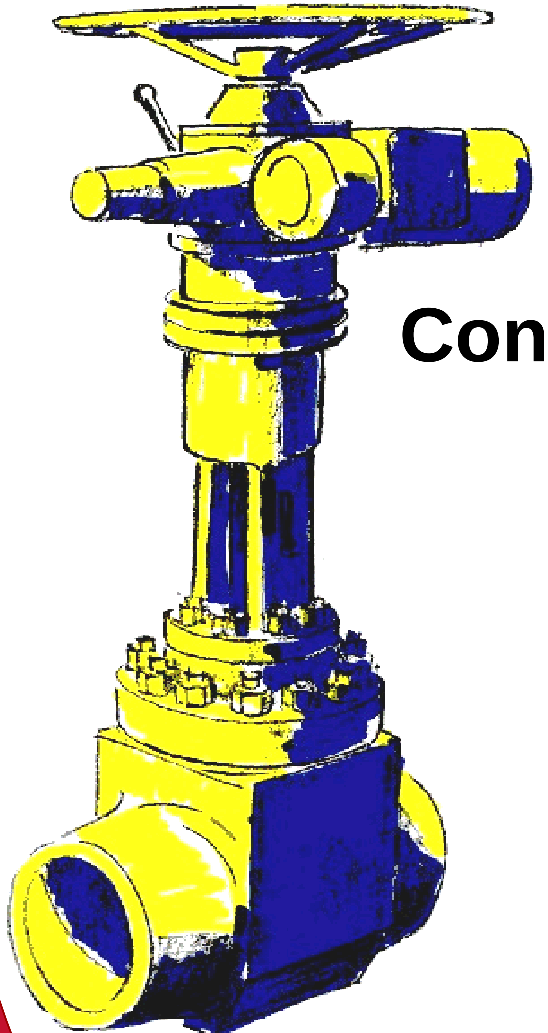

Moving Towards Condition Based Maintenance of Valves and Actuators

IEEE Subcommittee on Qualification
IEEE/NPEC/SC 2 Meeting 06-1
San Antonio, TX

April 18th, 2006

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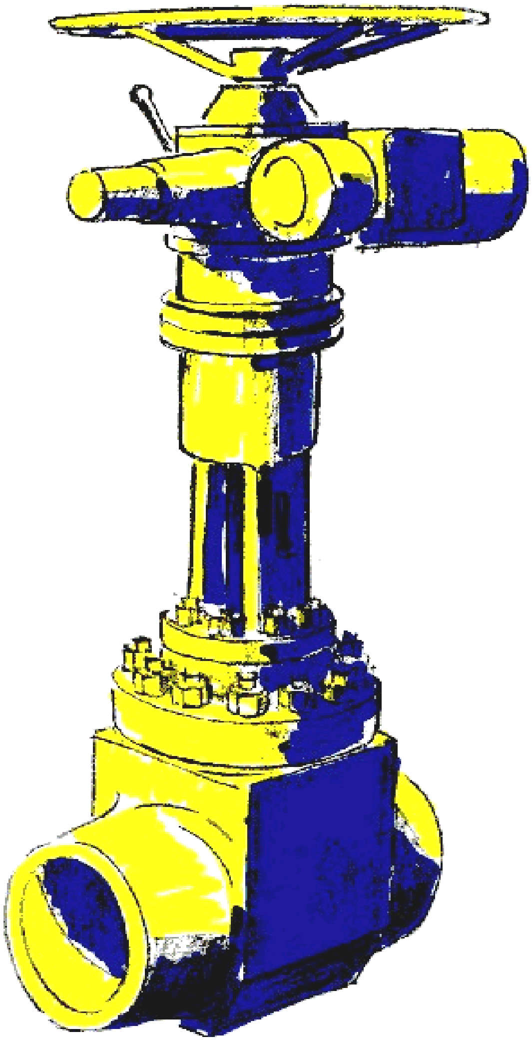
Who is AREVA NP ?

- "AREVA NP" new name effective since April 1st, 2006
- 2001 "Framatome-ANP", a joint venture of
  French/US Framatome, and
  German Siemens KWU
- Building, fuel supply and service for NPPs
- US branch headquarters in Lynchburg, VA
  French locations in Paris, Lyon, Chalon, and others
  German locations in Erlangen, Offenbach, Karlstein
- Now building the new EPR in Finland (Olkiluoto-3)

Part 1:

Introduction



Methods of Maintenance

- **Maintenance on occurrence of faults**
  $\Rightarrow$ *Not acceptable for nuclear power plants*

- **Maintenance in regular time intervals (preventive m.)**
  $\Rightarrow$ *Standard for safety related components*
  $\Rightarrow$ *Much unnecessary work if components are OK*
  $\Rightarrow$ *Faults detected too late*

- **Condition Based Maintenance**

Condition Based Maintenance

Why ?

- Prevent unnecessary work
- Prevent faults caused by the maintenance work
- Save time and costs
- Improve plant safety and availability

Why not yet ?

- Rules and regulations of governments or authorities often require fixed intervals
- Lack of information about the condition

The way to condition based maintenance of Motor Operated Valves (MOVs)

- Use new diagnostic methods and tools to gain more information about the “health condition” of MOVs
- Start with non safety-related, operational important MOVs
- In Germany, possibilities for the prolongation of maintenance intervals are under negotiation between plant owners and the authorities

The Valve Performance Concept

Ability for Function
Analytical Concept

+

Readiness for Function
Monitoring, Trends during Lifetime

Calculation

Actuator and Valve Components

+

Design Evaluation

Function-relevant features, mechanics

Baseline Measurement

+

Periodical Tests, Trending

Full flow testing in test-rig or plant, covering operation and accident conditions

Measures during Lifetime

Condition Oriented Maintenance

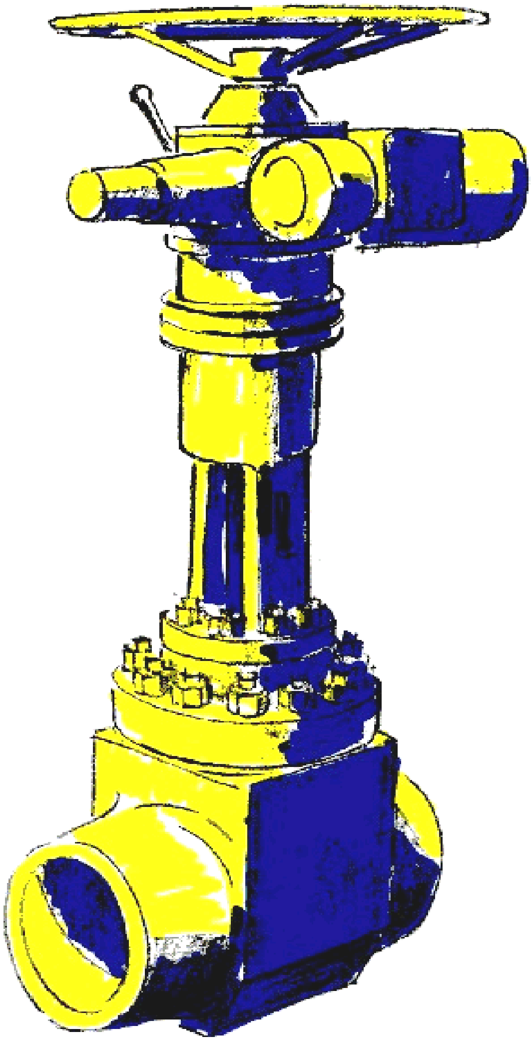
How to Know about the Condition of MOVs

- **Measurements in-situ at the MOV (with stem thrust)**
  - ⇒ *Best amount of information*
  - ⇒ *Many tools exist on the market*
  - ⇒ *High efforts and costs*
  - ⇒ *Often impossible during operation of plant*

- **Remote measurements from Motor Control Center (MCC)**
  - ⇒ *Less information requires additional methods*
  - ⇒ *Easy to do and relative cheap*
  - ⇒ *Possible even during operation of plant*

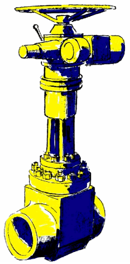
Part 2:

Theoretical Concepts and Backgrounds



The Concept of Remote Diagnosis from MCC

The motor is used as a sensor for the mechanical behaviour of the MOV



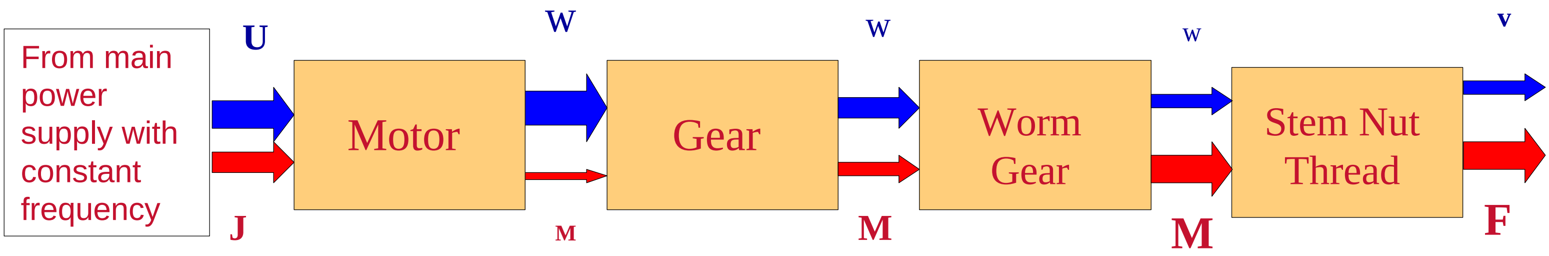
Periodic tests by electrical measurements from the switch gear (MCC)

⇨ Time saving, possible even during power operation
⇨ Mechanical parameters are calculated

Measurements at the valve only
- when anomalies are detected or
- for calibration
(Baseline Measurements)

The Motor as a Sensor for Actuator and Valve (1)

> Energy Flow



$P_{el} = f(U,I)$

$P_{mech1} = M * W$

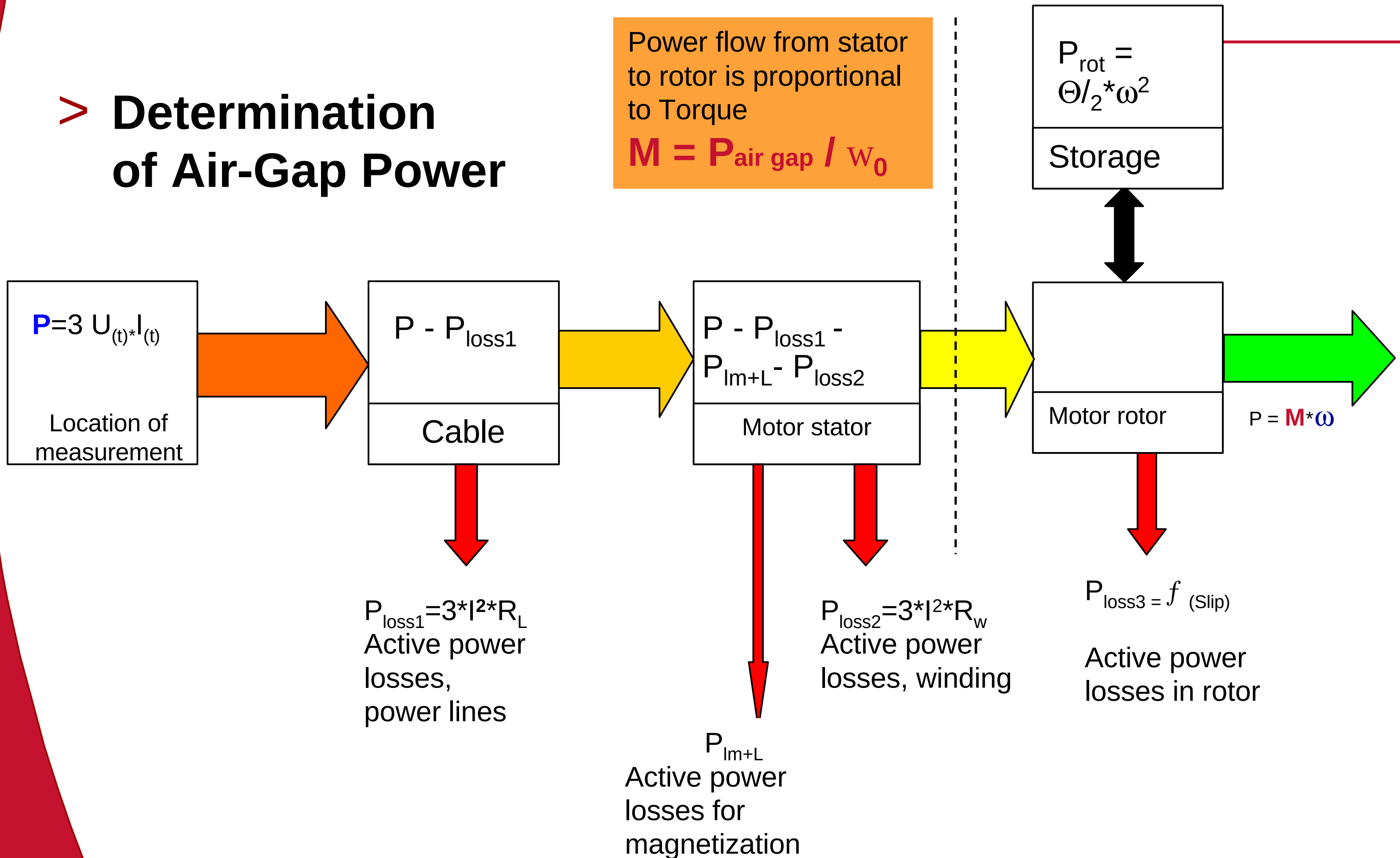
$P_{mech2} = M * w$

$P_{mech3} = M * w$

$P_{stem} = F * v$

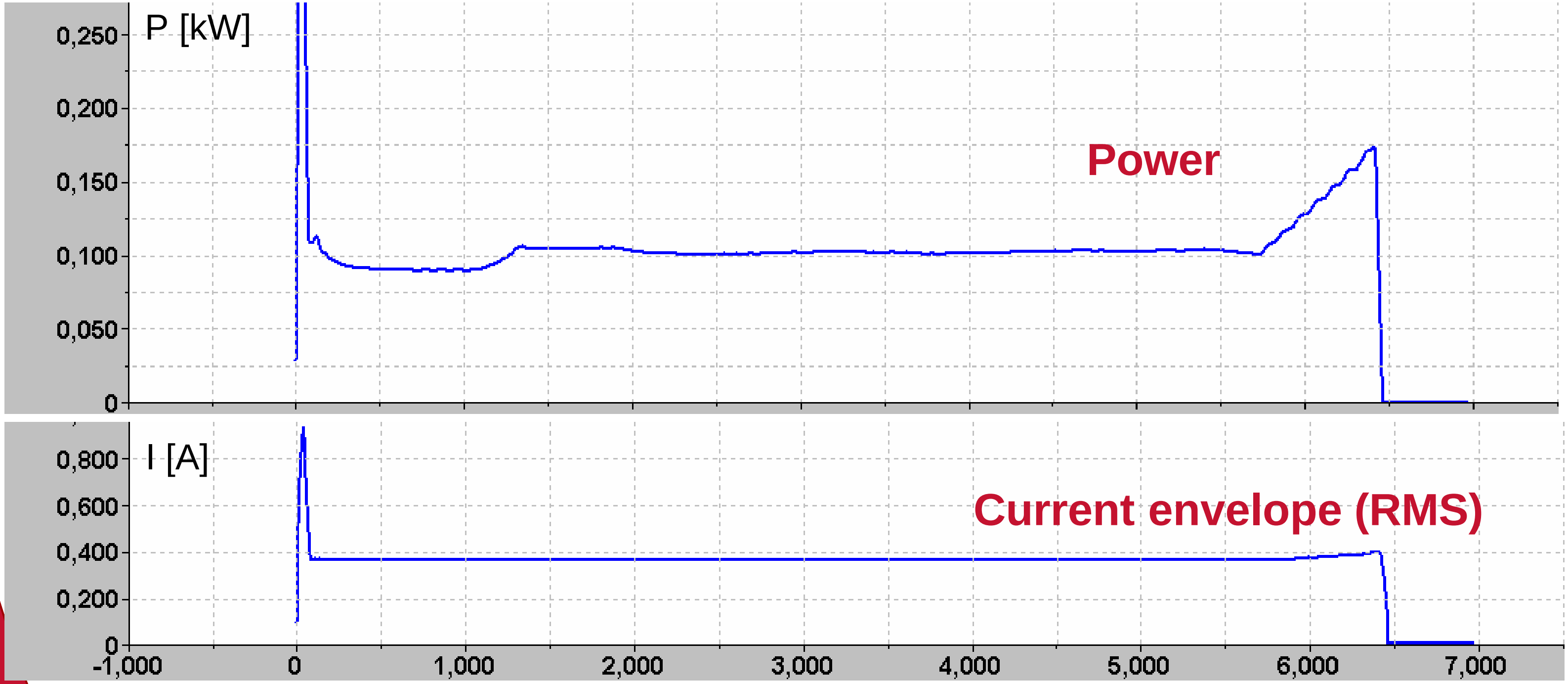
The Motor as a Sensor for Actuator and Valve (2)

> **Determination of Air-Gap Power**

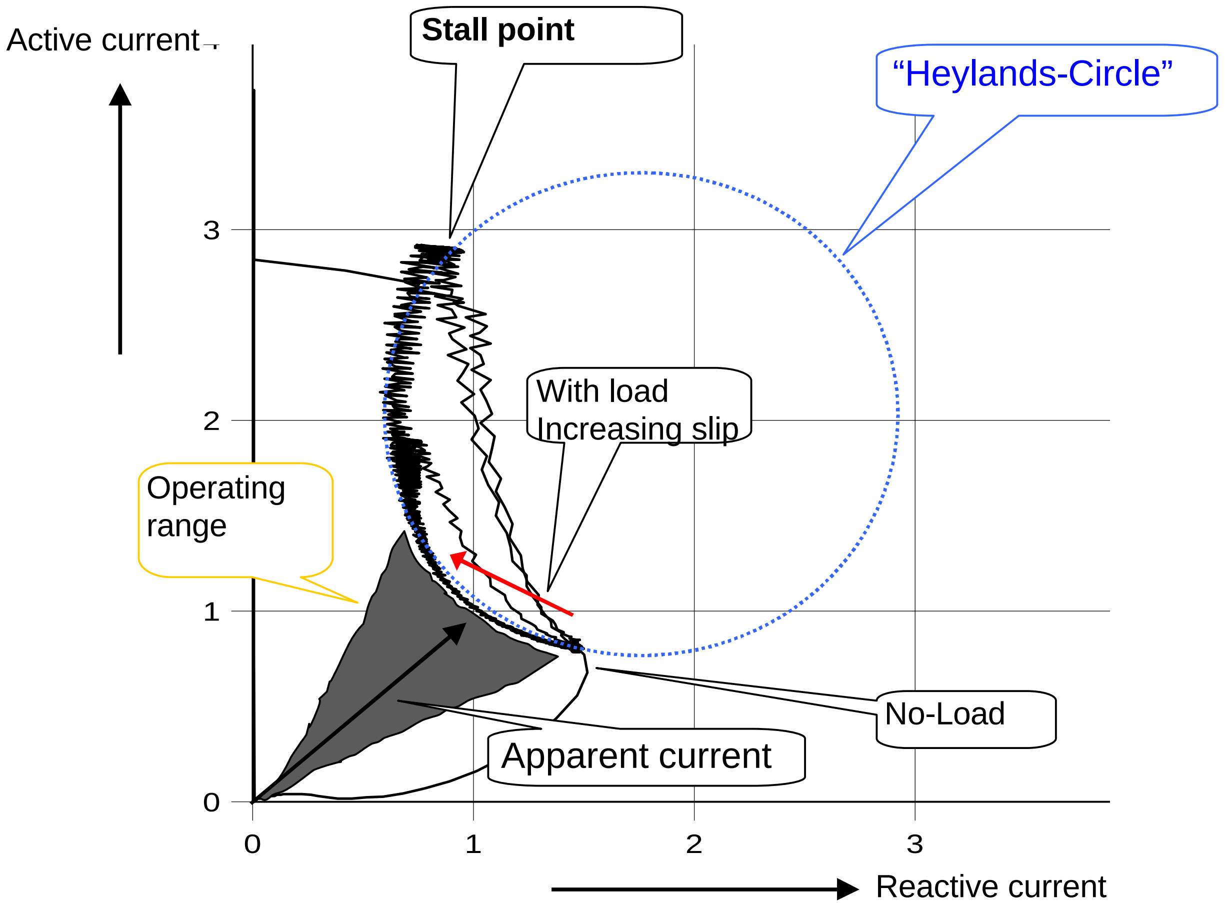


Why Power instead of Current Envelope ? (1)

- **Current envelope is no indication of the mechanical load, because of change of power factor !**

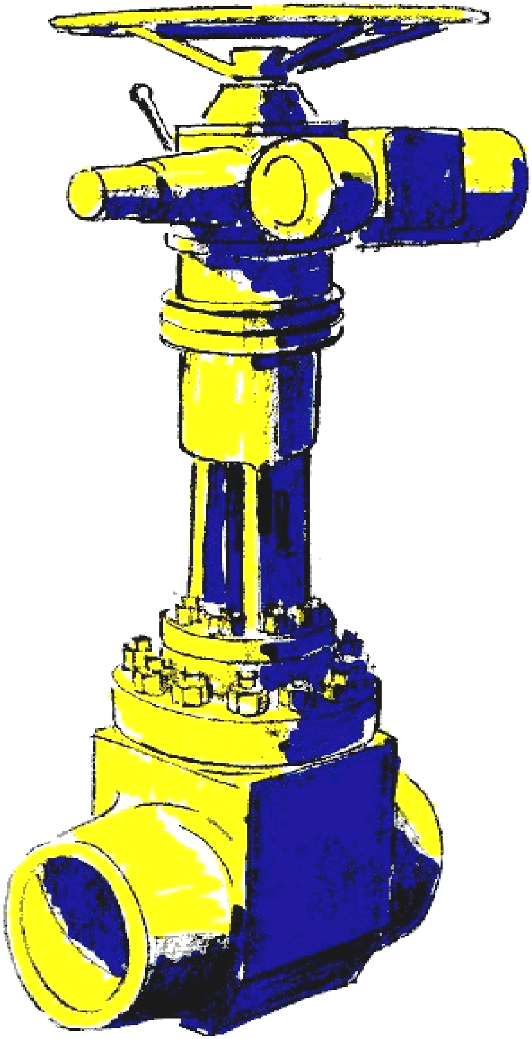


Why Power instead of Current Envelope ? (2)



Part 3:

Practical Implementation of Measurements



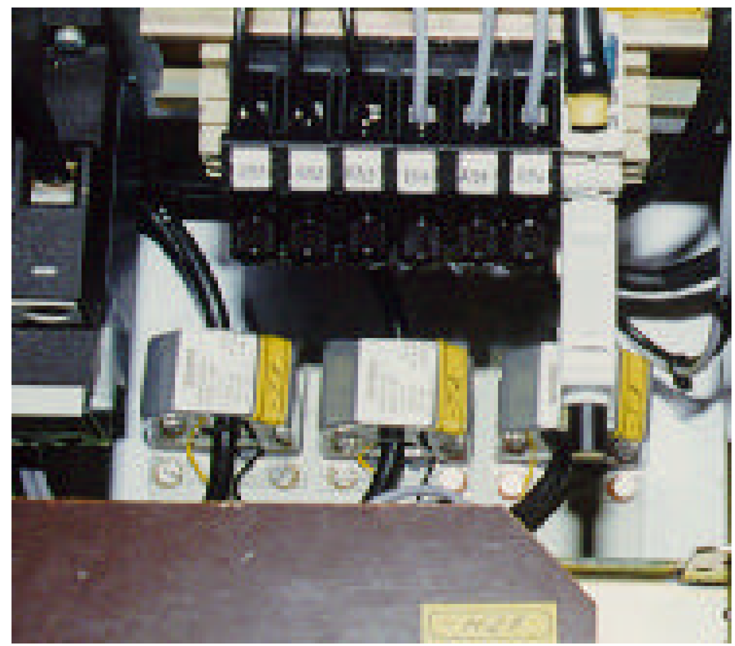
Requirements for Diagnosis Equipment in MCC (1)

- **Must be qualified for use in safety related environment**
  - ⇒ *Electrical safety*
  - ⇒ *Seismic tests*
  - ⇒ *Electromagnetic compatibility [EMC]*
  - ⇒ *Only qualified sub-components (e.g. fuses) at the interface to I&C*

- **High Accuracy**
  - ⇒ *<= 1% for electrical signals*

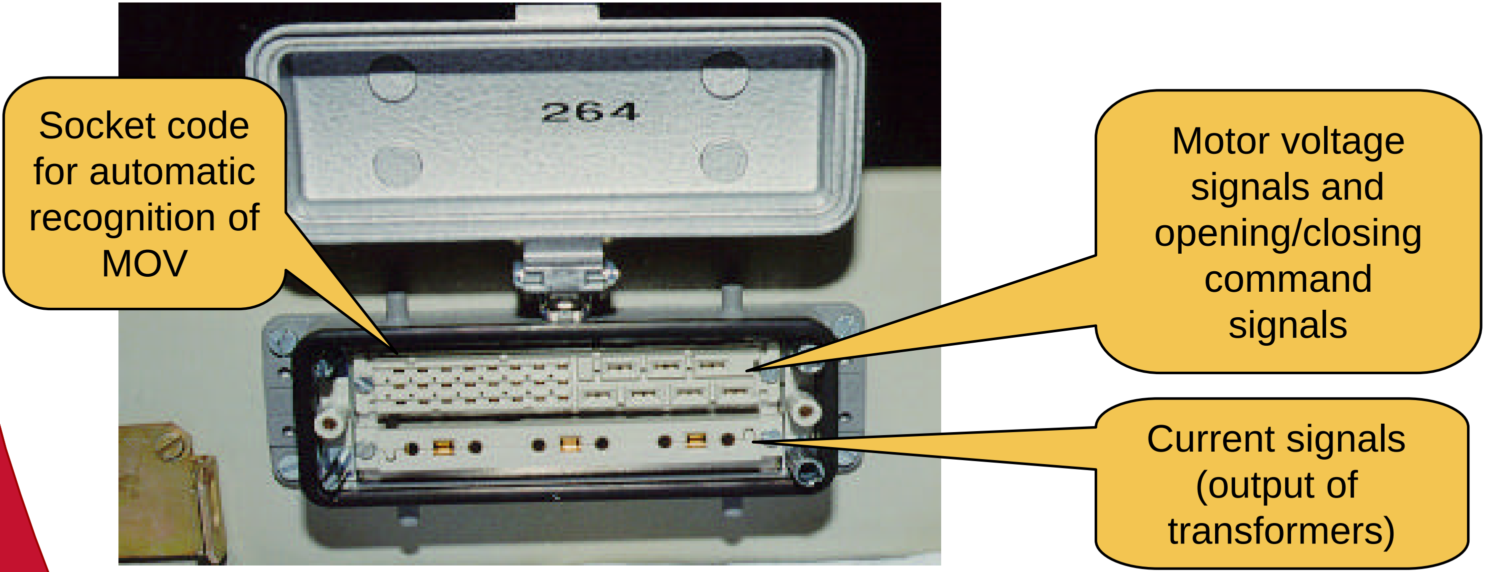
Requirements for Diagnosis Equipment in MCC (2)

- **Must <u>not</u> have any influence on the I&C and MCC**
  - ⇒ *Non-reactive design, inherently safe*
  - ⇒ *Solution: Voltage and current pick-ups via measurement transformers*

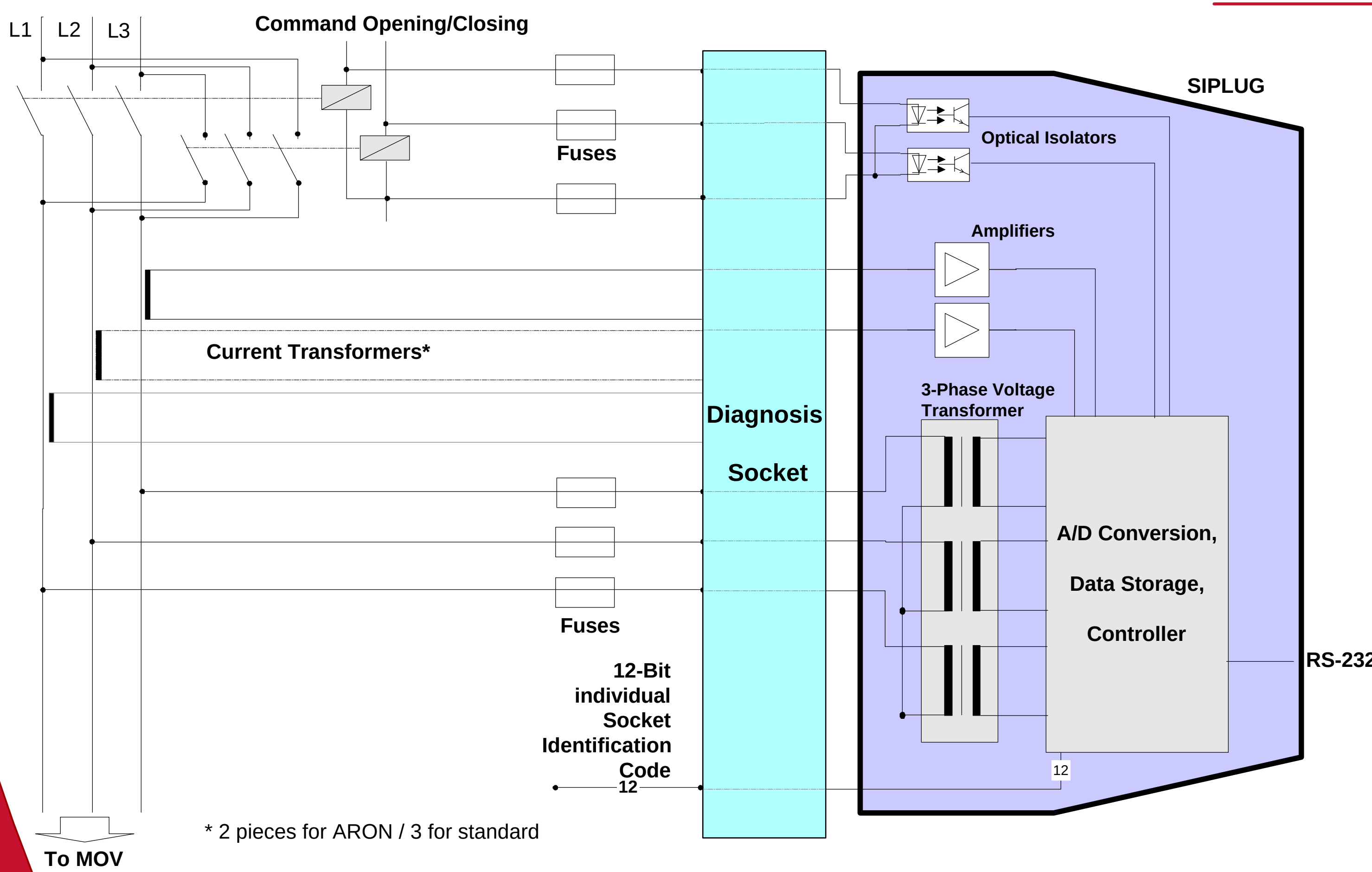


Requirements for Diagnosis Equipment in MCC (3)

- **Easy to use**
  - ⇒ *Short preparation time before measurement*
  - ⇒ *No risks with work at open high voltage*
  - ⇒ *As few as possible manual settings*



Functional Diagram of Mobile SIPLUG®



* 2 pieces for ARON / 3 for standard

History of Diagnosis Equipment by AREVA NP Karlstein (1)

> 1975 Qualification of actuators (LOCA tests) at the Karlstein laboratories (KWU)

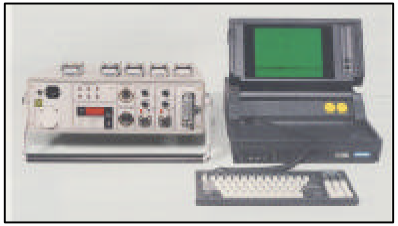
- ⇨ The motor is used as a remote sensor to estimate the actuator's mechanical behavior

Development of sensor technology

- ⇨ Torque and stem thrust with strain gauges
- ⇨ Sensors/transformers for active power measurement

> 1990 "MCC-DAW" Power Measurement during Operation

- ⇨ Active power measurement from the Motor Control Center (MCC)
- ⇨ Permanently installed current transformers and diagnosis sockets at the cabinets allow measurements at any time, even during power operation of plant



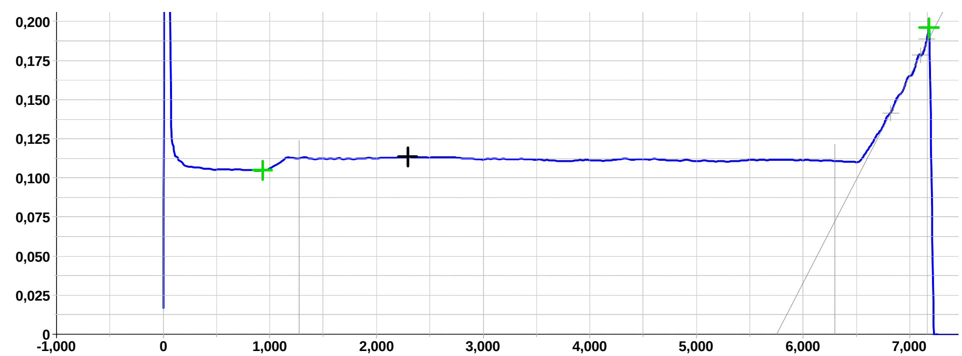
History of Diagnosis Equipment by AREVA NP Karlstein (2)

> 1997 "SIPLUG®" Miniature Measurement Device

- ⇨ Compatible to the MCC-DAW diagnosis sockets, but much smaller and easier to handle.
- ⇨ Low-cost compared to other equipment.

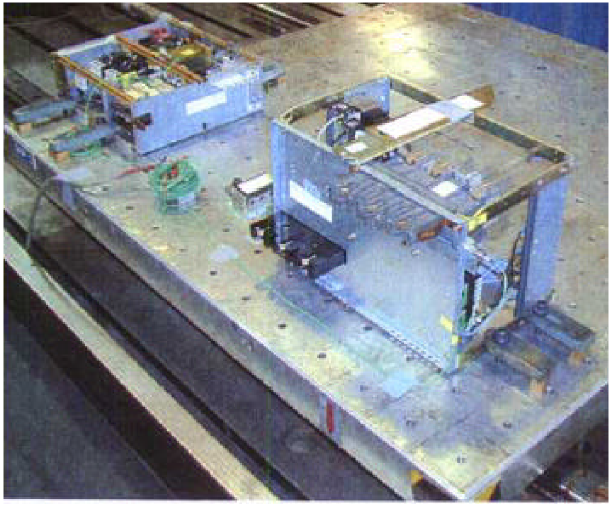
> 1998 "ADAM®" Evaluation Software for Valve Diagnosis

- ⇨ Database for all kind of data (master data, measurements, evaluation results)
- ⇨ Trending and statistical comparisons of results
- ⇨ Assessment based on calculated limits
- ⇨ Automatic evaluation
- ⇨ Easy to use graphical display

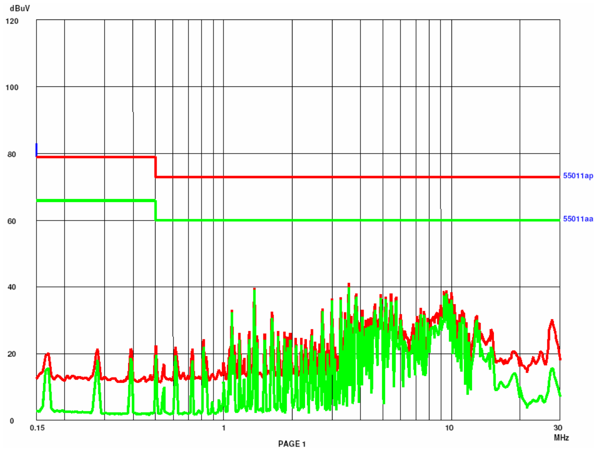


Qualification of SIPLUG components

- Seismic tests according to German KTA and “Konvoi” rules of:
    - Current transformers
    - Mounting material
    - SIPLUG sockets
    - Complete cubicles with
    - SIPLUG Online-3

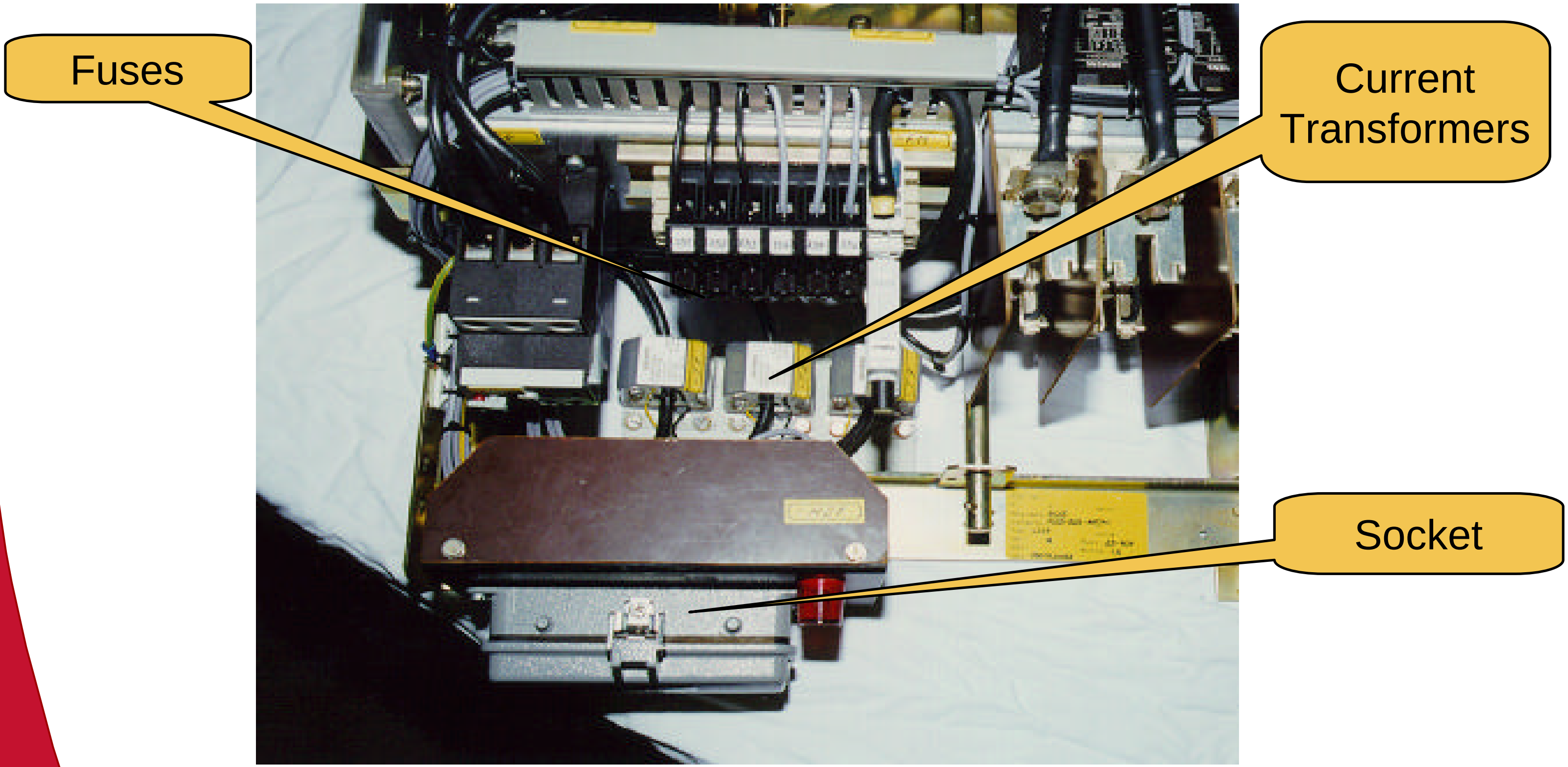


- EMC tests according to EN 61000-6-4:2001 and EN 61000-6-2:2001



- ADAM software qualification for NPP Neckarwestheim

Example for Installation of Diagnosis Socket

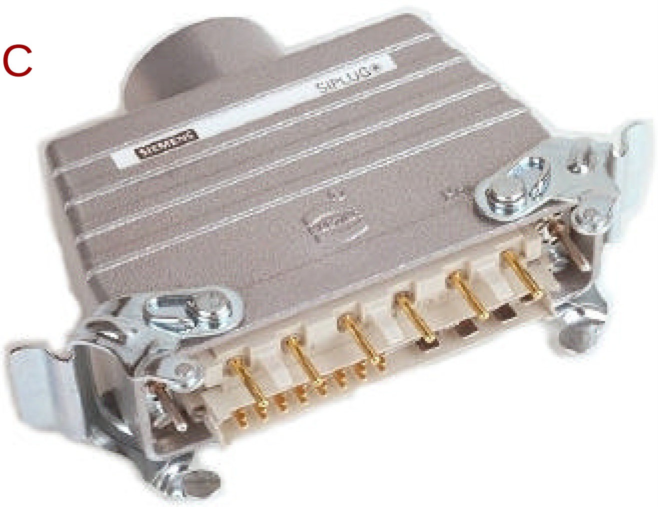


The Smart Solution with SIPLUG®

- Low preparation effort
  - -- Just plug the SIPLUG
  - -- Clearance from control room NOT required
- Only 1 person
  - -- No special knowledge
- No risks for operator
  - -- No open voltage
- Measurement without operator on site
  - -- e.g. during the night
- Automatic detection of valve and power range
  - -- by coded sockets

SIPLUG® Technical Data (1)

- Microprocessor controlled miniature data acquisition module
- Battery powered autonomous operation
  Up to 400 sec internal storage
- Measurement at any time from the MCC
  Permanently installed current transformers, it is not necessary to open circuit.
  Automatic trigger when actuator starts.
- Full ohmic isolation for plant safety
  Inductive current and voltage transformers, additional fuses for selective protection
- High accuracy
  < 1%, each SIPLUG is calibrated. (typ. 0.2 - 0.6%)
- Easy handling
- Low cost

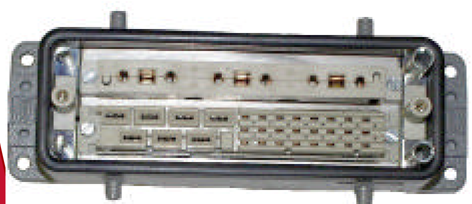


SIPLUG® Technical Data (2)

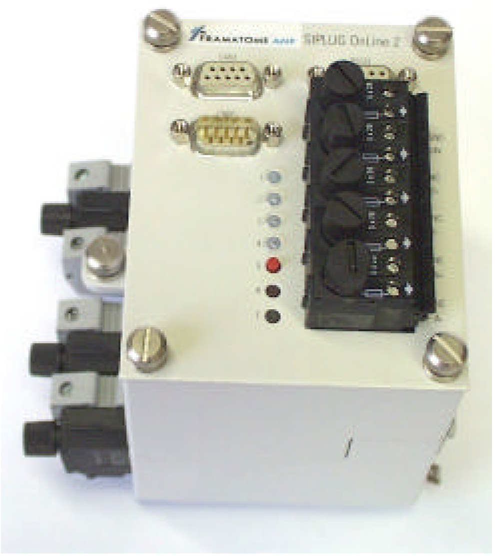
- Internal sample rate 4kHz, output rate 250Hz
  3 channels voltage, 2 or 3 channels current
- 1 MByte RAM (about 400s storage time)
- Output channels:
  - active power
  - 1 voltage L1-L3 (RMS)
  - 3 currents I1, I2, I3 (RMS)
  - command voltages opening/closing
- RS-232 interface
  for data transfer to PC, 57600 baud
- Standard 9V battery
  for approx. 6 months usage

The 3 Versions of SIPLUG® for Valve Diagnosis

Diagnosis Socket and Mobile, Pluggable SIPLUG®

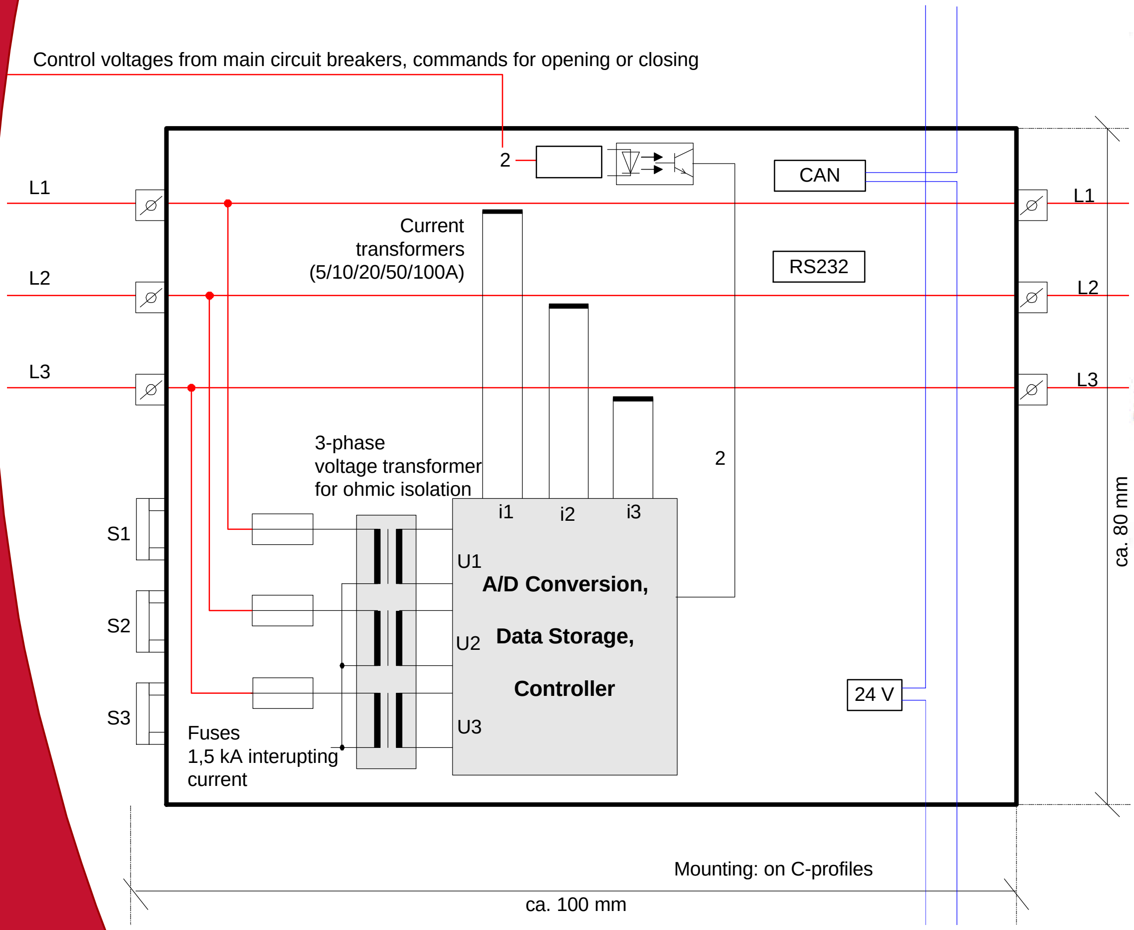


Online SIPLUG® for Cable Outlet („SIPLUG Online-2“)

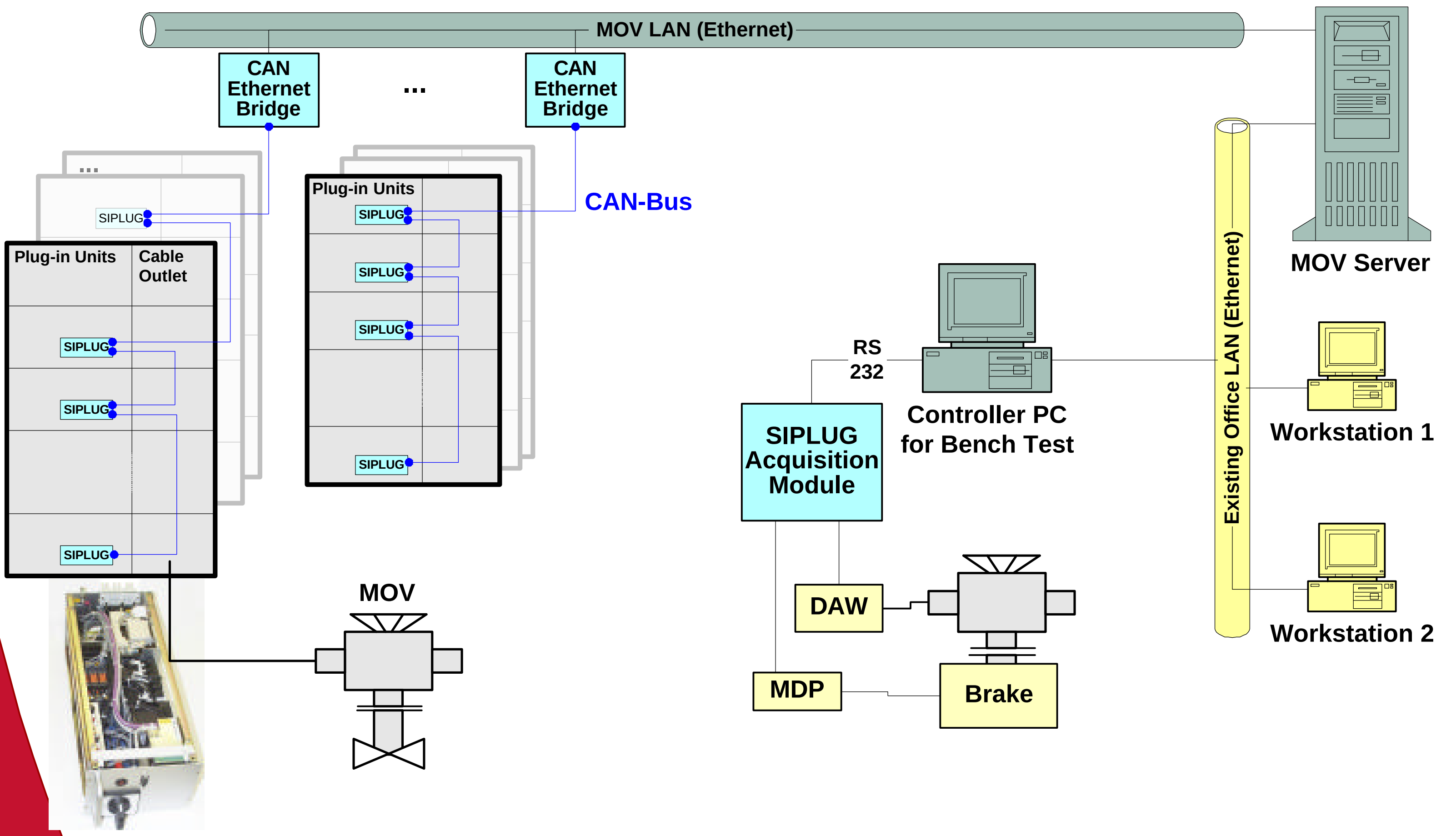


Online SIPLUG® for Integration into Plug-in Units („SIPLUG Online-3“)

Functional Diagram of SIPLUG® Online-2 (Cable Outlet Version)



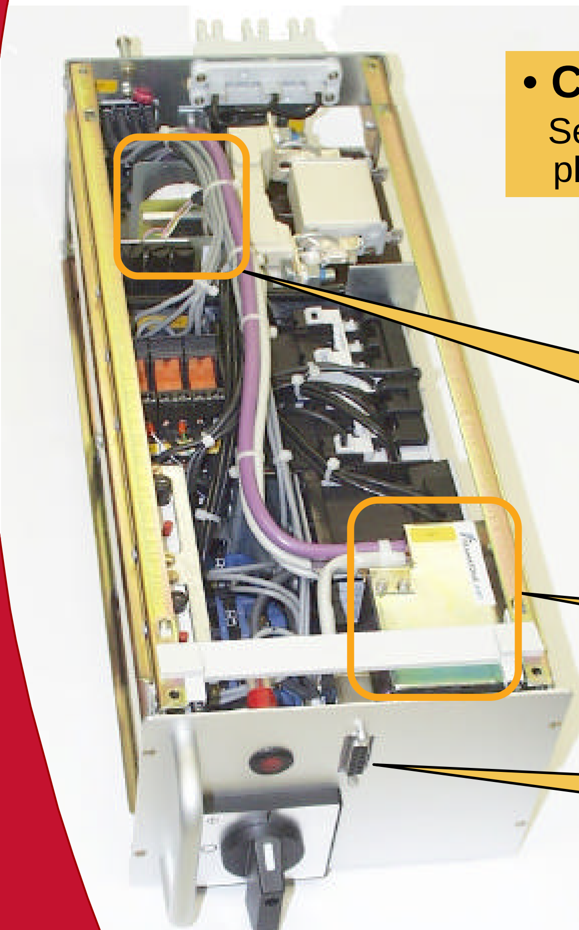
Overview of SIPLUG® Online-3 Installation (Plug-in Unit Version)



Integration of SIPLUG® Online-3 into Plug-in Control Unit

- **Complete Integration in the Plug-in Unit**
  Sensors as well as signal processing are firmly designed into the plug-in unit.

Example: German „8PU“ plug-in unit (very small !)
Can be adapted to other designs (e.g. EPR SIVACON)



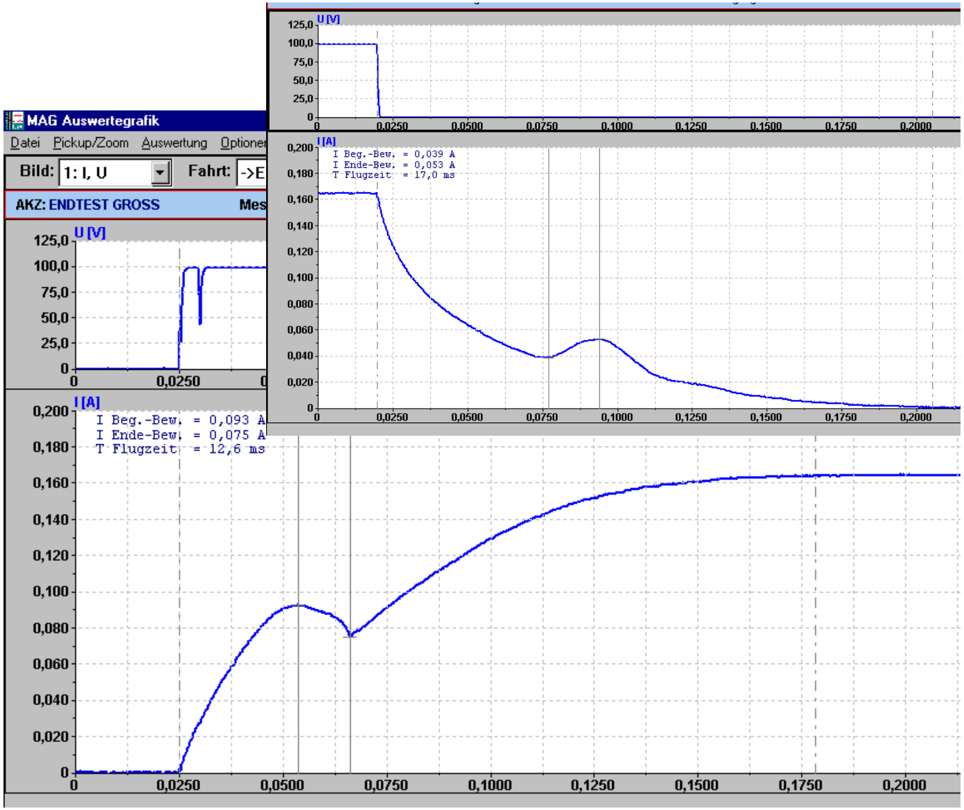
Power circuit interface (current transformers, voltage transformer, fuses) [Shielding removed]

SIPLUG Online-3 control electronic

Connector for external display and control button box

SIPLUG® SOV and ADAM® SOV for Solenoid Valves

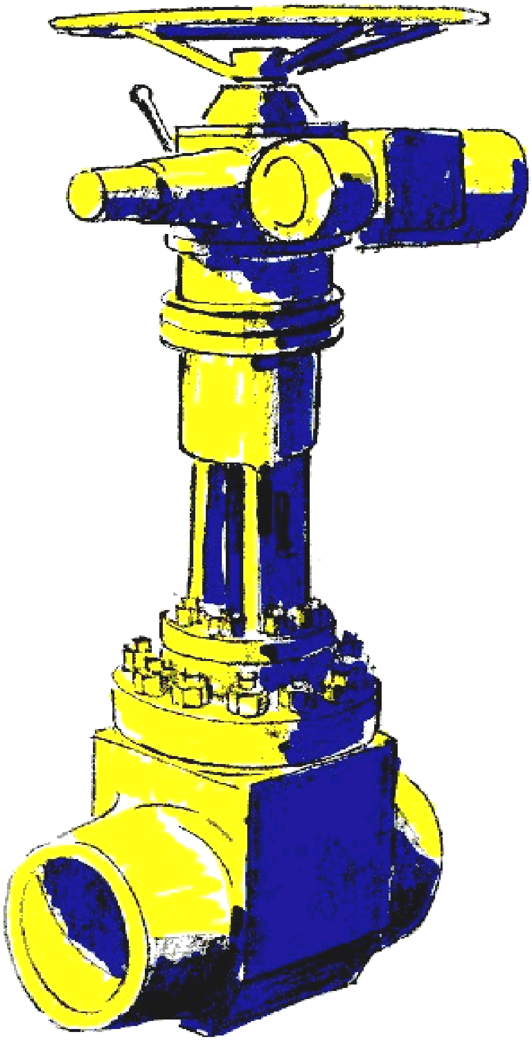
SIPLUG® SOV
Data acquisition hardware



ADAM® SOV Software
Diagrams of current and voltage

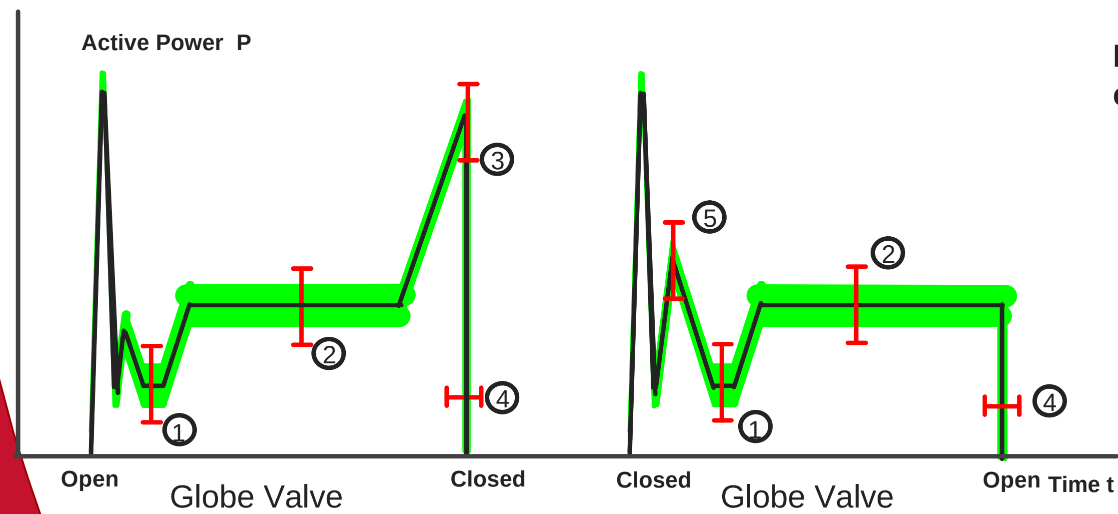
Part 4:

Analysis and Assessment of Measurements



Power Signature for Globe Valves

Analytical Evaluation by Calculation of Nominal and Limit Values + **Baseline Measurement** + **Diagnostic** Active Power Measurement + **Trending and Statistics** = **Condition-Based Maintenance**



Permissible tolerances for certain parameters, e.g.

1. Zero load power
2. Running power
3. Torque switch off
4. Running time
5. Max. unseating power

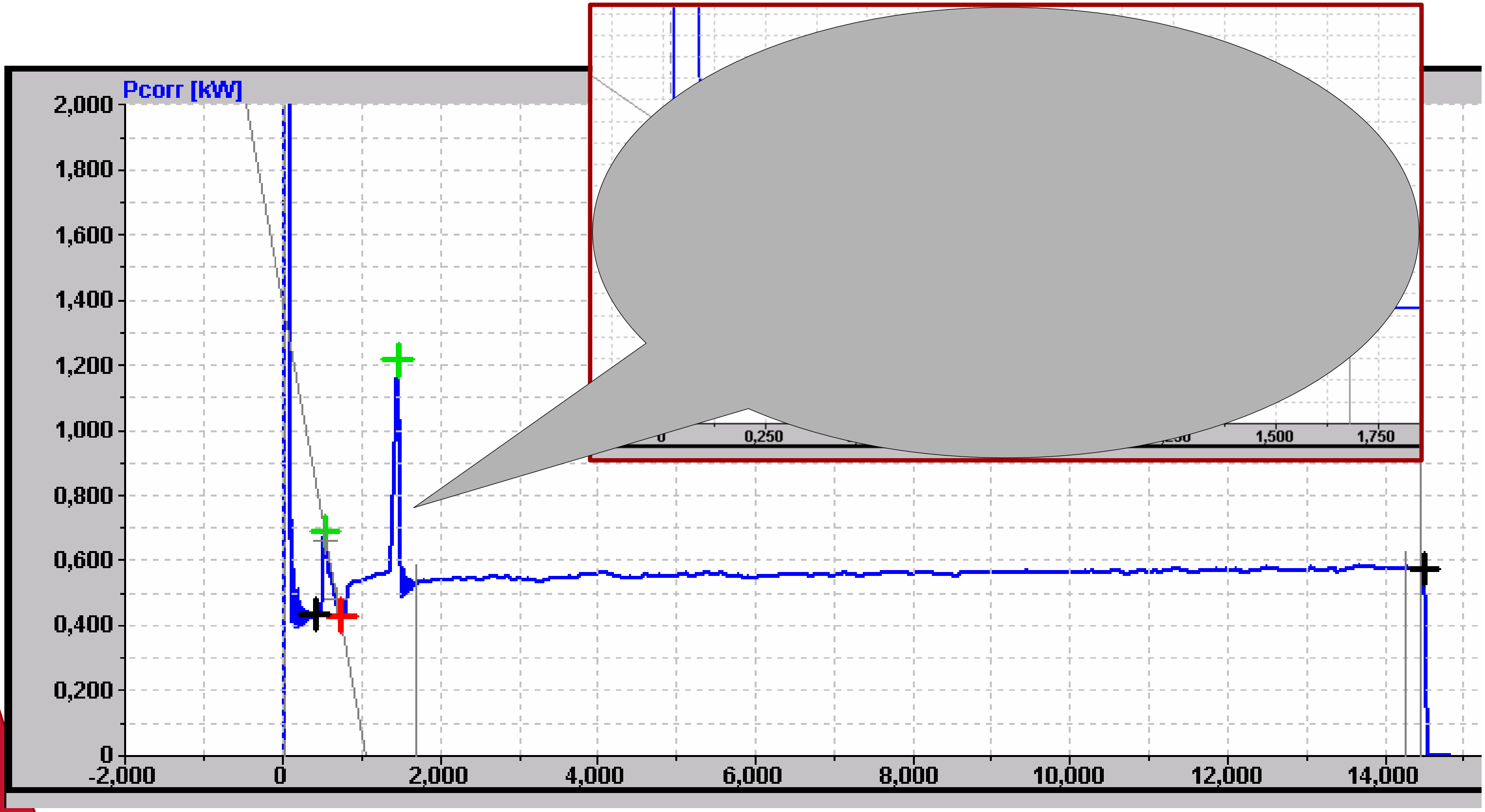
What can be Derived from Electrical Measurement ?

A)

- **Active Power minus losses on cables and stator gives the Air-Gap Power.**
- **Air-Gap Power is proportional to motor torque.**
- **By use of bench test characteristic curves, actuator output torque can be quantified later.**
- **If the rigidity of the valve is known, the final stem thrust can be calculated out of the stressing time.**
- **Trending and statistical comparison of similar MOVs.**

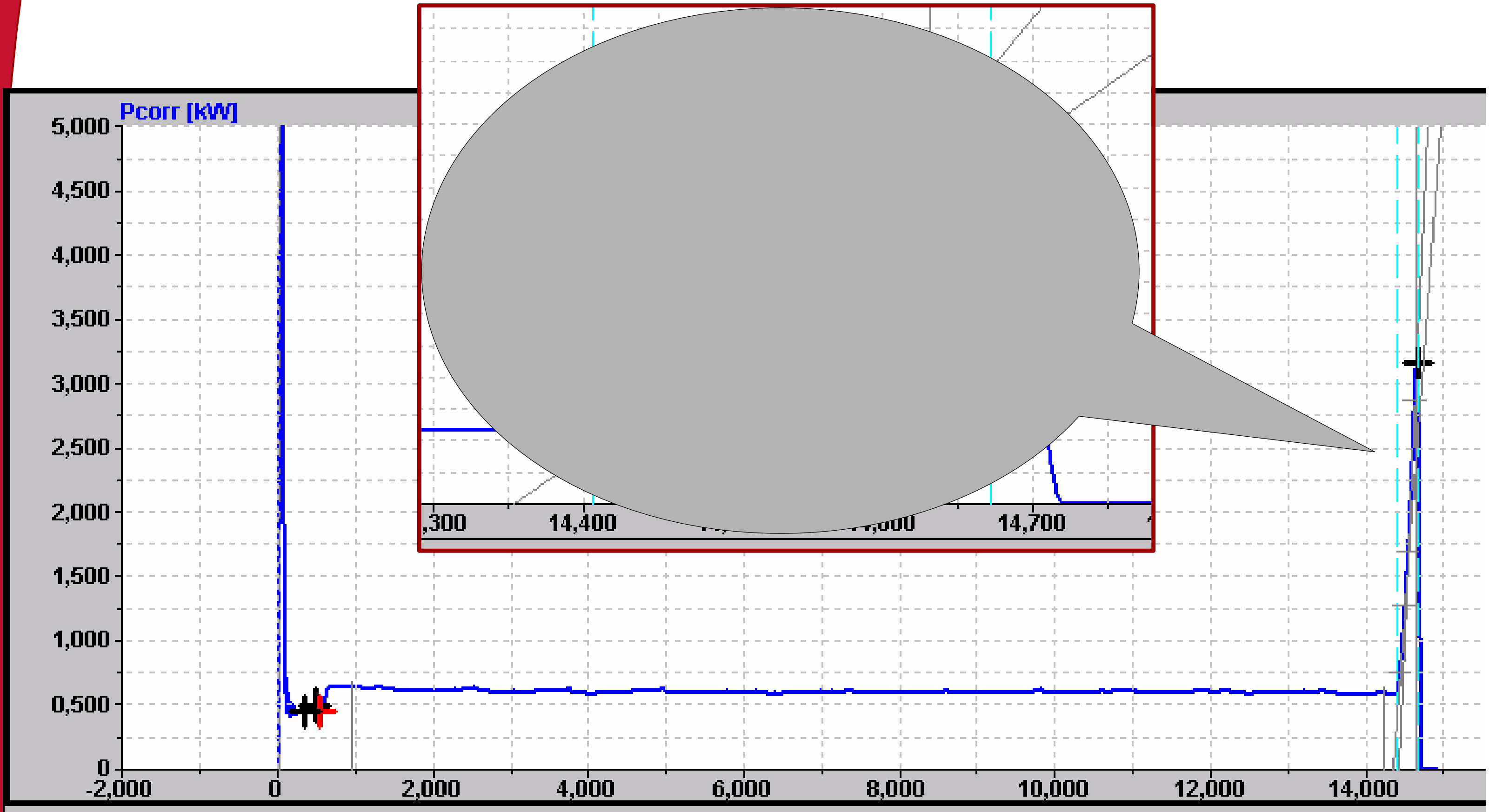
Power Signature of Wedged Gate Valves

Opening with Hammerblow & Unwedging

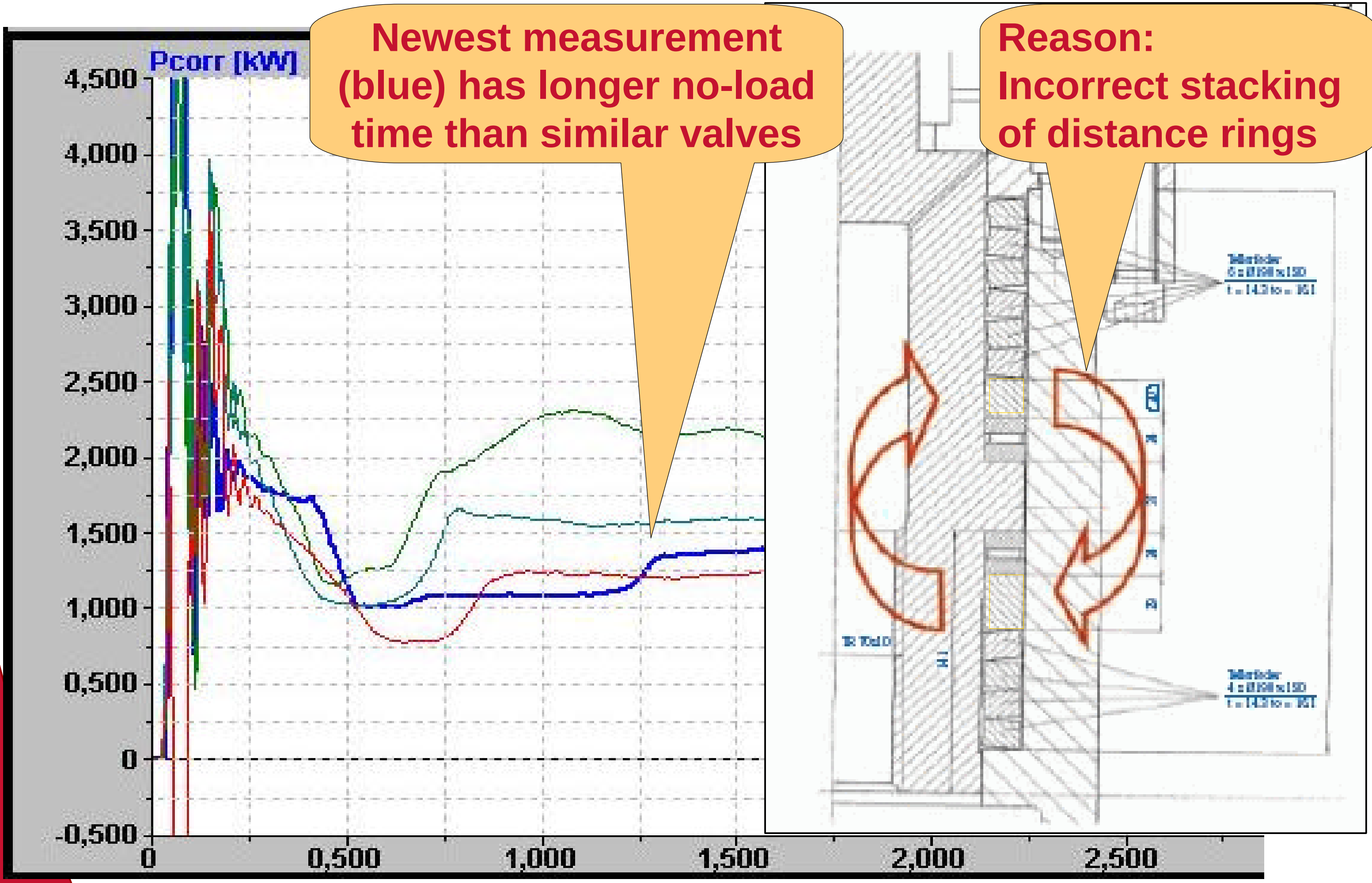


Power Signature of Wedged Gate Valves

Closing with Wedging



Qualitative Assessment of Power Signature



Newest measurement (blue) has longer no-load time than similar valves

Reason: Incorrect stacking of distance rings

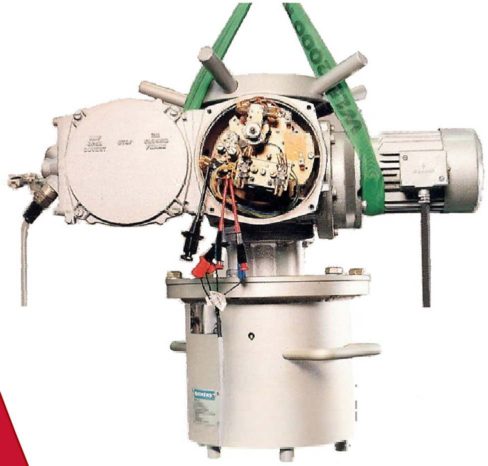
What can be Derived from Electrical Measurement ?

- Active Power minus losses on cables and stator gives the Air-Gap Power.
- Air-Gap Power is proportional to motor torque.

B)

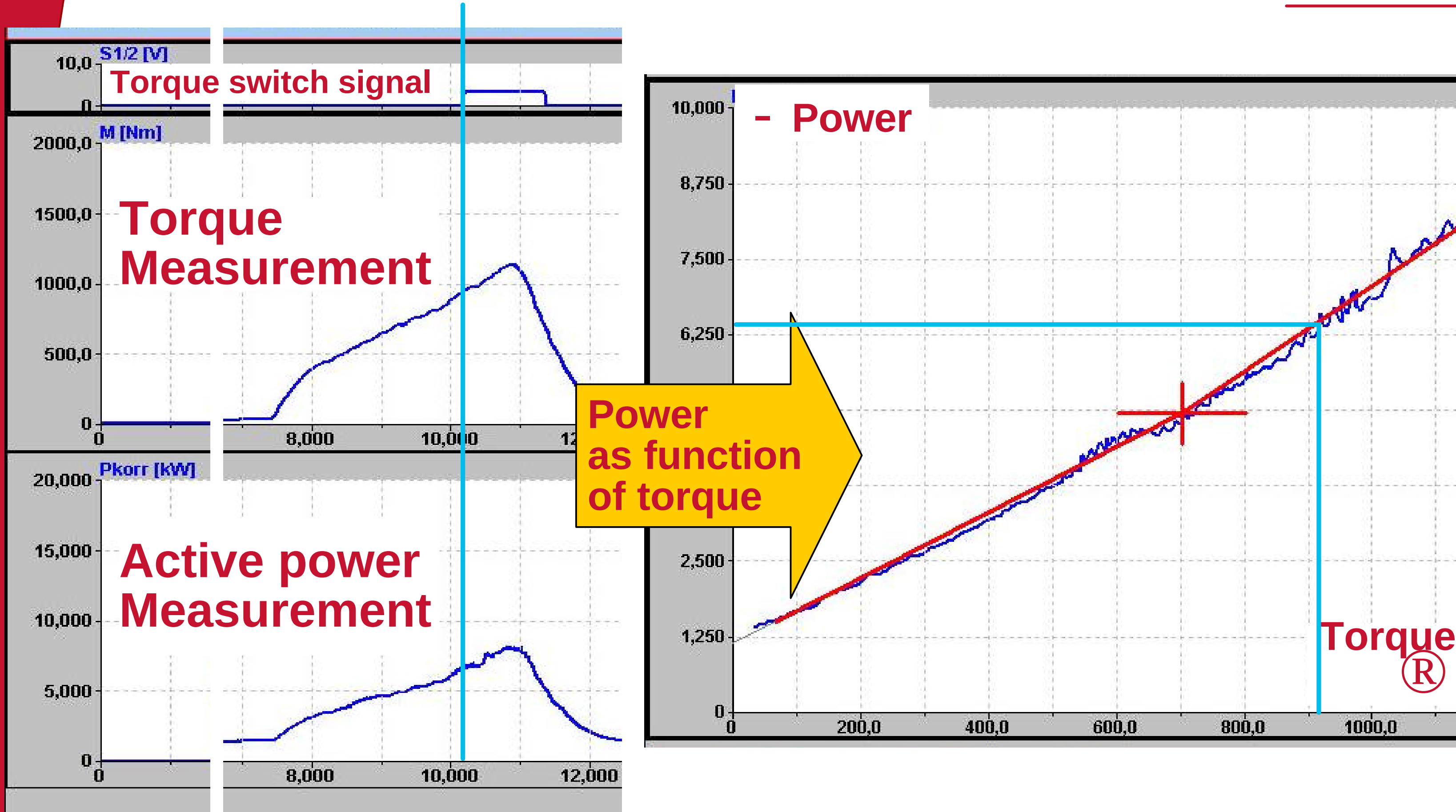
- By use of bench test characteristic curves, actuator output torque can be quantified later.
- If the rigidity of the valve is known, the final stem thrust can be calculated out of the stressing time.
- Trending and statistical comparison of similar MOVs.

Baseline Measurement - Bench Test



- **Periodic tests in line e.g. with German Nuclear Safety Standard KTA 3504.**
- **Setting the torque switch**
- **Measurement of actuator speed**
- **Calibration and determination of characteristic curves:**
  - Torque / active power
  - Torque / worm gear displacement angle of rotation

Evaluation of Bench Test Measurements



What can be Derived from Electrical Measurement ?

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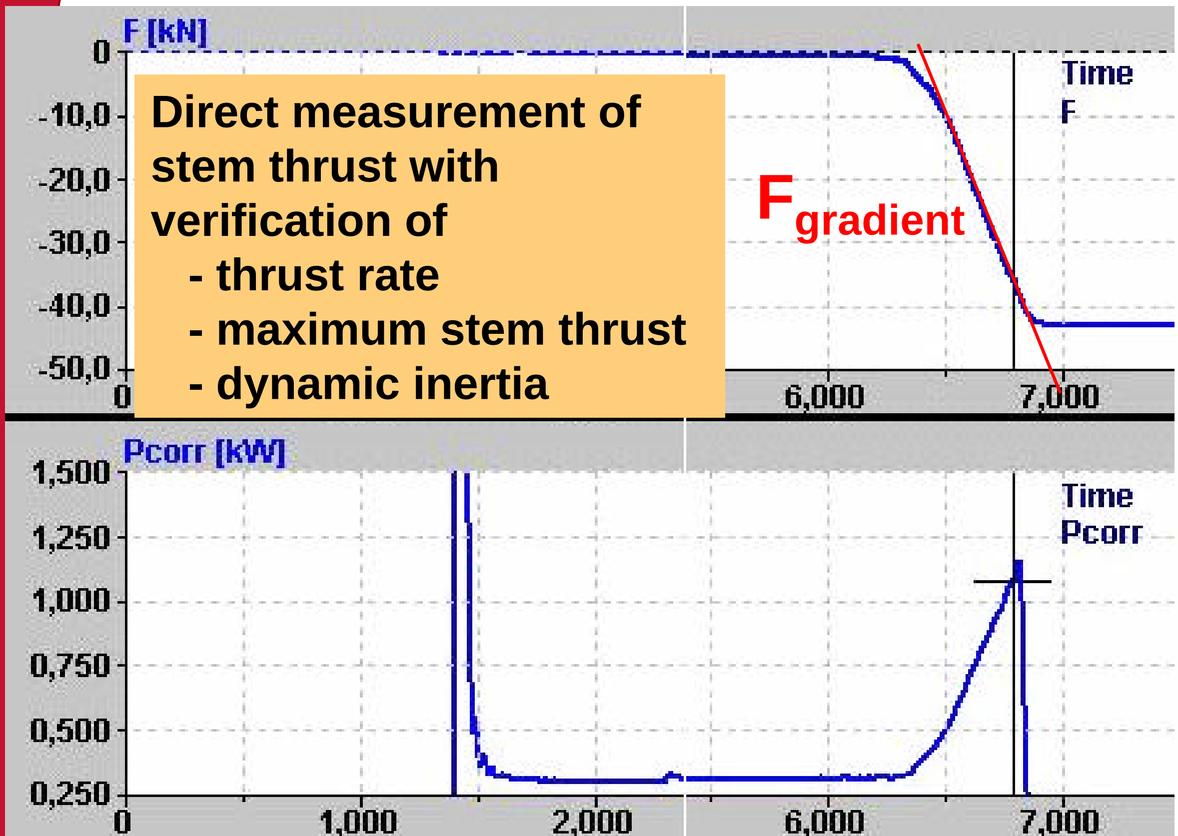
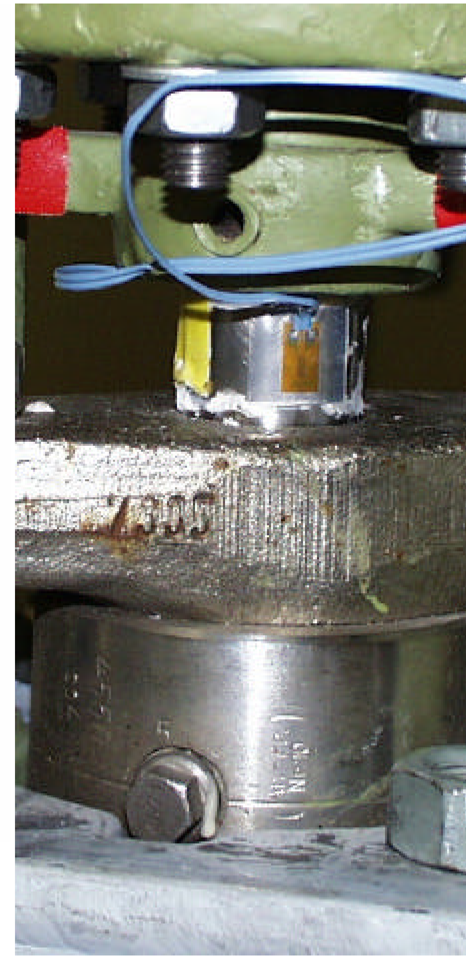
- Air-Gap Power is proportional to motor torque.
- By use of bench test characteristic curves, actuator output torque can be quantified later.

C)
- If the rigidity of the valve is known, the final stem thrust can be calculated out of the stressing time.
- Trending and statistical comparison of similar MOVs.

Baseline Measurement - Stem Thrust

Direct measurement of stem thrust with verification of
- **thrust rate**
- **maximum stem thrust**
- **dynamic inertia**





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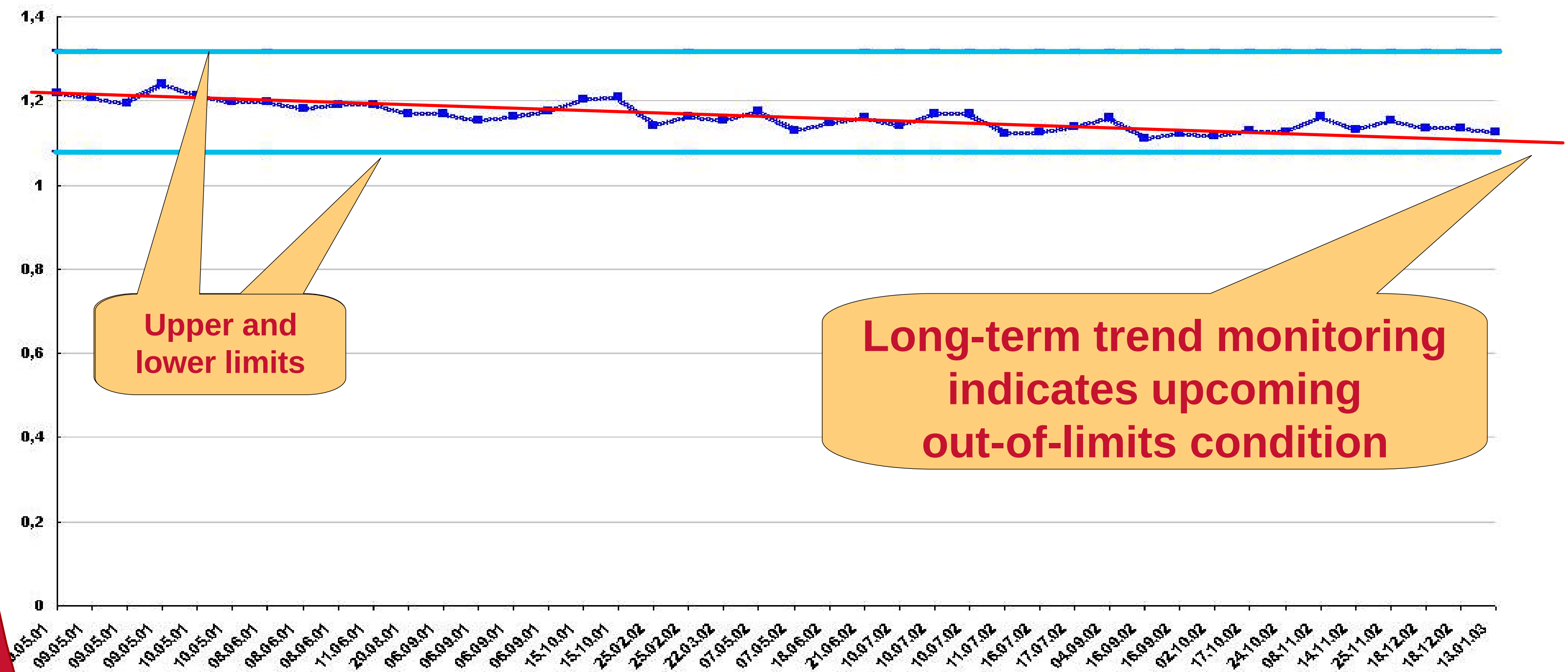
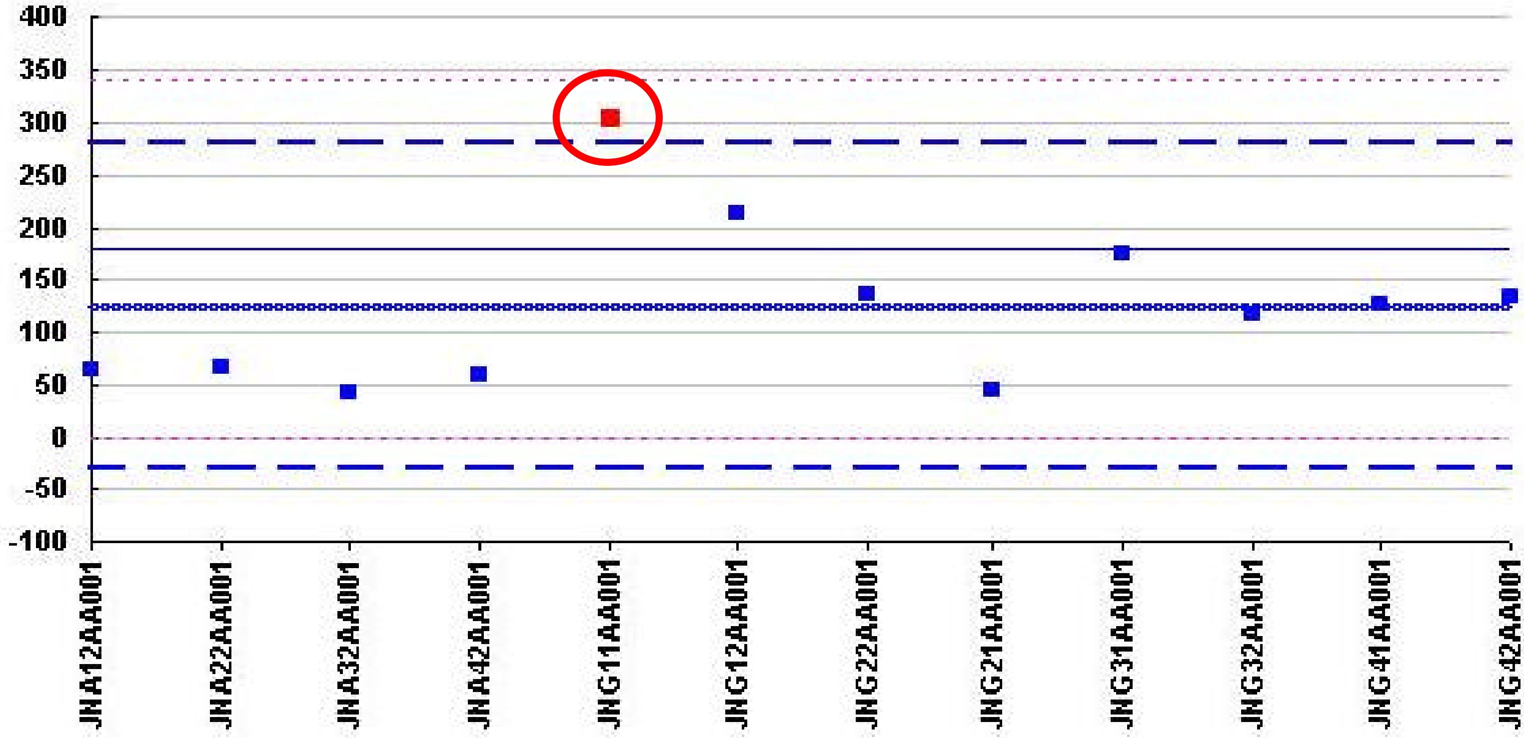
- Air-Gap Power is proportional to motor torque.
- By use of bench test characteristic curves, actuator output torque can be quantified later.
- If the rigidity of the valve is known, the final stem thrust can be calculated out of the stressing time.

D) ▪ Trending and statistical comparison of similar MOVs.

Long-Term Trending of Evaluation Results

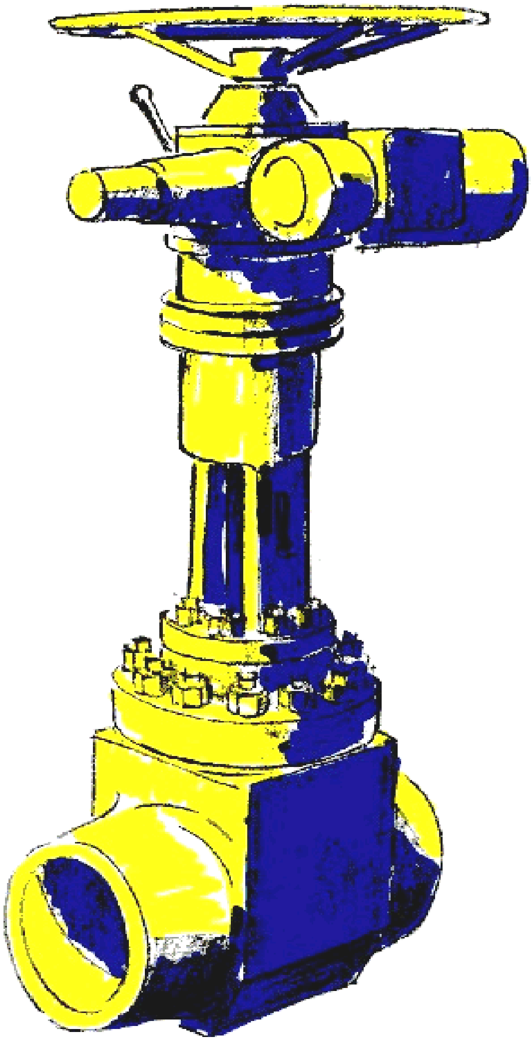


Comparison of Similar MOVs



Part 5:

Conclusion

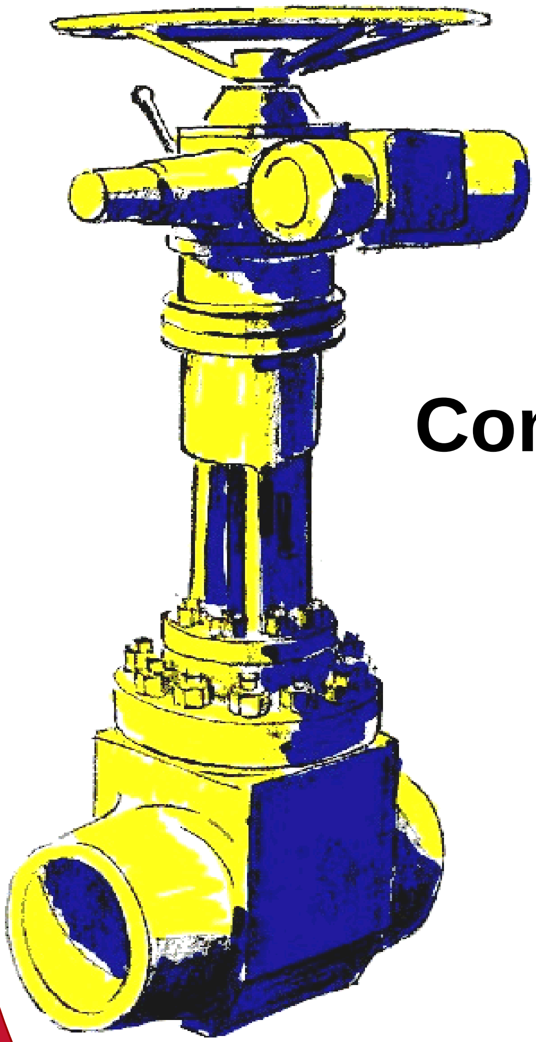


Conclusion

- **Modern monitoring methods with measurements from MCC can replace traditional in-situ measurements.**
- **Condition Based Maintenance (CBM) needs more frequent information about condition of components than other maintenance strategies.**
- **CBM (or maintenance planning !) can help to improve plant safety and availability.**
- **CBM can also reduce costs**

The tools SIPLUG® and ADAM® are in operation at the following plants:

- Germany: NPP Neckarwestheim (KWU PWR),
  2 units, together 1500 MOVs with online monitoring.
- Finland: New EPR at Olkiluoto (OL3),
  online monitoring of 600 MOVs and 100 SOVs.
- Germany: NPP Grohnde (KWU PWR),
  800 SIPLUG sockets, 20 mobile SIPLUGs.
- Switzerland: NPP Beznau 1+2 (Westinghouse PWR)
  250 SIPLUG sockets, 20 mobile SIPLUGs. 100 SOV sockets.
- Others in Germany: KKP 1+2 (500/50), KKB (200/10), KKK (200/10)
  KGG, KKE, KKG: special equipment based on SIPLUG.
- Others worldwide: Angra-2 (Brazil), 100 sockets, 10 SIPLUGs,
  Smolensk (Russia) 15 sockets, 4 SIPLUGs,
  Trillo (Spain) 4 Current-Clamp-SIPLUGs



The End

Moving Towards Condition Based Maintenance of Valves and Actuators

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The End

Valve Diagnosis with ADAM® and SIPLUG® Technology