HOLISTIC APPROACH TO ON-LINE TRANSFORMER MONITORING: KNOWLEDGE MANAGEMENT FIRST!

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Paper Number 7.02
Session Number 7
16 November 2017

Introduction

- The ability of the organization of the knowledge within a power electric industry is a key element to ensure effective management of asset, reuse past experiences and enhance knowledge creation and innovation.

- The implementation of a Knowledge Management (KM) structured approach allows to:
  - convert tacit knowledge into explicit knowledge
  - share the knowledge within the organization (involving application of technologies, connecting people to people, create a competitive advantage using an holistic approach)
  - generate value from knowledge (administration of organization's intellectual capital)

State of the art

- The modern utility is overwhelmed by the volume of data being generated
- The availability of skilled personnel to best utilise this data is actually diminishing
- The basic information on asset condition is within every company, but very often with no easy access to it.
- For years there have been consistent investments in advanced diagnostic monitors, but the resulting data still require expert analysis.
- The majority of monitors are not even integrated into any IT infrastructure, relying on manual interrogation, either periodically or just after a failure

Scope

- An holistic approach for ranking power transformers is proposed in the paper, combining on-line parameters into an informative and intuitive parameter, called Condition Index.

- Additionally, the on-line data can then be combined with historical offline data, as well as transformer visual inspection results, in order to provide a more detailed and refined condition assessment and trending.

Health INDEX ?

Good Overall Condition
(Good Health Index)

Failure of one particular component
(High Risk Group)

IEEE / CIGRE CONDITION

IEEE C57.104

Status	Description	H2	CH4	C2H2	C2H4	C2H6	CO	CO2	TDCG
Condition 1	Normal	<100	<120	<1	<50	<65	<350	<2500	<720
Condition 2	Greater than normal	<700	<400	<9	<100	<100	<570	<4000	<1920
Condition 3	High level of decomposition	<1800	<1000	<35	<200	<150	<1400	<10000	<4630
Condition 4	Excessive decomposition	>1800	>1000	>35	>200	>150	>1400	>10000	>4630

CIGRE TB 443

Status	Description	H2	CH4	C2H2	C2H4	C2H6	CO	CO2	TDCG
Condition 1	Typical	<100	<80	<3	<170	<55	<500	<8900	<908
Condition 2	Level 2	<180	<129	<13	<270	<126	<766	<14885	<1542
Condition 3	Level 3	<254	<170	<32	<352	<205	<983	<20084	<2101
Condition 4	Level 4	<403	<248	<102	<505	<393	<1372	<29980	<3175
Condition 5	Pre-failure	>403	>248	>102	>505	>393	>1372	>29980	>3175

CAMLIN CONDITION GROUP

TABLE I: Condition Group description inspired by CIGRE TB227

CAMLIN Condition Group	CAMLIN description	CIGRE classification	CIGRE Description
1	Good as new	Normal	No obvious problems, no remedial actions justified. No evidence of degradation
2	Normal in service / Long risk term	Aged/Normal in service	Acceptable, but does not imply defect-free
3	Defective / Medium risk term	Defective	No significant impact on short-term reliability, but asset life may be adversely affected in long term unless remedial action is carried out
4	Faulty / Short risk term	Faulty	Can remain in service, but short-term reliability likely to be reduced. May or may not be possible to improve condition by remedial action
5	Failure	Failure	Cannot remain in service. Remedial action required before equipment can be returned to service (may not be cost effective, necessitating replacement)

DGA

- Possibility to select the reference standard
- Camlin recommended settings
- Possibility to customize the settings

DGA

Index	H2	CH4	C2H2	C2H4	C2H6	CO	CO2	TDCG
Condition 1	100	80	3	170	55	500	8900	903
Condition 2	180	129	13	270	126	776	14885	1542
Condition 3	254	170	32	352	205	983	20084	2101
Condition 4	403	248	102	505	393	1372	29980	3175
Condition 5	/	/	/	/	/	/	/	/

☑ Enabled

○ Custom
○ IEEE c57.104
◉ CIGREE TB443

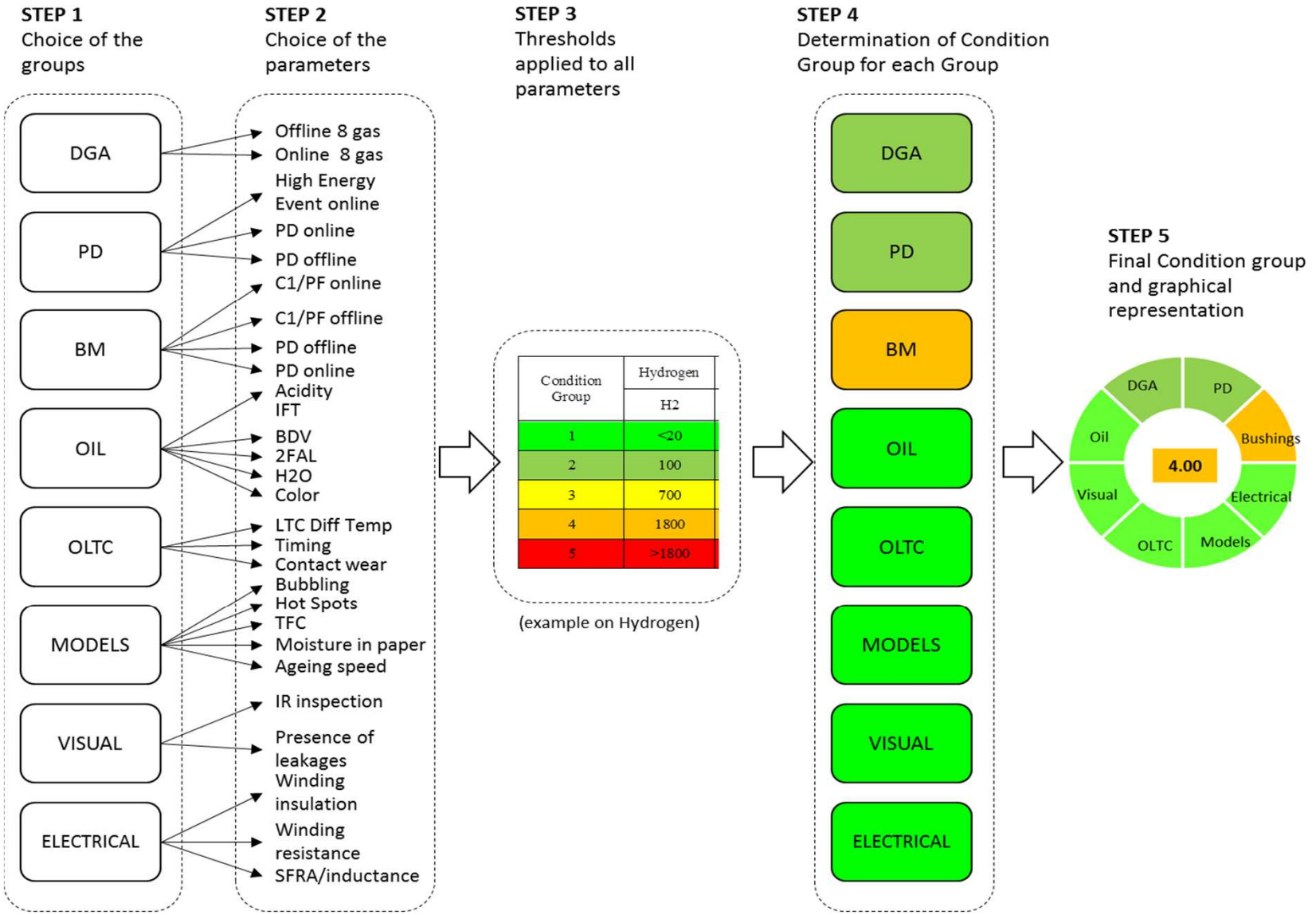
TABLE II: suggested thresholds for determining Condition Group basing on Bushing Monitoring Results

Condition Group	Bushing		
	TanD %	C1%	Partial Discharges (pps)
Condition 1	<0.1	<2.0	<1000
Condition 2	0.5	6.0	5000
Condition 3	1.0	12.0	10000
Condition 4	5.0	20.0	>10000
Condition 5	>5.0	>20	

TABLE IV: suggested thresholds for determining Condition Group basing on Oil quality

Condition Group	Oil Quality				
	BDV (kV)	Acidity (mKOH)	2FAL (ppm)	H2O (ppm)	Colour
Condition 1	>60	<1	<0.3	<15.0	<2.5
Condition 2	50	5	1.0	20.0	4.5
Condition 3	40	10	>1.0	30.0	>4.5
Condition 4	<40	>10		>30	

TRANSFORMER CONDITION GROUP



FLEXIBILITY

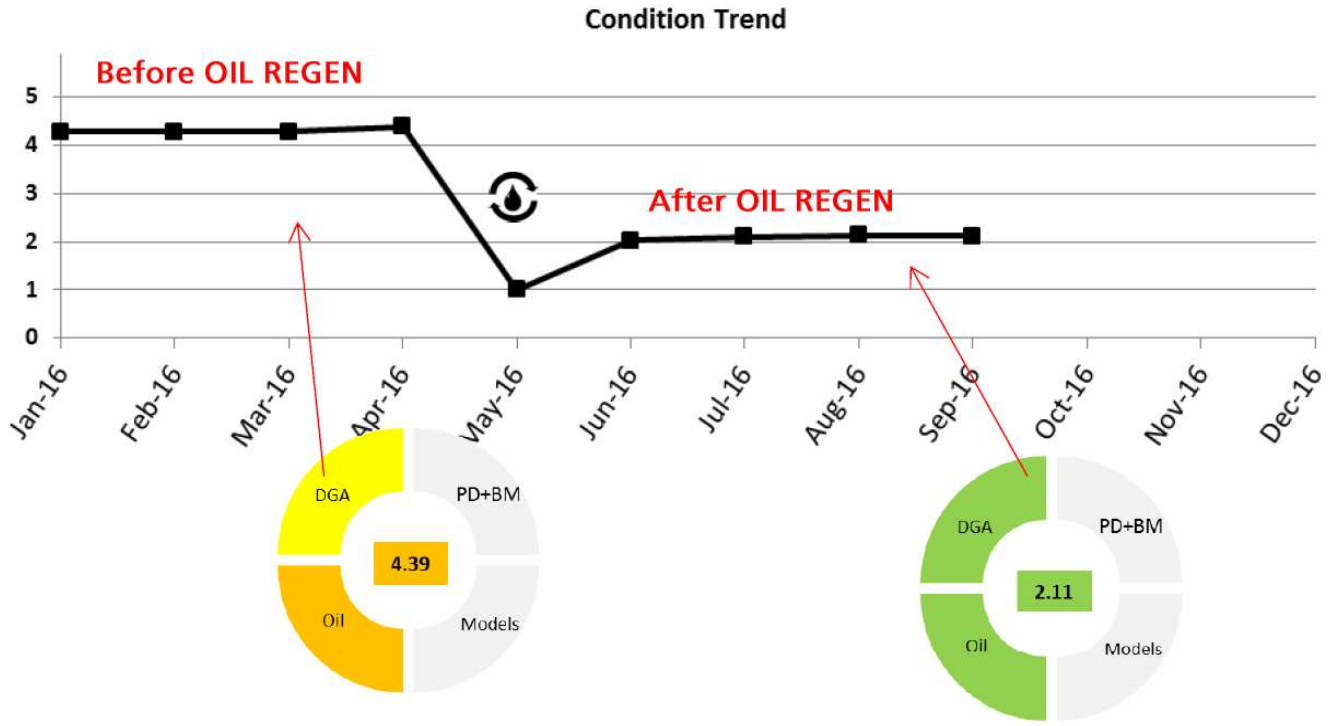
- Possibility of choosing N parameters

8 parameters

4 parameters

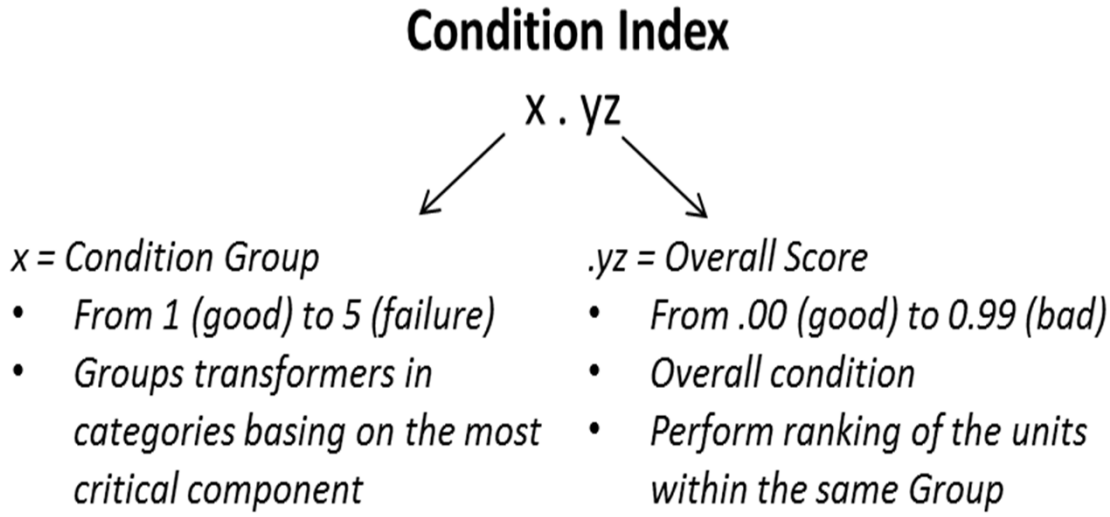
REAL CASE

- Example of Condition Group visual representation before and after oil regeneration on a distribution transformer. White sectors indicate that those data were not available at that time.

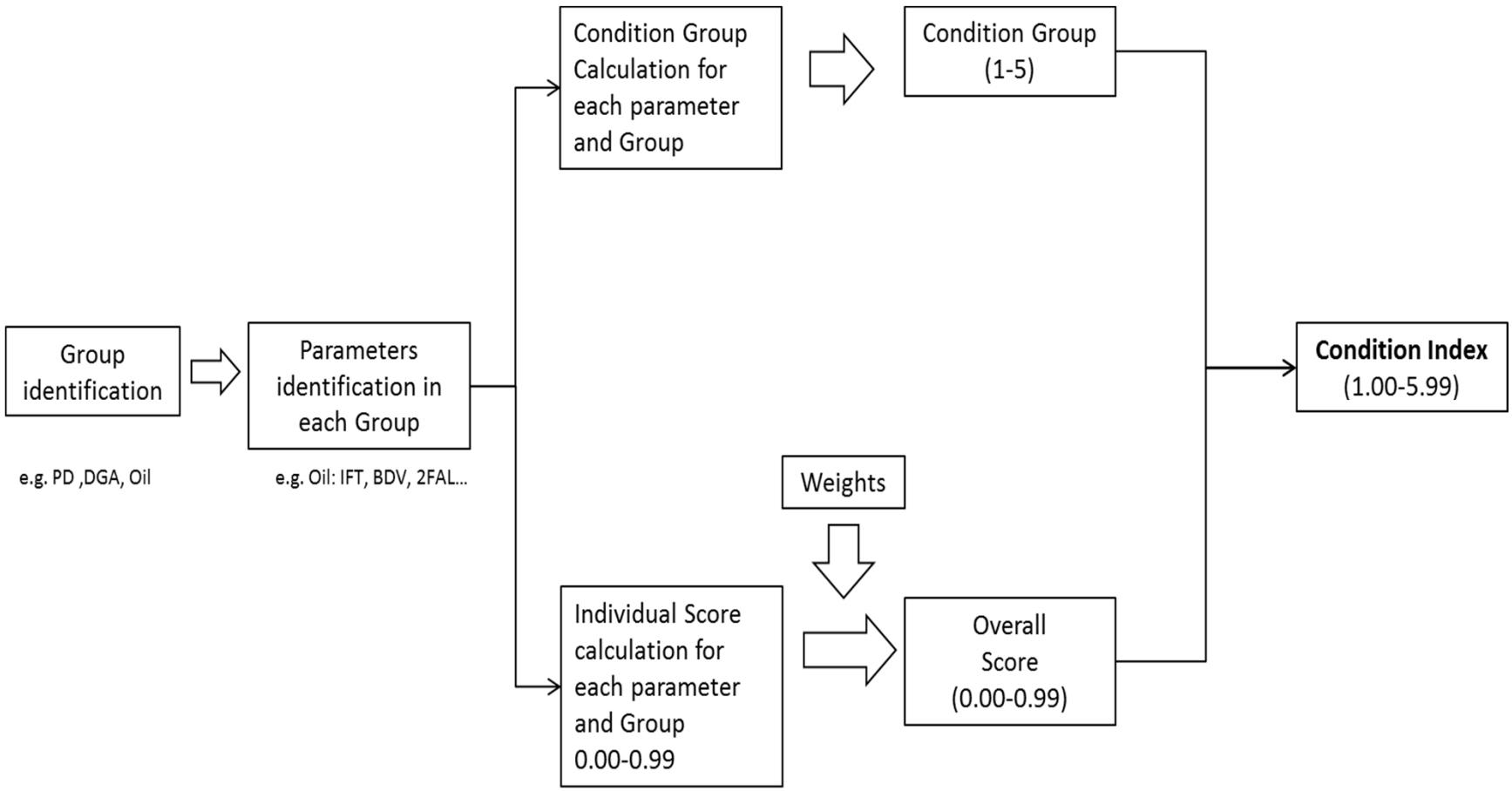


CONDITION INDEX

- Ranking of transfomer in same category (condition group)

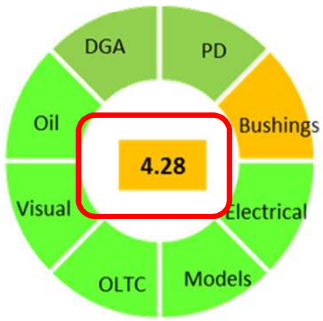


CONDITION INDEX



EXAMPLE

Condition Group	Groups	Fleet Ranking parameters	IS= Individual Score (0-0.99)	W=Weights	WI=Weighted Index
2	DGA	On-line DGA	0.25	0.3	0.075
		Off-line DGA			
2	PD	Medium persistence	0.25	0.1	0.025
		Severe persistence			
		High Energy Event			
4	Bushings	Max Capacitance %	0.9	0.2	0.18
		Max Tandelta %			
		Max PD			
1	Models	Hot Spots	0.01	0.05	0.005
		Ageing			
		Moisture in paper			
		Bubbling			
		Through Fault Currents			
1	Visual	IR camera	0.01	0.05	0.005
		Components Status			
		Leakage?			
1	Oil quality	IFT	0.01	0.1	0.001
		BDV			
		Color			
		Moisture			
		2FAL			
1	Electrical	Winding Inductance	0.01	0.1	0.001
		Winding Resistance			
		Insulation Test			
1	OLTC	LTC differential	0.01	0.1	0.001
		Overall condition			



Overall Score = $\sum_{i=1:N} (W_i * Is_i) = 0.28$

CASE STUDY

- A fleet ranking program has been started with a UK distribution utility who has engaged an oil-regeneration process of a wide part of the fleet.

- Due to the free-breathing design, fleet age and environmental condition, a significant amount of water has been absorbed by the oil and paper over the years resulting in a poor oil quality, high moisture levels and some high CO and CO2 levels.

- A commercially available device has been installed in 26 transformers, able to monitor:
  - DGA in oil (8 gas)
  - Moisture in oil
  - Partial Discharges
  - Bushing Capacitance, Tandelta, PD
  - Through Fault Currents
  - Hot Spots
  - Environmental, Top, Bottom and LTC Temperature
  - High Energy Events
  - Apparent Power
  - Load

OVERALL CONDITION TREND

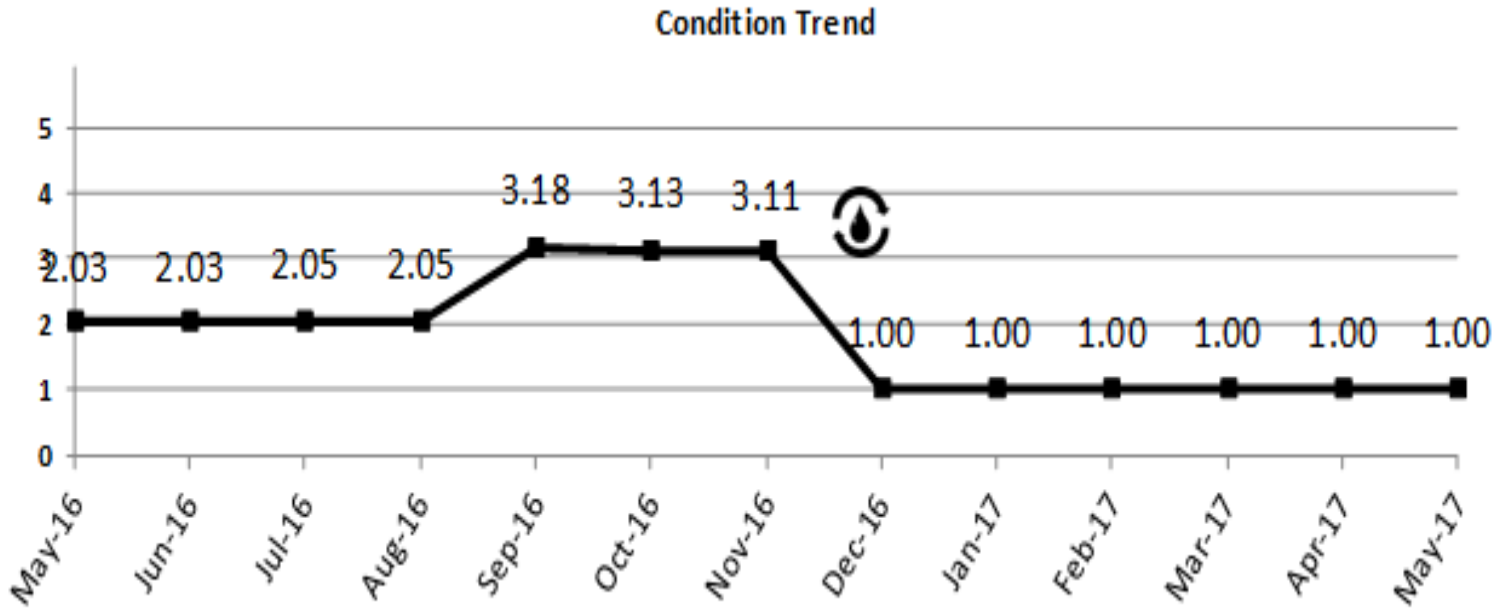
- Decreasing trend after oil regeneration

FLEET REPORT

Transformer	May '17 Condition	Worst component	Comments
HazT1	4.31	DGA	Signs of aging (CO=681 ppm, CO2=4816). Oil quality analysis required
New T11	3.42	OIL	Signs of oil aging and elevated moisture concentration (28 ppm).
Bro T11	3.25	OIL	Significant oil deterioration for Acidity (0.3 mKOH). Oil regeneration should be planned.
Hin T12	3.16	DGA	High Hydrogen concentration (106 ppm) with rising trend.
Low GT2	3.15	DGA/MODELS	Signs of ageing. Oil relative saturation 21%, moisture in paper 5.7%
Dro GT2	3.14	MODELS	Moderate oil deterioration. 5% moisture in paper. No additional action required.
Bam T11	3.13	DGA	Presence of Acetylene (2.7 ppm). Stable. No active faults. Oil quality analysis require for completeness.
Hin T11	3.13	DGA	Relatively High Hydrogen concentration (75 ppm). Presence of Acetylene (2.1 ppm). Oil quality analysis required for completeness.
Nel T11	2.16	/	No action required.
Tar T11	2.13	/	No action required.
Pee GT1	2.04	/	No action required.
Bam T12	2.03	/	A new oil sample for Oil Quality must be taken to check oil treatment process effectiveness.
Cha T12	1.00	/	No action required.

Cha T12

- Cha T12 unit BEFORE and AFTER oil regeneration process



Conclusions (1)

- HOLISTIC APPROACH monitoring a wide range of parameters is the key for defning transfomer Condition
- Minimize the number of BOXES -> maximise the number of INFORMATION
- Condition Index parameter
  - Combines the status of «worst» component with overall status
  - Allows fleet ranking
- PROS
  - Full configurability on number of groups and parameters
  - Full configurability of weights
  - Possibility to apply CIGRE, IEC or IEEE thresholds, where available
  - Calculation simplicity
  - Combines both offline and online data

Conclusions (2)

- The proposed approach helps to achieve organizational objectives by making best use of knowledge
  - Knowledge capture and creation
  - Knowledge sharing and dissemination
  - Knowledge acquisition and application