CIGRE WG A3-06 Tutorial
Reliability of HV Equipment

Seoul, 31st October 2008

HV Equipment Conditions Monitoring
Summary and Evaluation of Various Data Sources

D. KOPEJTKOVA
CEPS, a.s.

P. KOPEJTKO
EGU HV Laboratory, a.s.
Czech Republic

P. SPURNY
CEPS, a.s.

Maintenance strategies

For modern maintenance strategies different abbreviations are used

TBM→RCM→CBM→RBM→PFM

understanding based on CIGRE work

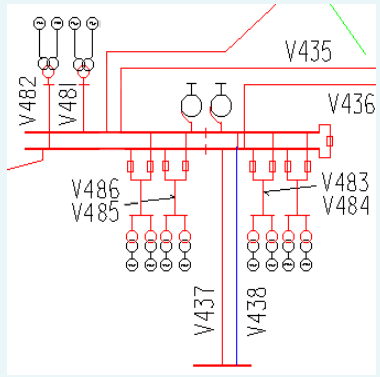
CEPS present practice : CBM

CEPS goal : RBM→PFM

Data sources - STRUCTURED TERMINOLOGY

Objects
(Installation place)

Network description (IP - single line diagram) DISPATCH CENTER VIEW

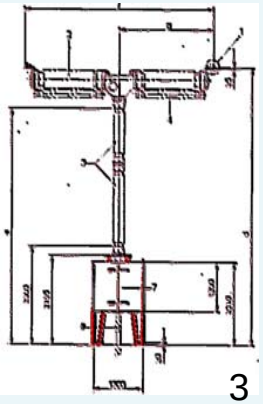


Components
(Equipment)

Specific equipment (EQ serial number) ASSET MANAGEMENT VIEW

Types
(Class)

EQ groups of the same design (manufacturer's designation & specification) ASSET MANAGEMENT VIEW



OBJECT (IP) EVENTS CHARACTERISTICS & DATA SOURCES

Events & characteristics:
Unplanned outages, Planned outages, Network service configuration changes, Load and alarm signaling, Transients and alarm signaling, Importance (weight)

Primary sources of information :
control systems (in substations and in dispatch center), protection systems (relays and fault recorders), system electronic diary

For AM purposes the data has to be transferred via object-component link and stored at the component which has been installed on the specific object at the time when the event happened

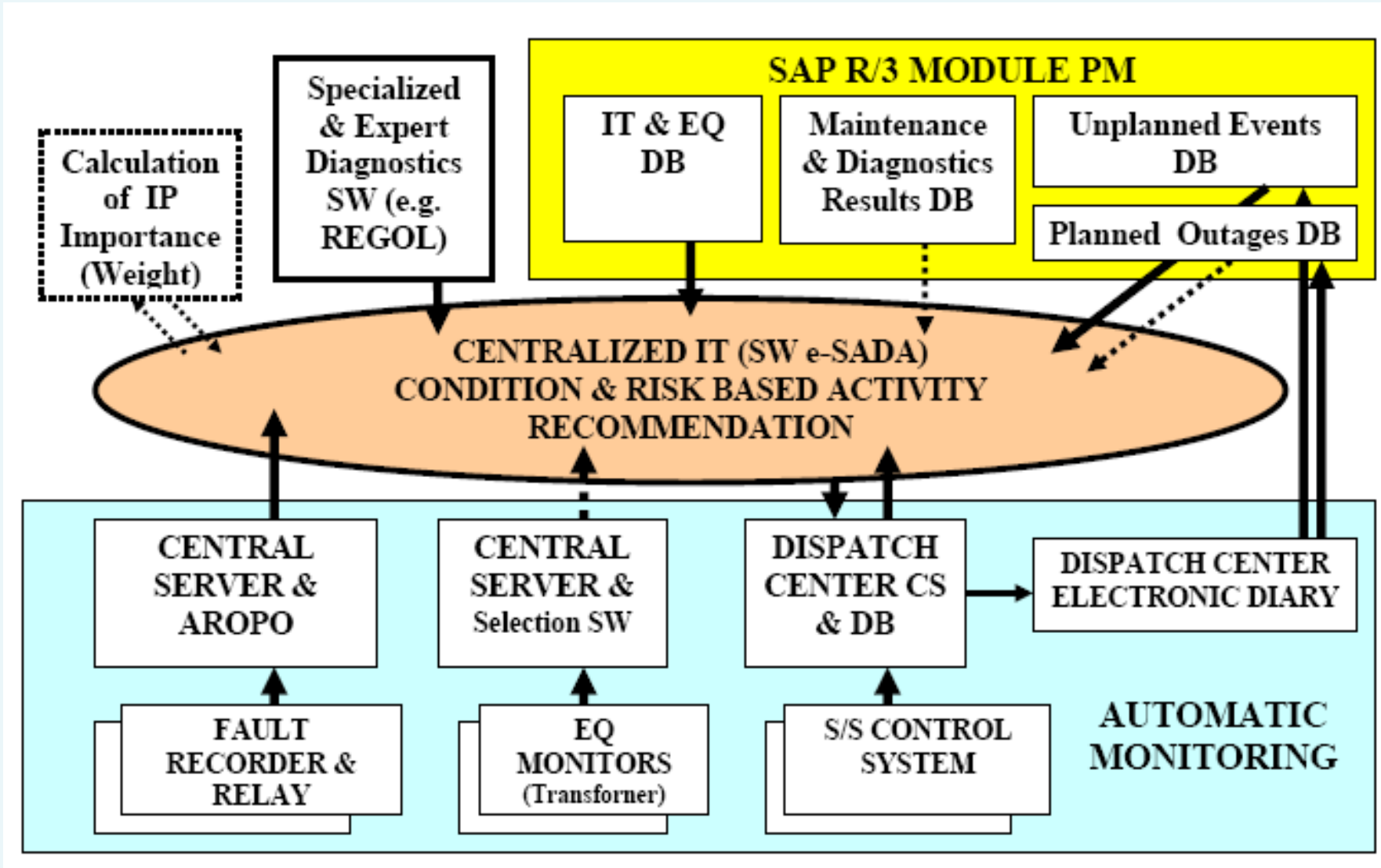
COMPONENT (EQ) EVENTS CHARACTERISTICS & DATA SOURCES

EQ events & characteristics:
Commissioning, Preventive maintenance (diagn. incl.), Failures (Ma & Mi), Repairs, Cumulative loading (steady state and transient), Alarm signaling, Ageing, Disposal

Technological type events :
Frequency of systematic failures (design, manufacturing, ageing, etc.), Ageing curve, Frequency of random failures, Reparability, Maintainability

Primary sources of information :
Maintenance results and different tests protocols (SAP), Failure records (SAP), Control systems (S/S and DC), Relays and Fault recorders, single EQ monitors (PT, OHL, etc.)

DATA MANAGEMENT – CENTRALIZED IT SYSTEM ARCHITECTURE



Monitored Data Main Sources – DATA EVALUATION

Control Systems (SCADA)

Dispatch Center DB basic types of information :

- **Raw loading characteristics (U, I) sampled in relation to requested delta criterion**
- **Calculated loading characteristics (U,I) - ! S/S single line diagrams**
- **S/S configuration change and regimes (+ time tag)**
- **Alarm signaling (+ time tag)**
- **Load I limit values**

Control System Data Evaluation

Loadings (loading curves) – per S/S bay, busbars and transformers :

- **average, maximum and minimum : current, voltage, watt and reactive power, regulation (U,I,t)**
- **time duration of exceeding limit value of load current**
- **time duration of exceeding limit value of voltage**

Ageing characteristics - per individual equipment:

- **CB, DS, ES close or open operation**
- **DS function timing (closing and opening time)**

Control System Data Evaluation

Warnings (minor and major failures) – per individual equipment:

- **1st alarm of SF6 leakage**
- **2nd alarm of SF6 leakage**
- **CB function failed**
- **alarm of transformer cooling failure**
- **alarm of dangerous transformer oil in tank temperature**

Indication of network configuration and regime:

- **transfer of data from IP to EQ records for normal service, service via transfer busbar and for testing regime**

Monitored Data Main Sources – DATA EVALUATION

Fault recorders

triggered by relays, SCADA, exceeding 120% $U_{n\ r.m.s}$ or 150-200% $I_{n\ r.m.s}$

Fault recorders provide basically 2 types of information :

- **I and U curves (single phase and zero) with sampling frequency 1 kHz for 0.2 to 0.3 sec before and 5 sec after the fault recorder function was triggered**
- **Binary records of signals, e.g. start and end of protection relays, start and end of O or C impulse, start of pole discrepancy, start of CB interlocking**

Fault Recorders Data Evaluation

Loadings (curves) – per S/S bay, busbars and T :

- **Resonance and feroresonance in a S/S bay**
- **Short circuit loads (Modules VROUD and ZKRAT)**
- **Temporary overvoltage 10-500 Hz (Module PREP)**

Incorrect behaviour and warnings - per individual EQ:

- **CB restrikes, reignitions and preignitions (Module PRUR)**
- **Delay among CB poles operation timing**
- **CB locking for O, C or AR operation**
- **VT problem (Module PETAN)**

Fault Recorders Data Evaluation

Ageing characteristics - per individual equipment:

- cumulative T loading by inrush I
- cumulative T loading by short circuit I
- cumulative CB ageing factor K ($K = \Sigma(n_i \,.\, I_i^m) < K_{critical}$)
- cumulative CB no-load OHL O-operations
- cumulative CB load switching
- cumulative SA TOV exposition

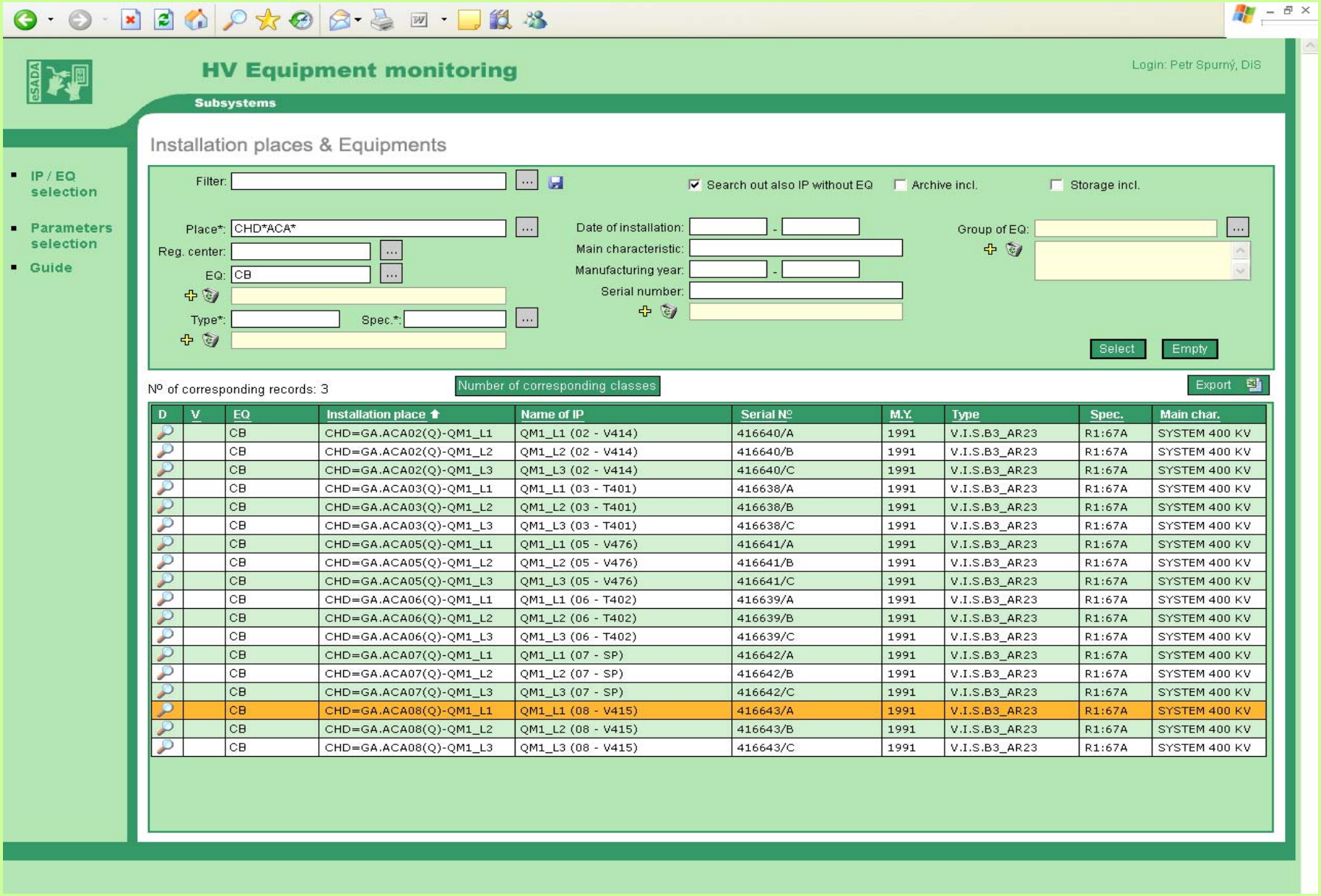
Indication of network configuration (binary records):

- correct transfer of records to specific EQ

Project history and future

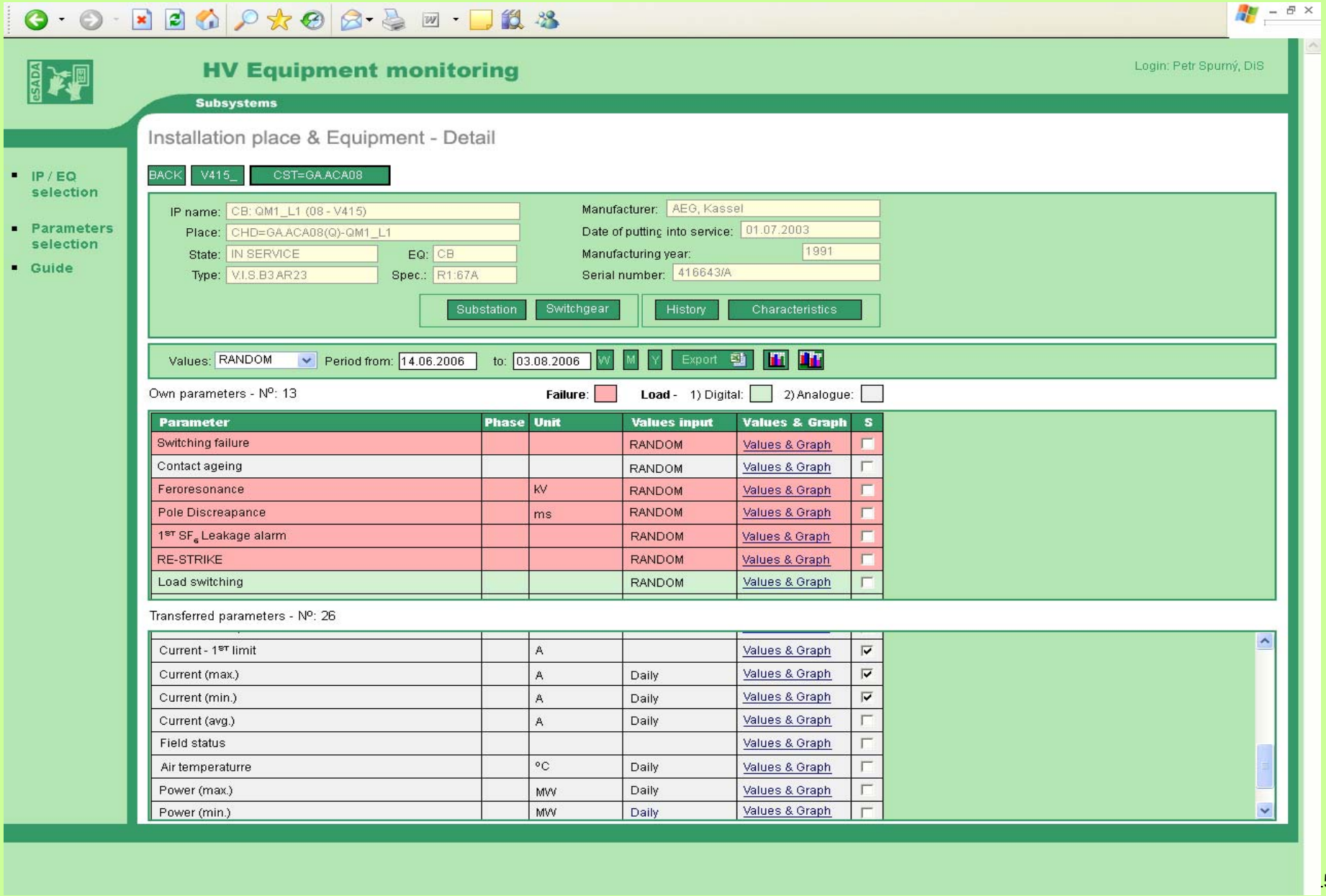
- 2002 – II/2003 : analysis of initial state, benchmarking, theoretical model, selection of suitable IT tool
- II/2003 – II/2005 : service of “tailor made” Techn. Info IT (B-SW)
- II/2005 : top management decision to buy SAP
- III/2005 – I/2006 : B-SW “transfer” to SAP
- I/2006 : SAP R/3 PM module service
- IV/2006 : SAP R/3 Data warehouse service
- II/2006 – 2007 : Development and modular service of “tailor made” centralized IT system to collect and evaluate automatically monitored data about asset loading and characteristics (AROPO and eSADA)
- 2008 - 2010 : Interconnection of other data sources, development of asset conditions evaluation expert modules, health index and risk assessment calculation

e-SADA – IP and EQ data (transfer from SAP)



D	V	EQ	Installation place	Name of IP	Serial №	M.Y.	Type	Spec.	Main char.
		CB	CHD=GA.ACA02(Q)-QM1_L1	QM1_L1 (02 - V414)	416640/A	1991	V.I.S.B3_AR23	R1:67A	SYSTEM 400 KV
		CB	CHD=GA.ACA02(Q)-QM1_L2	QM1_L2 (02 - V414)	416640/B	1991	V.I.S.B3_AR23	R1:67A	SYSTEM 400 KV
		CB	CHD=GA.ACA02(Q)-QM1_L3	QM1_L3 (02 - V414)	416640/C	1991	V.I.S.B3_AR23	R1:67A	SYSTEM 400 KV
		CB	CHD=GA.ACA03(Q)-QM1_L1	QM1_L1 (03 - T401)	416638/A	1991	V.I.S.B3_AR23	R1:67A	SYSTEM 400 KV
		CB	CHD=GA.ACA03(Q)-QM1_L2	QM1_L2 (03 - T401)	416638/B	1991	V.I.S.B3_AR23	R1:67A	SYSTEM 400 KV
		CB	CHD=GA.ACA03(Q)-QM1_L3	QM1_L3 (03 - T401)	416638/C	1991	V.I.S.B3_AR23	R1:67A	SYSTEM 400 KV
		CB	CHD=GA.ACA05(Q)-QM1_L1	QM1_L1 (05 - V476)	416641/A	1991	V.I.S.B3_AR23	R1:67A	SYSTEM 400 KV
		CB	CHD=GA.ACA05(Q)-QM1_L2	QM1_L2 (05 - V476)	416641/B	1991	V.I.S.B3_AR23	R1:67A	SYSTEM 400 KV
		CB	CHD=GA.ACA05(Q)-QM1_L3	QM1_L3 (05 - V476)	416641/C	1991	V.I.S.B3_AR23	R1:67A	SYSTEM 400 KV
		CB	CHD=GA.ACA06(Q)-QM1_L1	QM1_L1 (06 - T402)	416639/A	1991	V.I.S.B3_AR23	R1:67A	SYSTEM 400 KV
		CB	CHD=GA.ACA06(Q)-QM1_L2	QM1_L2 (06 - T402)	416639/B	1991	V.I.S.B3_AR23	R1:67A	SYSTEM 400 KV
		CB	CHD=GA.ACA06(Q)-QM1_L3	QM1_L3 (06 - T402)	416639/C	1991	V.I.S.B3_AR23	R1:67A	SYSTEM 400 KV
		CB	CHD=GA.ACA07(Q)-QM1_L1	QM1_L1 (07 - SP)	416642/A	1991	V.I.S.B3_AR23	R1:67A	SYSTEM 400 KV
		CB	CHD=GA.ACA07(Q)-QM1_L2	QM1_L2 (07 - SP)	416642/B	1991	V.I.S.B3_AR23	R1:67A	SYSTEM 400 KV
		CB	CHD=GA.ACA07(Q)-QM1_L3	QM1_L3 (07 - SP)	416642/C	1991	V.I.S.B3_AR23	R1:67A	SYSTEM 400 KV
		CB	CHD=GA.ACA08(Q)-QM1_L1	QM1_L1 (08 - V415)	416643/A	1991	V.I.S.B3_AR23	R1:67A	SYSTEM 400 KV
		CB	CHD=GA.ACA08(Q)-QM1_L2	QM1_L2 (08 - V415)	416643/B	1991	V.I.S.B3_AR23	R1:67A	SYSTEM 400 KV
		CB	CHD=GA.ACA08(Q)-QM1_L3	QM1_L3 (08 - V415)	416643/C	1991	V.I.S.B3_AR23	R1:67A	SYSTEM 400 KV

e-SADA – CB Monitoring



e-SADA – CT Loading

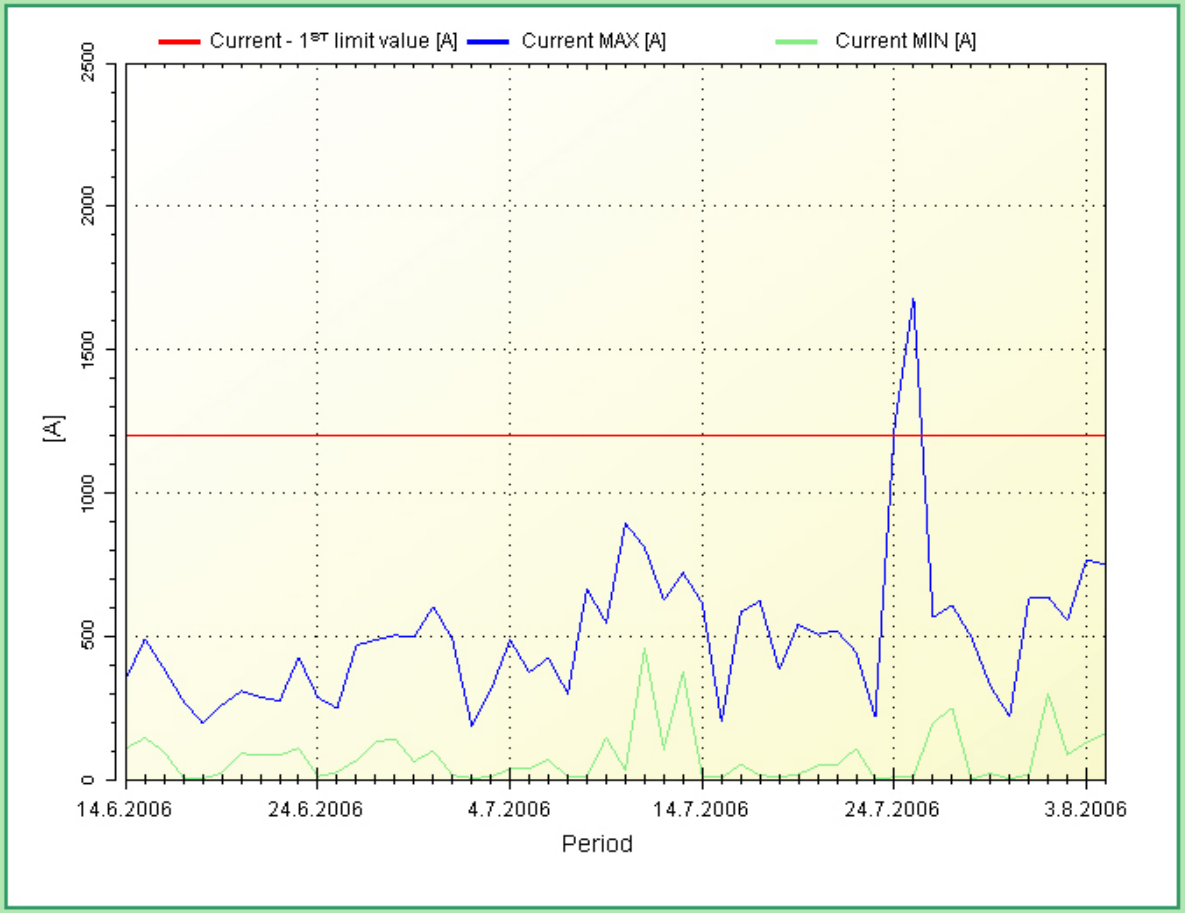
Value: RANDOM | Period from: 14.06.2006 | to: 03.08.2006 | W | M | Y | Y Axis scale: | - | Select

Installation place: CHD=GA.ACA08(Q)-QM1_L1 (type: V.I.S.B3 AR23, spec: R1:67A, S.Nº: 416643/A)

Parameter: Current - 1ST limit | Current (max.) | Current (min.)

Exported from: CHD=GA.ACA08 | CHD=GA.ACA08 | CHD=GA.ACA08 |

Curve Barr

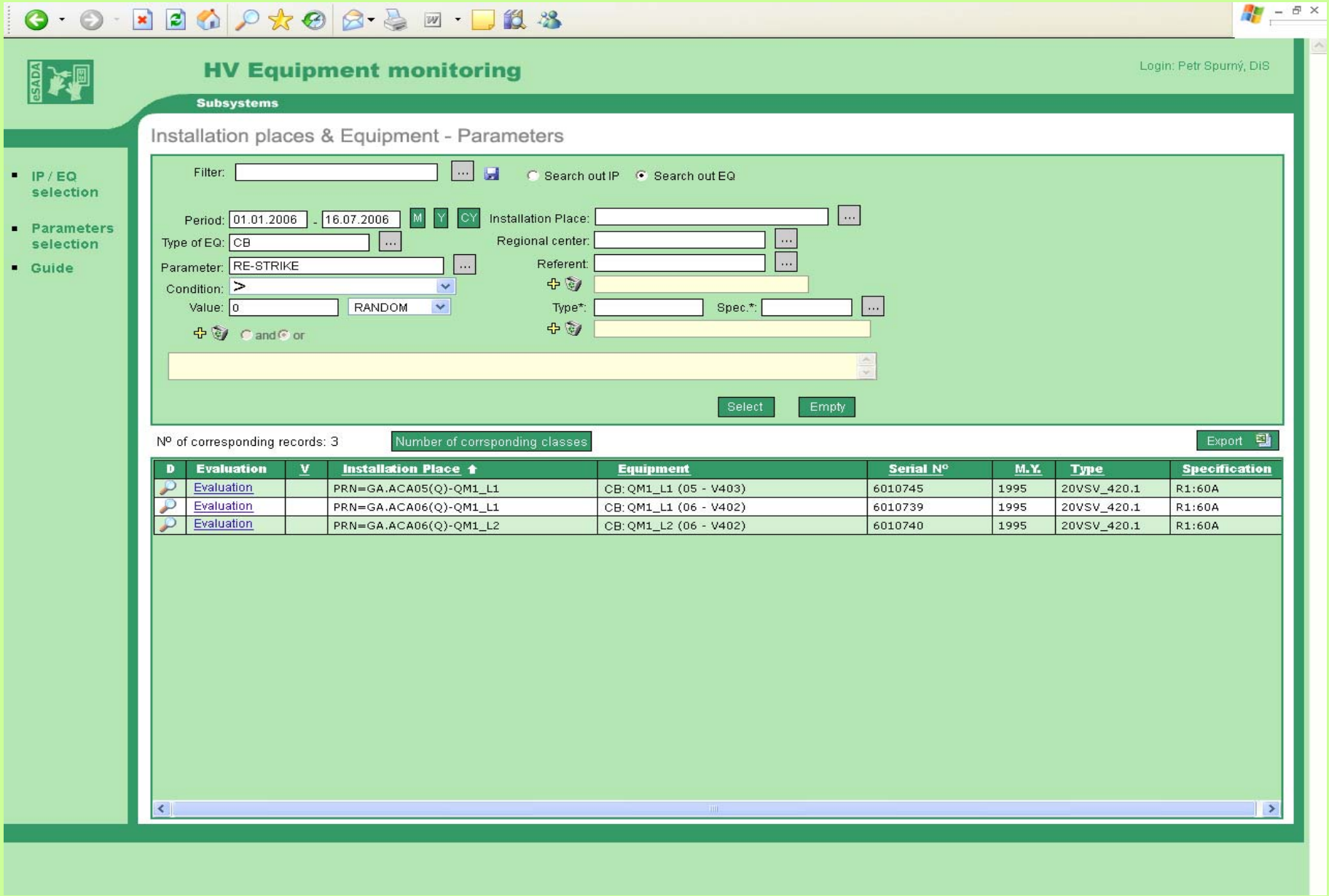


Current (max.)

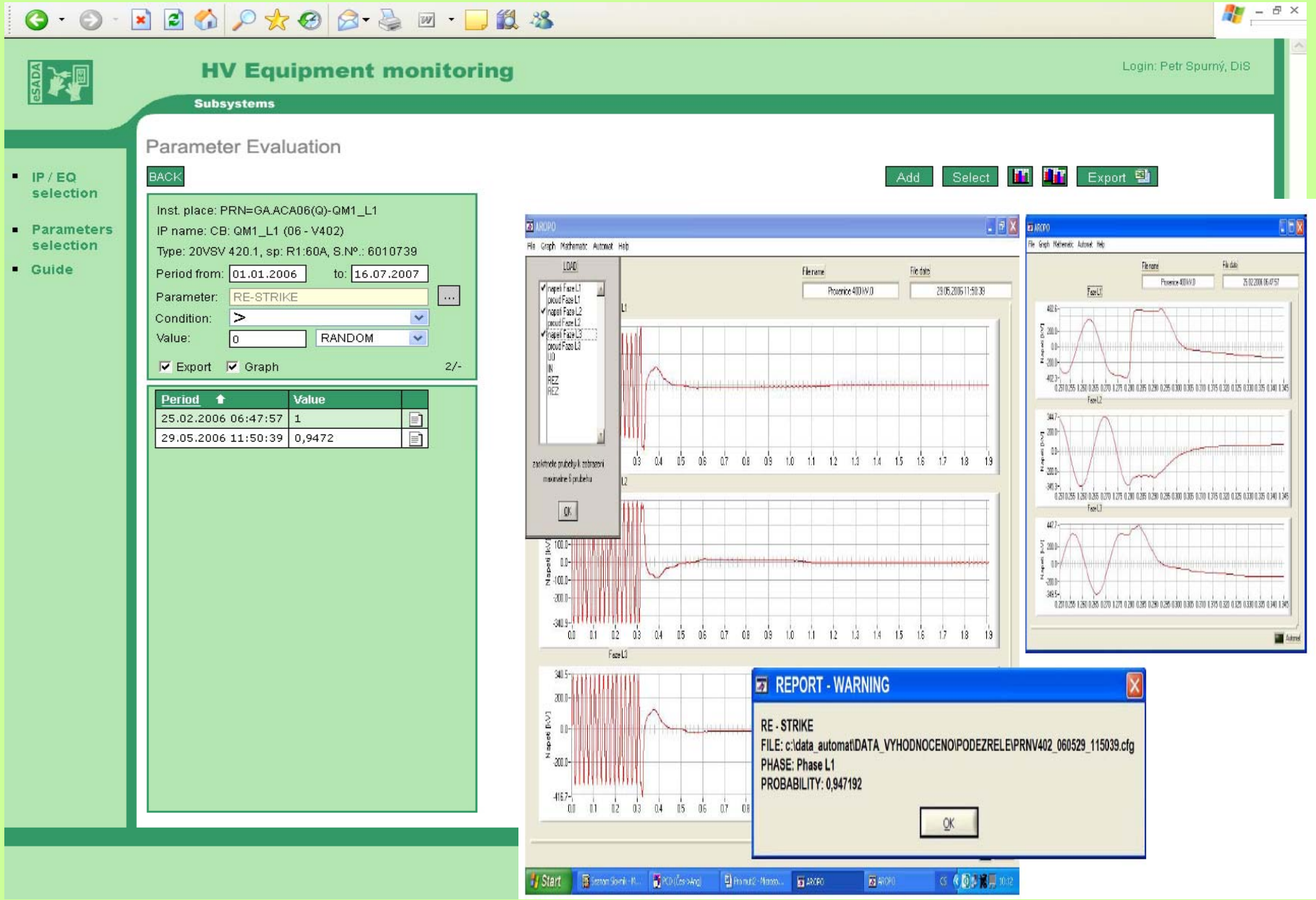
52/-

05.07.2006	375
06.07.2006	424,2
07.07.2006	300
08.07.2006	665
09.07.2006	547
10.07.2006	894
11.07.2006	808,8
12.07.2006	625,8
13.07.2006	721,2
14.07.2006	615,8
15.07.2006	200,8
16.07.2006	583,6
17.07.2006	623,6
18.07.2006	383,6
19.07.2006	541,4
20.07.2006	506,4
21.07.2006	518,8
22.07.2006	444,6
23.07.2006	218,8
24.07.2006	1227,6
25.07.2006	1684
26.07.2006	564,2
27.07.2006	607,2
28.07.2006	497
29.07.2006	325
30.07.2006	220,4
31.07.2006	633
01.08.2006	637,6
02.08.2006	554

e-SADA+AROPO – CB Re-strikes



e-SADA+AROPO – CB Re-strike Detail

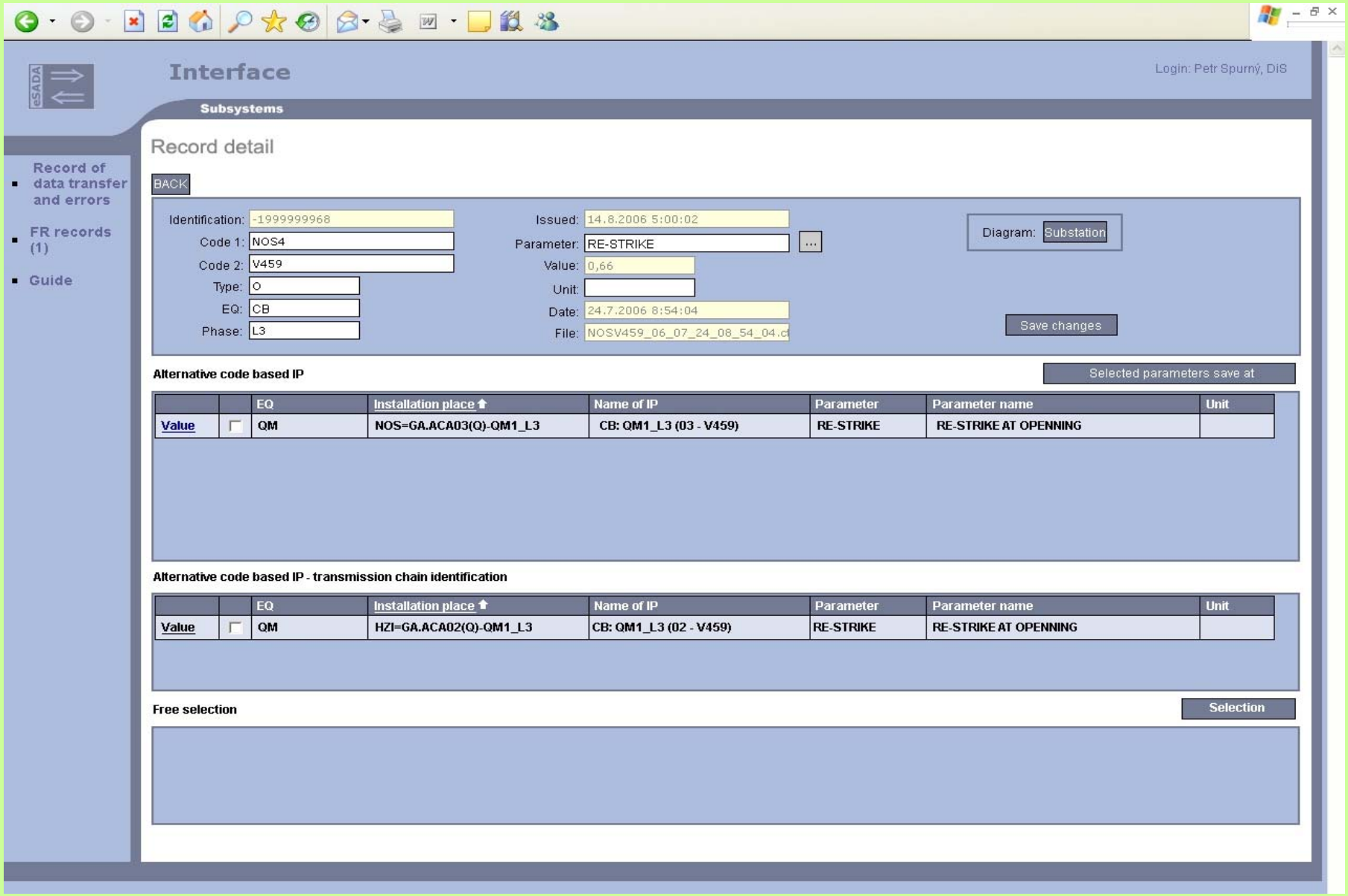


Module PRUR warning - Findings after CB opening

CB internal conditions after re-strikes (2006) :

- **CB type 20SVS420.1 (420 kV)**
- **Manufactured in 1995**
- **Major maintenance in 2000**

e-SADA – Decision Module



Specific already achieved ACM benefits

Maintenance and replacement:

- **Automatic monitoring of AQ type CB switching-off behaviour :** In 2005 special overvoltage measurement tests discovered re-strikes 3 CBs - **ACM enables continues monitoring of all CB in service (no outages, no extra costs for tests)**

- **Replacement of type 20VSV420.1 CBs –** ACM discovered repeated re-strikes + their past maintenance experience) **=> decision to replace all in two years**

- **Decision to postpone type S1-245 CBs major maintenance** Manufacturer recommendation : after 20 years (14 days outage, about 1 mil Kc). That concerns 54 CBs in 2008 and 2009 (dispatch centre - impossible to perform). Results of two most loaded CBs maintenance and continuous ACM monitoring **=> decision to perform only op. mechanism overhaul and rely on ACM and 5 years diagnostic measurement period results**

Specific already achieved ACM benefits

Maintenance (Cont.):

- **Automatic triggering of (∑CO a ∑I2t) CB based maintenance** – SAP showed not to be suitable
- **Prolongation of CB expected life beyond figures given in Grid Code**

Other examples:

- **Simple and user friendly view on SAP data**
- **Checking of SAP data validity and correctness**
- **Checking of dispatch control system data validity**
- **Generation of load limits for dispatch center grid loading**

ACM project 2007: costs x savings [mil.Kc]

Project costs for 2007 to 2011 (related to 2008)	**12,982**
Savings gained by ACM results application (rel. to 2008)	
S1-245 CBs interrupter units overhauls postpone (54 pcs.)	
Costs on interrupter units overhauls	25,763
Costs on Interrupter units overhauls postponed by 5 years	17,948
Saving	**7,815**
ELF_SL 4-2 CBs postponed replacements (13 pcs.)	
Costs on replacements performed acc. To Grid Code (30 years)	13,280
Costs on replacements postponed by 5 years	10,814
Saving	**2,466**
AQ CB type automatic monitoring instead of performing special tests (96 ks)	
Costs on special tests performed every 5 years	9,239
Saving	**9,239**
Sum of savings (rel. to 2008)	**19,520**
Net benefits of ACM project in 2007 (rel. to 2008)	**6,538**
Rentability of ACM project according to 2007 results	**50,4%**

GOAL = Risk analysis & Decision

Health index x importance index = D

Health index scoring (scale 1 to 4)

- **EQ Age** (4 given by Grid Code, 1 to 3 uneven distribution – see CIGRE WG A3-06 results)
- **EQ Cumulative loading** (comparison with present operational requirements)
- **EQ Actual conditions of the EQ** (maintenance and diagnostics results scoring)
- **EQ history** (mean time between major and minor failures)
- **Technological type history** (maintenance and diagnostics results average scoring & mean time between major and minor failures)
- **Technological Type Maintainability & Reparability** (manufacturer and spare parts availability, service contract and past experience with the manufacturer)

GOAL = Risk analysis & Decision

Health index x importance index = D

Importance index scoring

- **Basical weight –** availability demand scoring for external (generation, distribution and international connections) as well as internal tasks (network balance, N-1 criterium)
- **Loading weight –** annual average and peak monitored loads and future demands
- **Economical weight –** non-delivered, non-transmitted and balance energy prices

Recommendation based on D value →

replacement, refurbishment, major maintenance, extended diagnostics, standard maintenance schedule, postponed maintenance


Thank you for your attention
Questions?