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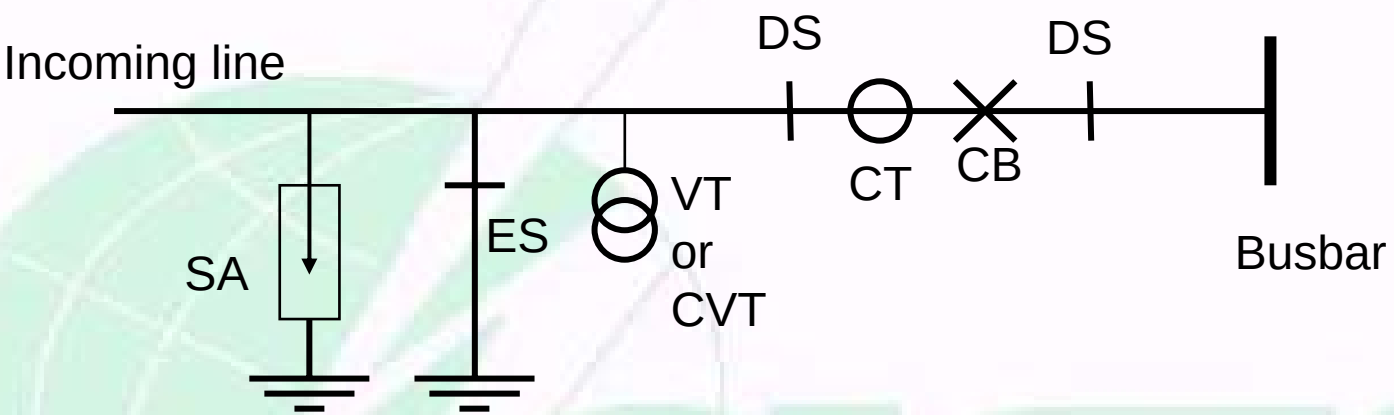
Past Cigré surveys on reliability of HV equipment

Content

- Why are we interested in equipment reliability?
- Different ways to define failures
- Old Cigré surveys, major results
- Impact of results
- New Cigré survey
- Conclusions

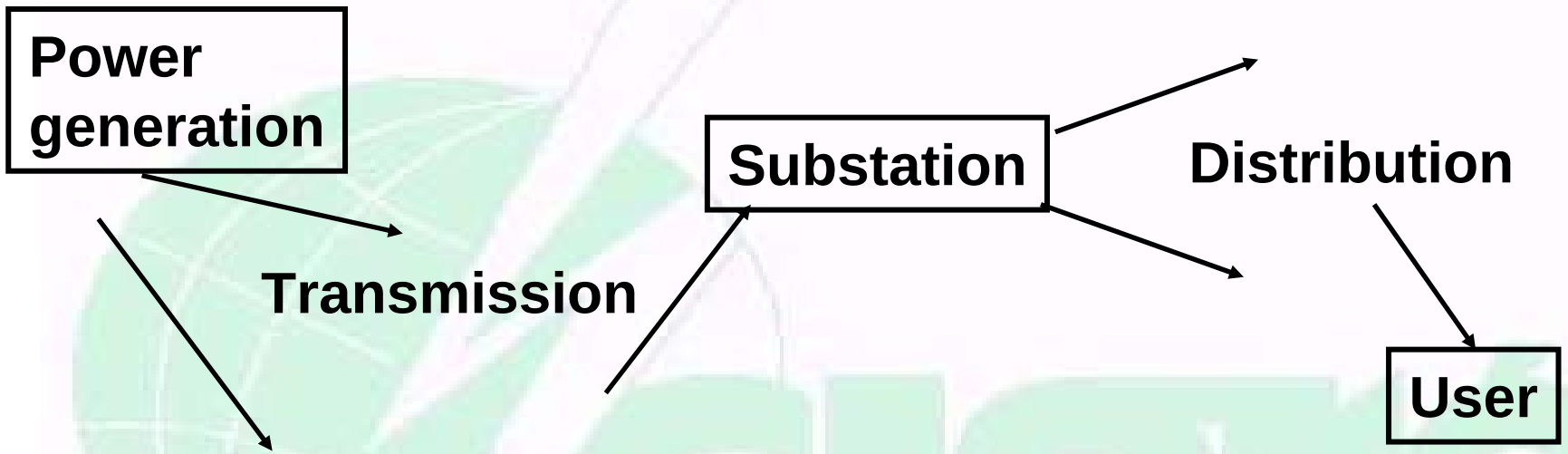
Failures will cause damage…

Failures may cause loss of power supply…



- Failure of any of the components in the bay means that the line is unavailable
- Failure of the busbar disconnector means that the busbar is unavailable
- The overall unavailability is determined by maintenance requirements and failures

Substations are important for the power flow!

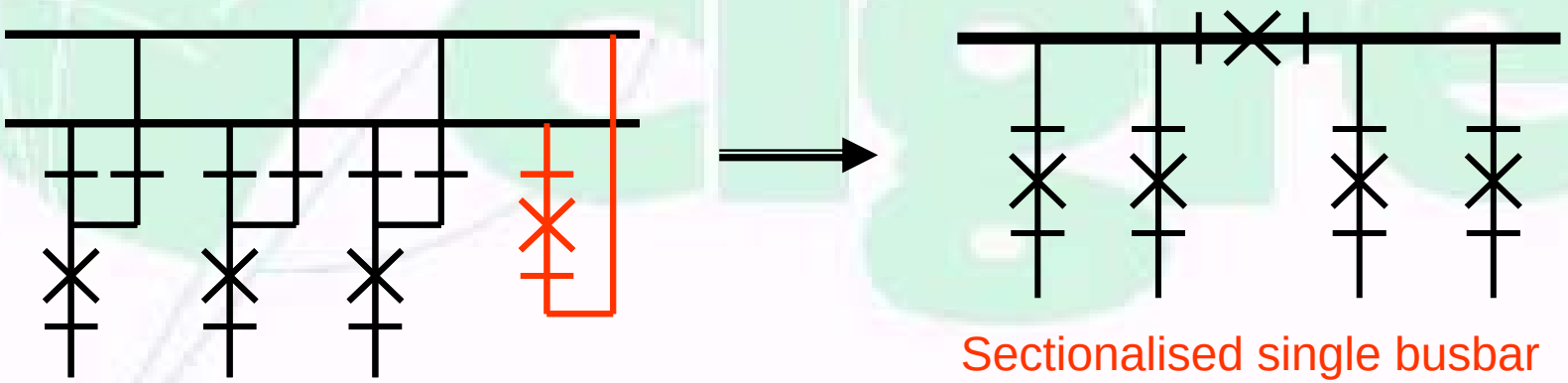


Substations and HV equipment play an important role in the power system

Reliable equipment means good economy

- **Few failures; few interruptions; only little repair work**
- **Reliable equipment makes it possible to decrease maintenance work**
- **Reliable equipment with low maintenance requirements may allow simplification of the substation**

Example: Simplification of single line diagram



Double busbar

Sectionalised single busbar

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Definition of failure – according to Cigre

Failure: Lack of performance by an item of its required function or functions.

Note: The occurrence of a failure does not necessarily imply the presence of a defect if the stress or the stresses are beyond those specified.

Major failure: Failure of a switchgear or controlgear which causes the cessation of one or more of its fundamental functions.
A major failure will result in an immediate change in the system operating conditions, e.g. the backup protective equipment being required to remove the fault, or will result in mandatory removal from service within 30 minutes for unscheduled maintenance.

Note: Or will result in unavailability for required service.

Minor failure: Failure of an equipment other than a major failure or any failure, even complete, of a constructional element or a sub-assembly which does not cause a major failure of the equipment.

Other ways to define failures…

21, rue d'Artois, F-75008 Paris
http://www.cigre.org

B3-105

Session 2004

Cigré Report B3-105,2004
Reliability centered maintenance of substation equipment in Fingrid Oyj
Yli-Salomäki, Kiiveri, Finland
The sum of major and minor failures is reported. The definitions of Cigré have been used.

Cigré Report A3-305, 2004
Evaluation of failure data of HV circuit breakers for condition based maintenance
Balzer et al, Germany
The recorded data involve major as well as minor failures.
"The listed failures in any case led to a reaction of the service department"

Other ways to define failures…

CEA, Canadian Electricity Association, Canada
Component forced outage: The automatic or emergency removal of a major component directly caused by defective equipment, adverse weather, adverse environment, system condition, human element or foreign interference.
…recording is not done for manual removal of a component from service where that removal may be delayed more than thirty minutes...

National Grid, United Kingdom
Fault: An event which causes plant to be automatically disconnected from the HV system for investigation and further action if required

Svenska Kraftnät, Sweden
Service disturbance: Forced or unfounded de-energizing, or unsuccessful energizing, due to failure in the power system.
Failure: Condition when an object lacks, or has decreased capability to perform its function.
Note: A service disturbance may be related to one or more failures.

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First Cigre survey; circuit breakers

Results published in Electra No 79, 1981
Additional Cigré studies 1985
Covers the time interval 1974-77
All types of circuit breakers
Service voltage above 63 kV

Main results:

- 70% of Major Failures (MF) were of mechanical origin
- 19% of MF were of electrical origin concerning the auxiliary and control circuits
- 11% of MF were of electrical origin concerning the main circuit
- 48% of MF were classified as “Does not open or close on command”
- The operating mechanism was the part of the circuit breaker responsible for the highest number of failures (37% of MF)
- The percentage of failures in auxiliary interrupters or resistors of circuit breakers with rated voltage 500 kV and above was of the same order as that on making and breaking units

Second Cigre survey; circuit breakers

- Results published in Cigré Technical Report 83, 1994
- Covers the time interval 1988-91
- Covers single pressure SF6 circuit breakers (live tank, dead tank and GIS-breakers), placed in service 1978-91
- Lowest rated voltage 72,5 kV

Results from the second survey; circuit breakers (1)

Voltage	Major failures per 100 cb years	Minor failures per 100 cb years
All voltages	0.672	4.749
63-100	0.275	2.225
100-200	0.680	4.753
200-300	0.814	6.970
300-500	1.210	7.764
500-700	1.847	8.179
700-	4.545	12.500

Major failure: Failure of a circuit-breaker which causes the lack of one or more of its fundamental functions.

- The major failure rate for single pressure SF6 circuit breakers is about 40% of the value in the first survey (for all technology circuit breakers)
- The minor failure rate is about 30% higher than in the first survey. Reasons:
  - SF6 leakage problems
  - More complex control and auxiliary systems of modern circuit breakers
  - Better response to the second questionnaire
- The major failure rate increases rapidly with voltage, but in comparison with the first survey the improvement in the higher voltage ranges is much greater, due to improved designs

Results from the second survey; circuit breakers (2)

Mechanical aspects:

- As with the first enquiry a large part of the major failures have mechanical origin
- The operating mechanism and the electrical control and auxuiliary circuits are the components responsible for the majority of both major and minor failures
- The dominant major failure modes are “Does not open or close on command” and “Locked in open or closed position”. These modes add up to almost 70% of the major failures (same as in the first enquiry)

Maintenance aspects:

- The average interval between scheduled overhaul is 8.3 years. ”This could in many cases be extended”
- The number of failures caused by incorrect maintenance has decreased compared to the first enquiry (85% decrease for major failures, 26% for minor failures), but there is still room for improvement
- About a quarter of the failures are caused by inadequate instructions and incorrect erection, operation and maintenance.

Second Cigre survey; operating mechanism

Rated voltages 63-800 kV

Mechanism type	Failures per 100 cb-years	
	Major failures	Minor failures
Hydraulic	0.31	2.89
Pneumatic	0.27	0.80
Spring	0.27	0.40

- Different types of operating mechanism have about the same major failure rate.
- Most of the minor failures of operating mechanisms are either hydraulic oil or air leakages. The minor failure rate of spring, pneumatic and hydraulic drive systems is 1:2:7, respectively.

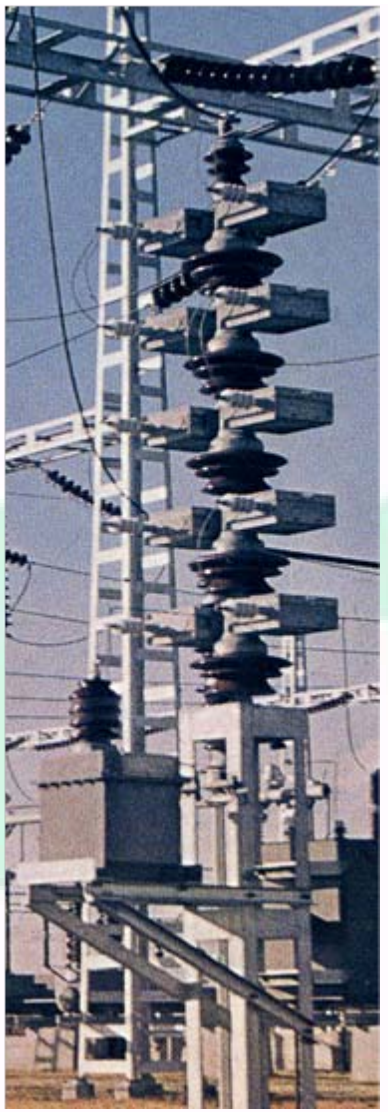
Previous Cigre studies; instrument transformers

First survey

- Cigré Technical Report 57, 1990, “The paper-oil insulated measurement transformer”
- See also Electra, July 1989
- Covers failures from the time interval 1970-86
- Both manufacturers and users contributed
- No age limitation to the overall population

Second survey

- Covers failures from the time interval 1985-95
- Only contributions from users
- No age limitation to the overall population
- So far the results are unpublished



CVT from 1955

CVT from 2000

First Cigre survey; instrument transformers

Type of IT	Violent failures per 100 IT years	Non violent failures per 100 IT years
CT	0.014	0.025
MVT	0.019	0.029
CVT	0.005	0.033
Comb CT/VT	0.006	0.022

Failure: When an instrument transformer is no longer able to perform its required function and therefore requires to be removed from service.
- Violent failure
- Non violent failure

- **Many non violent failures were due to inadequate design**
- **Most units that suffered violent failures were only subjected to insufficient and irregular inspection**

Comparison Cigre studies; instrument transformers

Type of IT	Failures per 100 IT years	
	First	Second
CT		
MF	0.014	0.04
mf + defect	0.025	0.117
MVT		
MF	0.019	0.044
mf + defect	0.029	0.236
CVT		
MF	0.005	0.026
mf + defect	0.033	0.248
Comb CT/VT		
MF	0.006	0.023
mf + defect	0.022	0.319

Unexpected high failure rates in the second survey; probably due to reporting only from utilities

However, decreasing trend in major failure rates during the reporting period; probably due to improved diagnostic and maintenance systems

Still too small population of resin and SF6 insulated designs; difficult to compare these designs to conventional paper/oil designs

Major failure (MF): Sudden explosive event that causes an immediate emergency system outage or trip
Minor failure (mf): Non-violent but still required an urgent system outage within, for instance, one hour.
Defect: A non-urgent (planned) outage to repair or replace the unit

Previous Cigre studies; GIS

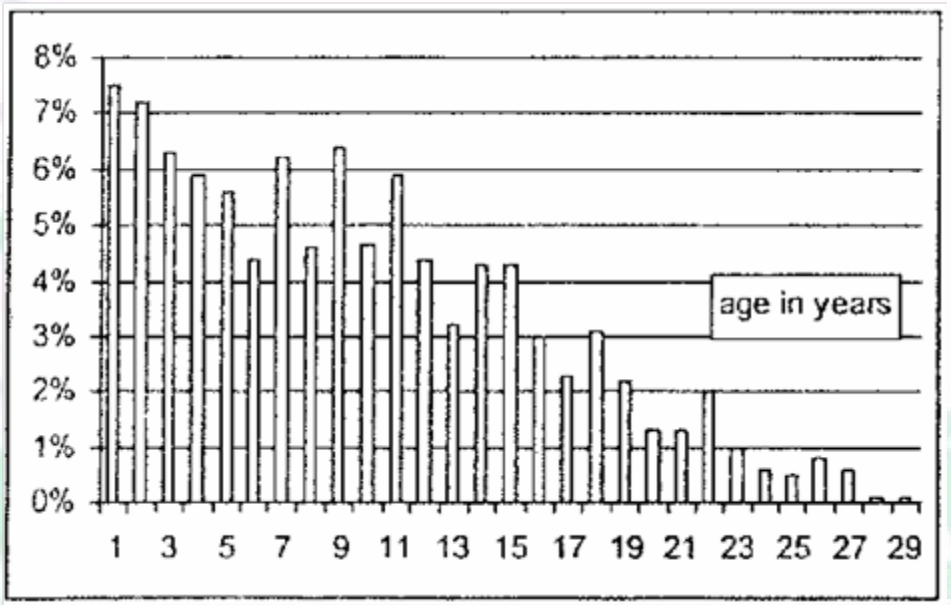
First survey
Published in 1992-94
Covered experience up to 1990
Based on information from both manufacturers and users

Second survey
Published in final form in 2000.
Cigré Technical Brochure 150.
Covered experience up to 1995
Based on information from uses only.

Both surveys covered the whole population of GIS, including apparatus, and all failures without age limitation.

Conclusions from second Cigre Survey; GIS (1)

GIS is still a relatively new technology, average age 9 years



The population of outdoor GIS has increased from the first survey; it is now 43% of cb-bay-years

Conclusions from second Cigre Survey; GIS (2)

Voltage Class kV	All period		
	Sample size /CB-bay-years/	Number of major failures	Failures per 100 CB-bay-years
60-<100	56884	28	0.05
100-<200	32048	465	1.45
200-<300	16040	138	0.86
300-<500	6371	179	2.81
500-<700	4525	49	1.08
>700	200	12	6.00
60-<700	115868	859	0.74
TOTAL	116068	871	0.75

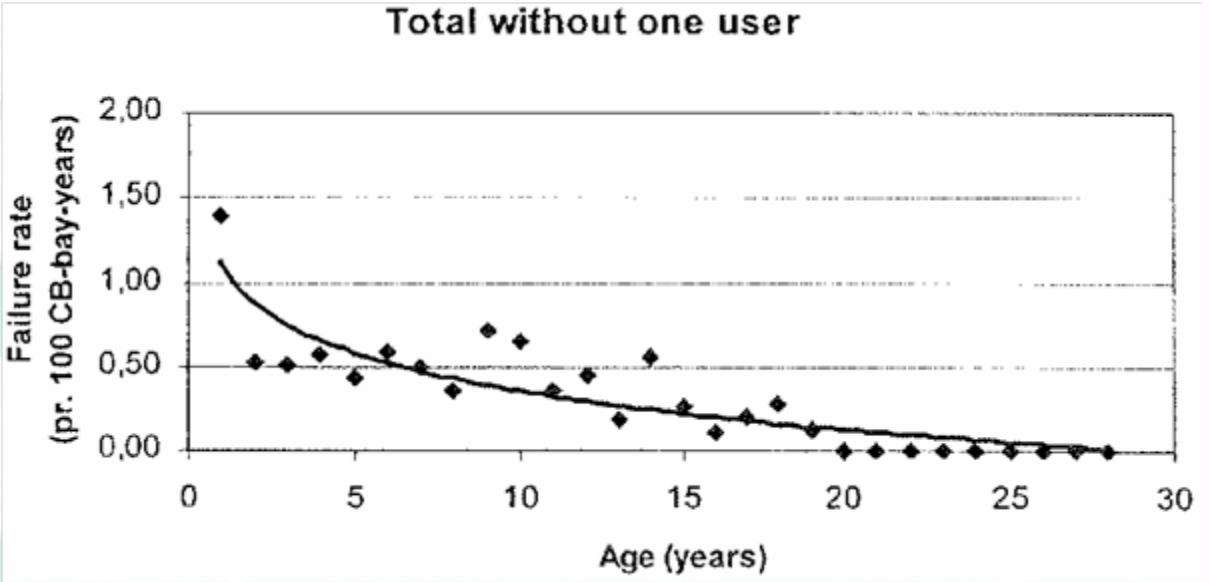
Failure frequency (failures/100 cb-bay-years):

Total population	0.75
Excluding one user	0.52
Excluding Japan	1.77

- Comparison of results from the first and second survey shows increasing reliability of GIS in service.
- Total downtime due to failure: average 13 days

Conclusions from second Cigre Survey; GIS (3)

There is normally a decreasing failure rate during the first part of the lifetime



- CB/switch, busbar/busduct, and disconnector are the three components most frequently involved in major failures
- About 50% of all failures are dielectric breakdowns, which occur during normal service
- About 50% of all failures are claimed to be caused by unadequate design and manufacture
- SF6 tightness is reported better than standard requirements, the majority reports 0.5% leakage per year

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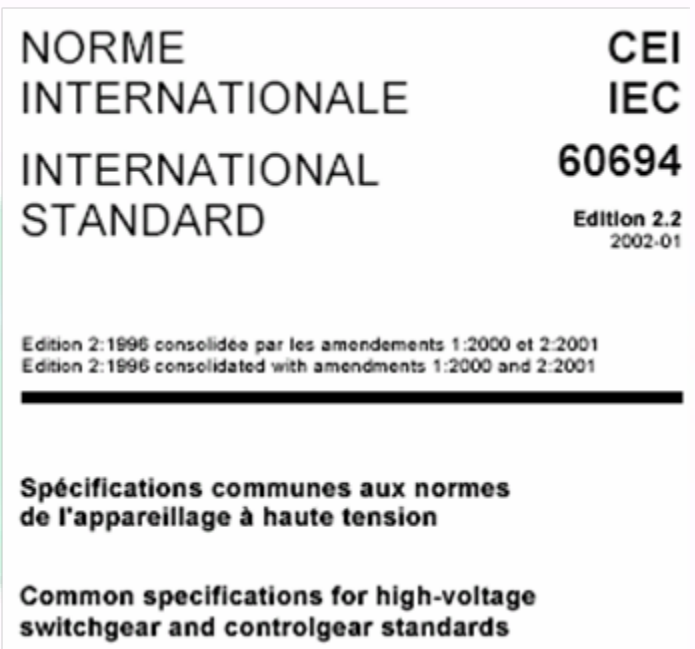
Influence on standards

Example
The first Cigré survey on circuit breakers influenced the IEC standards for circuit breakers

1987 IEC Publ. 56, Ed 4 (predecessor to present IEC 62271-100)

- New humidity tests
- New mechanical tests, 2000 and 10000 operating cycles
- New low- and high-temperature tests

1992 IEC Publ. 1208 Guide for maintenance
1996 The material was included in IEC 60694 Common specifications for HV switchgear and controlgear standards


NORME INTERNATIONALE
CEI IEC
INTERNATIONAL STANDARD
60694
Edition 2.2 2002-01
Edition 2:1996 consolidée par les amendements 1:2000 et 2:2001
Edition 2:1996 consolidated with amendments 1:2000 and 2:2001
Spécifications communes aux normes de l'appareillage à haute tension
Common specifications for high-voltage switchgear and controlgear standards

Driving force to improve designs

- Simplification of mechanical systems in circuit breakers
- Improved sealings in order to minimize SF6 leakage

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Scope of new Cigre survey

The survey covers:

- **SF6 Circuit breakers**
- **Disconnectors and earthing switches**
- **Instrument transformers**
- **GIS**

Voltage range 60-800 kV

Kind of service for circuit breakers is included: Transformer breaker, line breaker, etc

Time span covered 2004-2007

Reasons for new studies

Time has passed since previous studies

Our industry has been significantly liberalized

- **Increased competition**
- **Mergers**
- **Transition from regional providers to international corporations**
- **Reduced regulation**

Service and maintenance conditions have changed, as well as the HV equipment that is in service

- **Are we over-maintaining or under-maintaining our equipment?**
- **Is equipment reliability improving or deteriorating?**
- **When is equipment end-of-life?**

Customers question reliability

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Conclusions

- The reliability surveys have shown positive trends; HV equipment is getting better
- Results of old reliability surveys have
  - Helped users to choose optimal equipment and maintenance procedures
  - Helped manufacturers to improve their products
  - Contributed to improvement of international standards
- New Cigré study is now well under way, and is beginning to generate results