

CIGRE WG A3-06 Tutorial Reliability of HV Equipment

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HV Equipment Conditions Monitoring Summary and Evaluation of Various Data Sources

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Maintenance strategies

For modern maintenance strategies different abbreviations are used

CEPS present practice : CBM CEPS goal : RBM→PFM

Data sources - STRUCTURED TERMINOLOGY



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 objectcomponent 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 = $\Sigma(n_i \cdot I_i^m) < K_{critical}$)
- 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)

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	D V EQ > CB CB > CB CB	Installation place * CHD=GA.ACA02(Q)-QM1_L1 CHD=GA.ACA02(Q)-QM1_L2 CHD=GA.ACA02(Q)-QM1_L3 CHD=GA.ACA03(Q)-QM1_L1 CHD=GA.ACA03(Q)-QM1_L2 CHD=GA.ACA03(Q)-QM1_L2 CHD=GA.ACA05(Q)-QM1_L2 CHD=GA.ACA05(Q)-QM1_L3 CHD=GA.ACA05(Q)-QM1_L12 CHD=GA.ACA05(Q)-QM1_L13 CHD=GA.ACA06(Q)-QM1_L13 CHD=GA.ACA06(Q)-QM1_L12 CHD=GA.ACA06(Q)-QM1_L13 CHD=GA.ACA07(Q)-QM1_L13 CHD=GA.ACA07(Q)-QM1_L12 CHD=GA.ACA07(Q)-QM1_L13 CHD=GA.ACA07(Q)-QM1_L12 CHD=GA.ACA08(Q)-QM1_L12 CHD=GA.ACA07(Q)-QM1_L12 CHD=GA.ACA08(Q)-QM1_L12 CHD=GA.ACA08(Q)-QM1_L12 CHD=GA.ACA08(Q)-QM1_L12 CHD=GA.ACA08(Q)-QM1_L12 CHD=GA.ACA08(Q)-QM1_L12 CHD=GA.ACA08(Q)-QM1_L12	Name of IP QM1_L1 (02 - V414) QM1_L2 (02 - V414) QM1_L3 (02 - V414) QM1_L1 (03 - T401) QM1_L2 (03 - T401) QM1_L1 (05 - V476) QM1_L2 (05 - V476) QM1_L2 (06 - T402) QM1_L1 (06 - T402) QM1_L1 (07 - SP) QM1_L2 (07 - SP) QM1_L3 (07 - SP) QM1_L1 (08 - V415) QM1_L2 (08 - V415)	Serial № 416640/A 416640/B 416640/C 416638/A 416638/A 416638/A 416638/A 416638/A 416638/A 416638/A 416638/A 416638/A 416641/A 416641/C 416639/A 416639/A 416639/C 416642/A 416642/B 416643/A 416643/A	M.Y. 1991	Lype V.I.S.B3_AR23	Spec. R1:67A R1:67A	Indiff Crial: SYSTEM 400 KV SYSTEM 400 KV

e-SADA – CB Monitoring

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CEADA	HV Equipment monito	ring					Login: Petr Spurný
- 10/00	Installation place & Equipment - Det	ail					
IP / EQ selection Parameters selection Guide	IP name: CB: QM1_L1 (08 - V415) Place: CHD=GA.ACA08(Q)-QM1_L1 State: IN SERVICE EQ: CB Type: VI.S.B3AR23 Spec.: R1:67/						
	Values: RANDOM V Period from: 14.06.2006 to: 03.08.2006 V M Y Export I II III						
	Parameter	Phase	Unit	Values input	Values & Graph	S	
	Switching failure			RANDOM	Values & Graph		
	Contact ageing			RANDOM	Values & Graph	Г	
	Feroresonance		κv	RANDOM	Values & Graph	Г	
	Pole Discreapance		ms	RANDOM	Values & Graph	Г	
	1 ^{डт} SF _e Leakage alarm			RANDOM	Values & Graph	Г	
	RE-STRIKE			RANDOM	Values & Graph		
	Load switching			RANDOM	Values & Graph		
	Transferred parameters - Nº: 26						
	Current - 1 st limit		A		Values & Graph		
	Current (max.)	2,	A	Daily	Values & Graph	~	
	Current (min.)		A	Daily	Values & Graph	~	
	Current (avg.)		A	Daily	Values & Graph	Г	
	Field status				Values & Graph	Г	
	Air temperaturre		°C	Daily	Values & Graph	Г	
				1000 000	Contract assesses and the	1000	
	Power (max.)		MVV	Daily	Values & Graph		

e-SADA – CT Loading

Value: RANDOM 🕑 Period from: 14.06.2006 to: 03.08.2006 🛛 🕅 🍸 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)	Current (max.)		*
Parameter: Current - 1 st limit Current (max.) Current (min.)			52/-
Exported from: CHD=GA.ACA08 CHD=GA.ACA08 CHD=GA.ACA08	05.07.2006	375	- <u>^</u>
🖲 Curve 🔿 Barr	06.07.2006	424,2	
	07.07.2006	300	-
Current - 1≋T limit value [A] — Current MAX [A] Current MIN [A]	08.07.2006	665	1
	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	
g_l	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	
$ \left[\left[\begin{array}{c} 1 \\ 1 \end{array}\right] \right] = \left[$	27.07.2006	607,2	
	28.07.2006	497	
	29.07.2006	325	
	30.07.2006	220,4	
14.6.2006 24.6.2006 4.7.2006 14.7.2006 24.7.2006 3.8.2006	31.07.2006	633	
Penuu	01.08.2006	637,6	
	02.08.2006	554	

e-SADA+AROPO – CB Re-strikes

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ESADA	HV Equips	ment monitoring				Log	in: Petr Spurný, DiS		
 IP / EQ selection Parameters selection Guide 	Installation places & Equipment - Parameters Filter: Period: 01.01.2006 - 16.07.2006 M Y Installation Place: Type of EQ: CB Parameter: Referent: Parameter: Referent: Yalue: 0 RANDOM Type*:								
	Select Empty Nº of corresponding records: 3 Number of corresponding classes Export Export D Evaluation V Installation Place + Equipment Serial N° M.Y. Type Specification								
	Evaluation Evaluation	PRN=GA.ACA06(Q)-QM1_L1 PRN=GA.ACA06(Q)-QM1_L2	CB:QM1_L1 (06 - V402) CB:QM1_L2 (06 - V402)	6010739 6010740	1995 1995	20VSV_420.1 20VSV_420.1	R1:60A R1:60A		
	<		III				2		

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

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esada	Interface Subsystems					Login: Petr Spurný, DiS
Record of data transfer and errors FR records	Record detail BACK Identification: -1999999968	Issued:	14.8.2006 5:00:02		Diagram: Substation	
(1) • Guide	Code 1: NOS4 Code 2: V459 Type: 0 EQ: CB Phase: 13	Parameter: Value: Unit: Date:	RE-STRIKE 0,66 24.7.2006 8:54:04 NOSM459, 06, 07, 24, 08, 54, 04, c		Save changes	
	Alternative code based IP	Installation place ♠	Name of ID	Parameter	Selecte	d parameters save at
	Value CM	NOS=GA.ACA03(Q)-QM1_L3	CB: QM1_L3 (03 - V459)	RE-STRIKE	RE-STRIKE AT OPENNING	
	Alternative code based IP - transm	nission chain identification				
	EQ	Installation place	Name of IP	Parameter	Parameter name	Unit
	Free selection	HZI=0A.ACAU2(Q)-0M1_L3	CB: QMT_L3 (U2 - V439)	RE-STRIKE		Selection

Specific already achieved ACM benefits

Maintenance and replacement:

Automatic monitoring of AQ type CB switching-off behaviour : In 2005 special overvoltage measurement tests discovered restrikes 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 ($\sum CO a \sum I2t$) 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 k	S)
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, nontransmitted and balance energy prices

Recommendation based on D value \rightarrow

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

Thank you for your attention

Questions