003 [6]	EDF Emeraude contract – A. 2 [8]	ER G5/4:2001 [9]	H.-Q. Voltage characteristics [10]
Purpose			Defines compatibility levels for MV public networks	Indicative Planning levels for controlling emissions	Supply voltage characteristics for public networks	Recommended practice for emissions and system design values		Minimum standard used by the regulator	Supply voltage characteristics	Planning levels for the connection of non-linear equipment to public network	Information on supply voltage characteristics
Objectives MV	Voltage level		1 to 35 kV	1 to 35 kV	1 to 35 kV	120V to 69kV		1 to 44 kV	1 to 50kV	6.6 to 20 kV	0,75 to 34,5 kV
	Order		h ≤ 50	Typically h ≤ 40	h ≤ 25	All order		h ≤ 40	h ≤ 25	h ≤ 50	h ≤ 25 +THD
	Levels	Odd	(e.g.: 6% at h=5) See Table 3	(e.g.: 5% at h=5) See Table 3	(e.g.: 6% at h=5) See Table 3	3% all order		(e.g.: 6% at h=5) See Table 3	(e.g.: 6% at h=5) See Table 3	(e.g.: 3% at h=5) See Table 3	(e.g.: 6% at h=5) See Table 3
		Even				3% all order					
		THD	8%	6,5%	8%	5%		8%	8%	4%	8%
Objectives HV-EHV	Voltage level		Not applicable	>35 kV	Not applicable	>69 to 161 kV	>161kV	> 44 to ≤400 kV	>50 kV	20 to 400 kV	≥44 to ≤315 kV
	Order			Typically h ≤ 40		All order		h ≤ 40	h ≤ 25	h ≤ 50	h ≤ 50 +THD
	Levels	Odd		(e.g.: 2% at h=5) See Table 3		1,5%	1%	(e.g.: 2% at h=5) See Table 3	(e.g.: 2% at h=5) See Table 3	(e.g.: 2% at h=5) See Table 3	(e.g.: 2% at h=5) See Table 3
		Even				1,5%	1%				
		THD		3%		2,5%	1,5%	3%	3%	3%	3%
Remarks			Higher levels (THD up to 11%) are specified for very short time effects.	Covers MV to EHV.	Applies to LV and MV only	Standard currently under revision		Objectives for harmonics at HV are informative	Objectives for harmonics are informative		Covers LV-MV and HV-EHV

Source: Joint Working Group Cigré/Cired C4.07, Power quality indices and objectives, 2004

Summary of Flicker Objectives

FLICKER OBJECTIVES		International standards or guidelines		Regional or national standards or guidelines				
Standard / Document		IEC 61000-3-7 [2]	IEC 61000-2-12 [11]	EN50160:1999 [5]	NRS048-2:2003 [6]	EdF Emeraude contract – A. 2 [8]	ER P28: [13]	H.-Q. Voltage characteristics [10]
Purpose		Defines planning levels for controlling emissions	Defines compatibility levels for MV public networks *	Supply voltage characteristics for public networks	Minimum standard used by the regulator	Supply voltage characteristics	Planning levels for the connection of disturbing loads	Information on supply voltage characteristics
Objectives at MV	P_{st}	0,9	(1,0) **			--	V≤132 kV = 1,0	
	P_{lt}	0,7	(0,8) **	1,0	1,0	1,0	V≤132 kV = 0,8	1,0
Objectives at HV-EHV	P_{st}	0,8*	Not applicable	Not applicable	--	--	V≤132 kV = 1,0 V>132 kV = 0,8	
	P_{lt}	0,6*	Not applicable	Not applicable	--	1,0	V≤132 kV = 0,8 V>132 kV = 0,6	0,6
Remarks		Covers MV to EHV (* assuming an attenuation factor of 1 between HV-EHV to MV-LV)	** No compatibility levels for flicker are defined at MV, however it refers to IEC 61000-2-2 for flicker that can be transferred at LV	Applies to LV and MV only	High flicker values flagged according to IEC 61000-4-30 to be removed	HTA from 1 to 50 kV and HTB > 50 kV		Covers LV-MV and HV-EHV

Source: Joint Working Group Cigré/Cired C4.07, Power quality indices and objectives, 2004

Summary of Unbalance Objectives

VOLTAGE UNBALANCE OBJECTIVES		International documents		Regional or national standards and guidelines				
Standard / Document		IEC 61000-2-12 [11]	Cigre 1992 Paper 36-203 [14]	EN50160:1999 [5]	NRS048-2:2003 [6]	EDF Emeraude contract – A. 2 [8]	ER P29: [16]	H.-Q. Voltage Characteristics [10]
Purpose		Compatibility levels on public systems at MV	Assessing voltage quality in relation to harmonics, flicker and unbalance	Supply Voltage characteristics for public LV and MV networks	Minimum standard used by the regulator	Supply voltage characteristics	Planning levels for controlling emissions.	Supply voltage characteristics
Objectives at MV	Very short time (3-sec))	-	2%					
	Short time (10-min)	-	2%	2%	2%	2%	2% (1-min. values)	
	Other	2%	-					2% (2-hr)
Objectives at HV-EHV	Very short time (3-sec)	n/a	1%	n/a				
	Short time (10-min)	n/a	1%	n/a	2%	1%	2% (1-min. values)	
	Other	n/a		n/a				HV=1,5% (2-hr); EHV=1% (2-hr)
Remarks		(up to 3% may occur in some areas)	Covers LV to EHV.	(up to 3% in some areas)	(up to 3% may occur in some areas)	HTA is 1 to 50kV and HTB > 50kV	Applies at 132 kV and below. Lower emission limits are specified for unbalanced loads.	Covers LV-MV and to HV-EHV

Source: Joint Working Group Cigré/Cired C4.07, Power quality indices and objectives, 2004

Summary of Voltage Sag Objectives

- Suitable voltage sag objectives are not yet found in international standard documents specifying the environment for public supply systems.
- The main reasons are the lack of relevant information concerning voltage sags, and the widely different network topologies and operating environments.
- Some immunity standards define minimum immunity levels to guide users of some equipment connected at low voltages, but as such these cannot be considered directly in comparison relating to objectives applicable to supply networks.

Retained voltage	0.02-0.1	0.1-0.5s	0.5-1s	1-3s	3-20s
85-90%	17.3	7.4	0.3	0.3	0
70-85%	26.7	6.4	0.7	0	0
40-70%	9.5	2.7	0.2	0	0
10-40%	2.3	0.2	0	0.2	0
0-10%	1.0	0.8	0.7	0.3	0

measurement results for EHV networks, number of events per year.

Retained voltage	0.02-0.1 s	0.1-0.5 s	0.5-1 s	1-3 s	3-20 s
85-90%	53.0	36.0	16.4	7.0	0
70-85%	55.0	25.8	7.6	5.0	0
40-70%	30.2	15.6	4.4	1.6	0
10-40%	19.4	4.8	1.0	0.6	0
0-10%	1.8	1.4	0	1.2	0.2

: measurement results for HV networks, number of events per year.

Retained voltage	0.02-0.1 s	0.1-0.5 s	0.5-1ss	1-3 s	3-20 s
85-90%	57.7	16.3	4.7	2.2	1.0
70-85%	85.5	42.8	7.7	2.4	0.3
40-70%	50.4	49.3	7.4	2.1	0.3
10-40%	19.7	40.3	5.0	1.9	0.3
0-10%	0	2.4	1.0	2.9	2.7

measurement results for MV networks, number of events per year.

Source: Joint Working Group Cigré/Cired C4.07, Power quality indices and objectives, 2004

PQ Contracts - Principles

For customers who wish premium power, in many cases, the most cost effective method is modifying the distribution system in all customers on that branch of the system. (If customers are not fully or partially charged systems upgrades might be an option).

The distribution company can identify the additional costs involved in providing this type of above average service and bill the customer for it.

The customer is free to evaluate this solution against local alternatives.

Some price sensitive customers can be interested in reduced costs and are perhaps willing to accept lower levels of reliability than the level provided under the basic regulated service.

These customers can "sell" interruption rights back to the power system. The distribution company can then interrupt these customer when the system is under stress and avoid interrupting other customers.

Example: France

In France, both the Transmission System Operator (RTE) and the main distribution company (EdF) offer their customers customized contracts with assigned voltage quality levels ("*engagements*" or contractual levels). (In 1994, EdF began to use the so-called Emeraude contract as an experiment for 6,000 customers.)

If the customer wants better contractual levels than the normal ones, he can ask the operator for customized contractual levels in his contract and pay an extra charge.

The contract had been developed jointly between EdF and customer representatives.

- Basic contract with standard quality thresholds
- Basic contract with customer-adjusted levels
- Plus contract (Réseau plus)

Example: Italy - 1

The energy regulator (the Autorità) is responsible for setting tariffs and quality standards. It has legal powers to establish minimum quality standards with corresponding incentives i.e., penalties/rewards. (This has been implemented in the case of continuity of supply.)

Presently there is NO regulation system for voltage quality in Italy.

The strategy is to first get a better understanding of existing voltage quality levels:

• A voltage quality measurement campaign has been set up. (Utility companies have to install voltage quality meters at strategic locations and report on voltage quality performance to the Autorità)

• There is also an obligation for utility companies to install voltage quality meters at the request of customers. (The costs of these meters are borne by the customer.)

• Finally, there is the possibility for customers and utility companies to enter into a voltage quality contract. Currently, however, no voltage quality contracts have been established.

Example: Italy - 2

- Performance monitoring campaign launched in early 2006 (2 years, until early 2008.)
- There are about 600 locations
  - 400 meters installed in MV and HV/MV substations. (The costs of these meters are paid through the R&D component of the tariff.)
  - 200 meters installed at delivery points to customers (75 were requested and paid for by customers at their delivery point. The other 125 meters are installed at supply points to other customers. Their costs are paid by the utility companies.)

The following voltage quality aspects need to be monitored and reported:

1 supply voltage variations
2 supply voltage dips and peaks
3 voltage interruptions
4 voltage harmonics
5 flicker
6 supply voltage unbalance
7 rapid voltage changes.

Example: South Africa

Eskom introduced an extensive PQ program at the start of 1990. (High priority, i.e., the performance of the network was linked to the remuneration for the management of the company!)

In 1992, Eskom started implementing extensive power quality measurements at more than 150 of its transmission and distribution substations to quantify the levels of power quality experienced by customers.

Three different types of guaranteed power quality contract:

1. Delivery according to national power quality standard (NRS 048), i.e., Eskom guarantees a minimum power quality level according to the NRS 048 standard. If the level is not met, Eskom is obliged to improve the power quality to the costumer.
2. Network-specific option
3. Premium power option

Example: USA

The Detroit Edison Company (DEC), offers a special manufacturing contract with premium power quality for manufacturers (automotive industry) in their region and special interruptible rates to residential, commercial and industrial customers. (Customers get discounted electricity prices in return for permission to occasionally interrupt electrical service.) E.g., contracts for 58 plants operated by the three car manufacturers covers offices, assembly factories, and processing plants and component delivery departments. The car manufacturers are compensated when certain levels have been exceeded. The level for interruption was based on measurements for the year 1993. The penalty for interruption agreed in the contract varies according to the type of activity that the electricity supply serves (office building, etc.).

Type of activity	Number of production plants	Numbers interruptions a year	Penalty
Assembly and pressing	6	3	\$50,000 - \$88,000
Gearboxes	4	2	\$159,000 - \$326,000
Components	9	9	\$16,000 - \$152,000
Offices	1	1	\$30,000
Other	8	3	\$2,000 - \$11,000
Affiliates	1	1	\$2,000 - \$11,000

Example: Argentina

Argentina introduced (1992) a system with penalties in order to decrease the number of interruptions in the power networks to international levels.

The change to a lower number of interruptions was implemented over a period of 3 years with gradually increased requirements on the reduction of the number interruptions, while penalties were gradually increased.

There were two aims:

- to compensate the electricity consumers
- to give the utility companies a signal for investments.

Measurements were started to record the interruptions in the medium voltage grids. Several indexes of reliability were tightened during the three year period and in the case of exceeding the levels a penalty payment was credited to the customer rated at up to 1 $/kWh (currently up to 2.70 $/kWh)

Different PQ Contract Requirements

Quality assurance of electricity deliveries	EDF (France)	Escom (South Africa)	Detroit Edison (Michigan)	San Diego Gas & Electric (California)	Duke Energy (N. Carolina)	United Illuminating (Connecticut)	Public Service Electric & Gas (New Jersey)	Edenor m. Fl. (Argentina)
Benchmarking								
against own network	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
against regional level	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
against national level	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
methodology	Own	EPRI RBM	EPRI RBM	EPRI RBM	EPRI RBM	EPRI RBM	EPRI RBM	Own
Index	Interuptions, dips	Interuptions, dips	Interuptions, dips	Interuptions, dips	Interuptions, dips	Interuptions, dips	Interuptions, dips	Interruptions
Measurement								
Systematic	Yes	Yes	when necessary	when necessary	when necessary	Continuous	when necessary	Yes
Ad hoc	No	No	No	No	No	No	No	No
interruptions, at PCC	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
interruptions, at customer	Emeraude	On request	Acc. to agreement SMC	Acc. to agreement	Acc. to agreement	Acc. to agreement	Acc. to agreement	No
Voltage dips	Emeraude	NRS 048	Acc. to agreement SMC	Yes	Yes	Yes	Yes	No
Harmonics	EN / IEC	Yes	IEEE	IEEE	IEEE	IEEE	IEEE	IEC
Flicker	IEC	IEC	IEEE	IEEE	IEEE	IEEE	IEEE	IEC
Guarantees								
Restore time	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
number of interruptions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
number of voltage dips	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Acc. tot PQ standard	No	NRS 048	No	No	No	No	No	No
Acc. tot PQ agreement	Emeraude	Yes	SMC	Yes	Yes	Yes	Yes	No

Source: 30620162-Consulting 07-0401 Premium Power Quality contracts and labeling, Work package 2 of the Quality of Supply and Regulation project, KEMA Consulting

Type of Incentive/Penalties Regimes

TYPE OF INCENTIVE/PENALTY REGIMES ADOPTED IN EUROPEAN COUNTRIES

	Objectives	Incentive and/or penalty	Other schemes	Duration
GB	Improve continuity levels	both	Guaranteed Standards (GS) on maximum restoration time: GS on maximum yearly number of long unplanned interruptions	5 years (as price control period)
HU	Improve continuity levels Compensate drawbacks of price cap regulation	both	GS on maximum restoration time	No predetermined duration. From 1 January 2006 a new regime will be introduced for 3 years. No correlation with the price control period (4 years).
IE	Improve continuity levels	both	GS on maximum restoration time	5 years (as price control period)
IT	Improve continuity levels and reduce regional gaps in continuity through a "convergence" mechanism	both	GS on maximum yearly number of long unplanned interruptions per HV and MV customer GS on maximum restoration time under consultation	4 years (as price control period)
NO	Achieve a socio- economically acceptable level of continuity (rather than to improve it)	both	None	No predetermined duration until now. From 2007 there will be some small changes in the scheme.
PT	Improve continuity of service levels	both	GS on Maximum yearly cumulative duration of unplanned interruption (all voltage levels), GS on Maximum yearly number of long unplanned interrup-tions (all voltage levels), Special Plans for improving Quality of Supply	No predetermined duration
SE	Achieve a socio-economically acceptable level of continuity	both	GS on maximum restoration time under evaluationObservation of the worst performing areas	No predetermined duration (ex-post regulation, year by year)

Source: Third benchmarking report on quality of electricity supply, Council of European Energy Regulators ASBL, RPM 0861.035.445

Indicators for Incentives/Penalties

INDICATORS USED FOR INCENTIVE/PENALTY SCHEMES				
	Indicators	Planned	Exclusions	Rolling average
GB	CIs: number of customers interrupted per 100 customers, CML: average number of customer minutes lost per customer	Included in CML and CIs with 50% weighting from 2005	exceptional events; separate regulatory mechanism (see Additional information 2.6)	No
HU	Network Security (NS) indicators: *Outage rate*, Number of MV faults per grid length, Average repair time of MV network, Average number of LV grouped faults. Continuity of Supply (CS) indicators, *SAIDI*, *SAIFI*, Percentage of interruptions restored within 3 and within 24 hrs	Excluded	NS: no CS: yes	Yes: three year rolling average
IE	SAIDI and Losses (SAIFI being added from 2006)	Included	days with daily SAIDI with deviation larger than twice the standard deviation from the mean	No
IT	SAIDI	Excluded	force majeure and external causes; Statistical method	Yes: two year rolling average
NO	ENS Energy Not Supplied	Included in the incentive regulation (evaluated separately)	Yes (exceptional events can be evaluated upon request by the company)	No
PT	ENS Energy Not Supplied, which is determined on the basis of TIEPI (indicator of frequency of interruption weighted with the installed power in MV)	Excluded	force majeure, public interest, service reasons, safety reasons, agreements with the customer, facts attributable to the customer.	No
SE	SAIDI, SAIFI	Included in the incentive (evaluated separately)	Force majeure	No

Source: Third benchmarking report on quality of electricity supply, Council of European Energy Regulators ASBL, RPM 0861.035.445

Economic Effects

ECONOMIC EFFECTS

	Incentive/penalty	Incentive rate	Symmetry
GB	±3% of price control revenue is exposed to the continuity incentives	Average value of energy not supplied implicitly used in the scheme: 4.18 €/kWh not served	Yes (but minimum improvement required)
HU	Tariff-related incentives and penalties apply to 3 indices out of NS & CS: outage rate; SAIDI, and SAIFI; Fines apply to all NS and CS indicators	Not applicable	No
IE	±2% of price control revenue is exposed to the incentives (2001-2005)±4% of price control revenue is exposed to the incentives (2006-2010)	Average value of energy not supplied used in the scheme: 7.2 €/kWh-not-supplied (year 2000)	Yes (but minimum improvement required)
IT	The price-cap formula contains a Q factor that funds the net difference between incentives and penalties.	Differentiated according to type of consumers (domestic and business); respectively 10.8 and 21.6 €/kWh-not-supplied	Yes (but minimum improvement required)
NO	The difference between expected interruption costs and actual interruption costs (using actual ENS) is calculated annually for each company and added to the company's revenue cap if positive and subtracted if negative. From 2007 companies will have to adjust tariffs yearly on the basis of the incentive/penalty effect	Costs of energy not supplied, differentiated according to type of consumers (unplanned - planned in €/kWh-not-supplied); Industrial: 7.90 - 5.51; Trade/Service: 11.86 - 8.14; Agricultural: 1.80 -1.20; Residential: 0.96 - 0.84; Public service 1.56 - 1.20; Wood processing/ energy intensive industry: 1.56 - 1.32	Yes
PT	Rewards (penalties) are proportional to the difference between the actual performance level and the target (excluding the dead band)	Fixed incentive rate for any deviation from the targetValue of energy not supplied used in the scheme: 1.5 €/kWh-not-supplied.	Yes
SE	The difference between "expected interruption costs" and actual interruption costs (using reported SAIDI and SAIFI) is calculated annually for each company. The tariff for the company is adjusted accordingly. An upper boundary (totally underground network) and a lower boundary (quality of a pure radial network) are used.	Costs of energy not supplied and cost of power interrupted, differentiated according to density of line, i.e., meter line per number of customers. €/kWh-not-supplied (unplanned/planned) Urban: 12 / 8.6; Suburban: 8.8 /6.3; Rural: 7.4 /5.2; €/kW-interrupted (unplanned/ planned); Urban 2.5 /0.4 Suburban 1.9 /0.3; Rural 1.6 / 0.2	Yes

Source: Third benchmarking report on quality of electricity supply, Council of European Energy Regulators ASBL, RPM 0861.035.445

Overview of Monitoring - 1

Norway

- Monitoring system has been applied for several years.
- From 2006, mandatory voltage quality monitoring.
- Each network company (even the smallest one) is obliged to monitor quality parameters continuously in different characteristic parts of its MV, HV and EHV power system.
- At least the following parameters have to be monitored:
    - long (duration > 3 min.) an short (duration between 1 sec. and 3 min.) interruptions
    - voltage dips,
    - temporary overvoltages
    - rapid voltage changes (>3%).

Overview of Monitoring – 2

Hungary

- The regulator owns 400 voltage quality recorders that are installed each semester in one of the six distribution companies, at low voltage level only (around 0.007% related to LV consumers).
- The cost of monitoring the system is shared between the regulator and the utilities, the former having paid the cost of VQ recorders, the latter bearing the cost of installation and removal.
- The regulator chooses the network points randomly, in a way that does not depend on previous events or complaints.

Portugal

- 61 points monitored on the transmission grid (40 for 4 weeks and the rest all year long); in distribution, all substations (423) in MV and 1270 power transformation stations in LV have been monitored for 3 years.
- The companies pay the cost of the monitoring system,

Overview of Monitoring - 3

Slovenia

• distribution and transmission companies are obliged to measure voltage quality parameters
• voltage quality monitoring is implemented in high voltage covering all the substations (8) and about 10% (160) of medium voltage systems;
• all the voltage quality parameters are monitored according to EN 50160.

Spain

• distribution companies and the regulator have been working on a procedure for controlling and measuring voltage quality; in the near future, 10% of the busbars in MV of each province will be involved (costs will be sustained by the distribution companies).

Czech Republic

• monitoring system is going to be installed at the interconnection points between transmission and distribution networks.

Quality of Supply Monitoring in Europe

MONITORING AND COMMUNICATION OF CONTINUITY INDICATORS	Measure long interruptions	Measure short int's	Measure separately planned/unplanned	Voltage level	Information to regulator	Publication
AT	✓		✓	HV, MV	Yearly	✓
BE	✓(>15' in LV)		✓	HV, LV	Yearly	
CZ	✓		✓	HV, MV, LV	Yearly	✓
EE	✓		✓	HV, MV	Yearly	✓
ES	✓		✓	HV, MV	Yearly	✓
FI	✓	✓	✓	HV, MV, LV	Yearly	✓
FR	✓	✓	✓	HV, MV, LV	Yearly	✓
GB	✓	✓	✓	HV, MV, LV	Yearly	✓
GR	✓		✓	HV, MV, LV	Yearly	✓
HU	✓	✓	✓	HV, MV, LV	Yearly	✓
IE	✓(>1')	✓(>1')	✓	HV, MV	Yearly	✓
IT	✓	✓	✓	HV, MV, LV	Yearly	✓
LT	✓		✓	HV, MV, LV	Quarterly	✓
LV	✓			HV, MV	Yearly	✓
NO	✓		✓	HV, MV	Yearly	✓
PO						
PT	✓		✓	HV, MV, LV	Quarterly	✓
SI	some data available	some data available	some data available	HV, MV	upon request	✓
SE	✓		✓	HV, MV	Yearly	✓

Source: Third benchmarking report on quality of electricity supply, Council of European Energy Regulators ASBL, RPM 0861.035.445

Voltage Quality Monitoring in Europe

VOLTAGE QUALITY MONITORING SYSTEMS	
Monitoring at both transmission and distribution level	IT*, NO, PT, SL
Monitoring only at transmission level	CZ*
Monitoring only at distribution level	HU
Proposal stage	ES, SE
None	AT, BE, EE, FI, FR, GB, GR, IE, LV, LT, PL

(*) Voltage quality monitoring system currently under commissioning

INDIVIDUAL VERIFICATION OF VOLTAGE QUALITY	
Distribution companies compelled to provide voltage quality individual verification when requested by the customer	AT, BE, CZ, EE, FR, HU, IT, LV, NO, PL
No duty for installing a voltage quality recorder but for providing information to the customer	FI, PT
Proposal stage	SW
No legal obligation	ES, GB, GR, LT, SL

Source: Third benchmarking report on quality of electricity supply, Council of European Energy Regulators ASBL, RPM 0861.035.445

Summary

- PQ contracts are rarely monitored by the regulator.
- In the majority of cases where contracts are foreseen, the regulator has no role in market mechanisms for quality (see table below where "interruptible" contracts, more widespread than power quality contracts, are not considered).
- PQ contracts are still at a starting phase but they can be seen as an efficient solution for improving voltage quality without imposing excessive costs on general tariffs.
- PQ contracts require that customers requiring better voltage quality have a clear willingness to pay for it.

POWER QUALITY CONTRACTS	
Power quality contracts with some ex-ante intervention of Regulator	FR, IT
Power quality contracts with only ex-post intervention of Regulator	SI
Power quality contracts with no intervention of Regulator	CZ, ES, GB, LV, PT
None (or simply special connections on customer request)	AT, BE, EE, FI, GR, HU, IE, LT, NO, PL, SE

Source: Third benchmarking report on quality of electricity supply, Council of European Energy Regulators ASBL, RPM 0861.035.445