TC 85: Measuring equipment for electrical and electromagnetic quantities

The Establishment and Design of Standard for Condition Monitoring (on-line) in Power System

“Condition Monitoring” Working Group in China

2019/01/18






CONTENTS

Condition Monitoring (on-line), CM

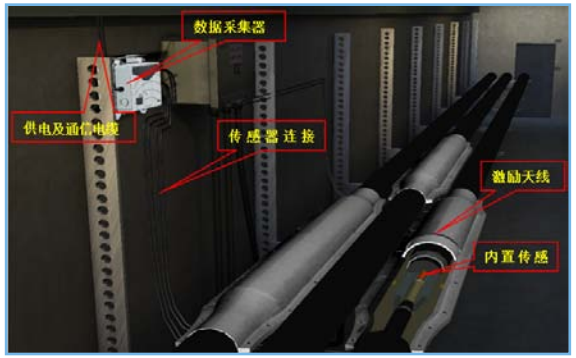
It has been widely used in the fields of “generation-transmission-transformation-distribution-consumption" of power systems.

Overhead line

Power cable

DGA

Arrester



Power cable

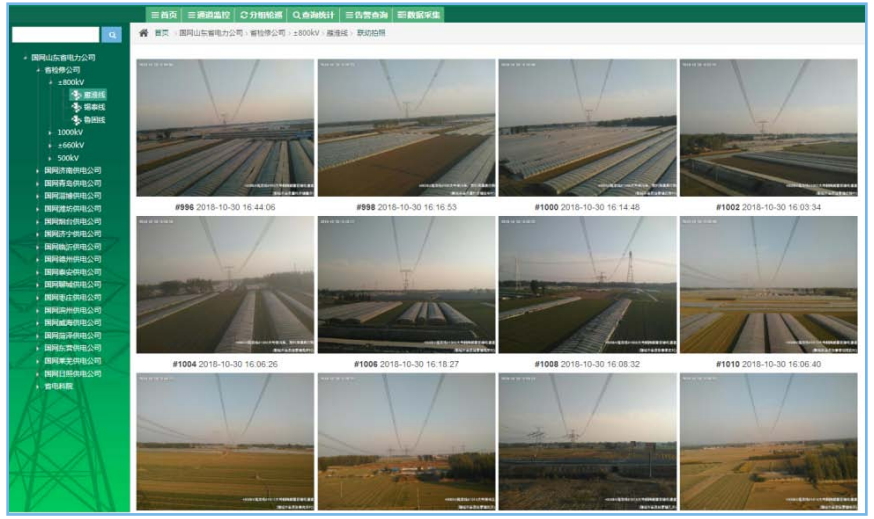
Power transformer

Substation

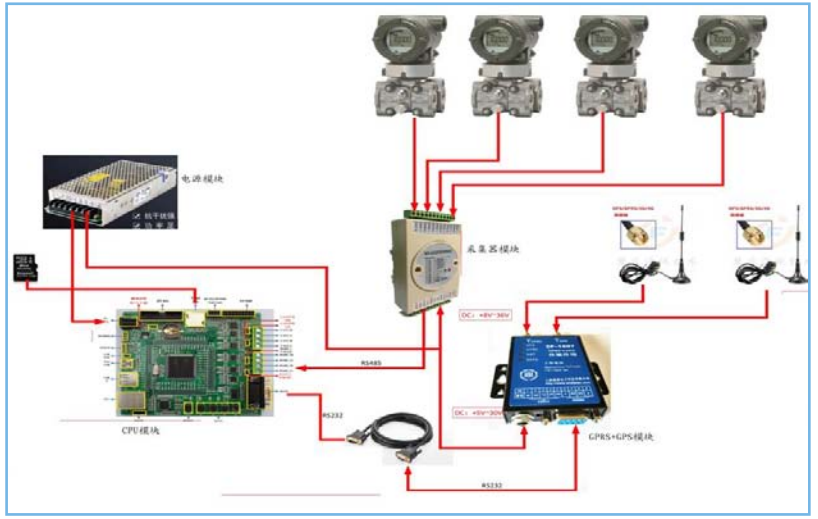
Outline

Development trend of CM

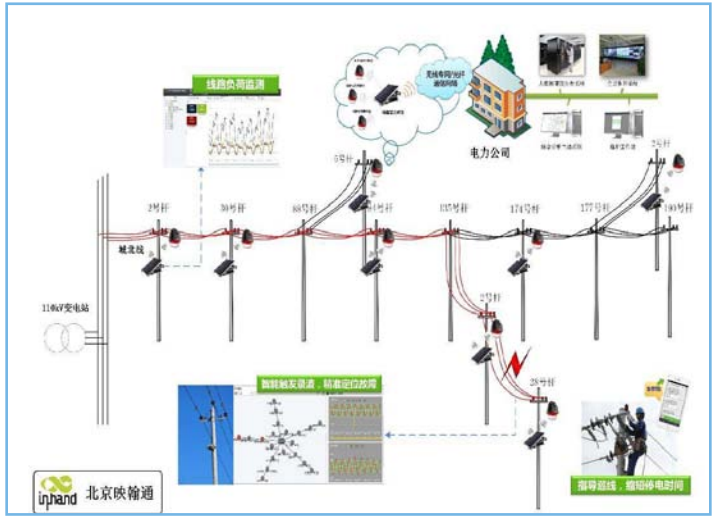
- Single parameter → Multiple parameters
- Electrical quantity → Multiple physical quantities
- Detached → Integrated monitoring
- centralized → Networked, Internet of Things
- …



Transmission line visualization terminal monitoring platform



Gas pressure sensing online monitoring system (GIS)



Intelligent distribution network

Application analysis of CM

Statistical results of CM operating condition in electric transformation

Voltage level Types of monitoring	1000kV	500kV	330kV	220kV	120kV	110kV	Total	Normal transmission data device	Real-time access rate(%)
SF6 gas pressure	15	/	/	/	/	/	15	0	0.00
PD of circuit breaker	6	/	/	/	/	/	6	0	0.00
PD of transformer	/	9	/	/	/	/	9	6	66.67
Metal oxide arrester insulation	/	129	/	96	/	/	225	139	61.78
Core grounding current	6	16	/	2	/	/	24	13	54.17
Transformer (reactor) dissolved gas in oil (DGA)	12	289	12	545	4	56	918	814	88.67
Micro water	/	10	/	/	/	/	10	6	60.00
Total	39	453	12	636	4	56	1207	978	81.03

Statistical results of CM operating condition in electric transmission

Voltage level Types of monitoring	1000 kV	±800 kV	500 kV	220 kV	110 kV	Total	Normal transmission data device	Real-time access rate(%)
Pole leaning	5	6	4	0	0	15	14	93.33
Wire sag	1	0	0	0	0	1	0	0
Wire temp	1	0	5	18	0	24	23	95.83
Breezing vibration	4	2	1	0	0	7	7	100
regelation	11	0	26	1	3	41	40	97.56
Conductor galloping	0	4	4	1	0	9	8	88.89
Contamination	1	0	0	0	0	1	1	100
Microclimate	26	11	130	43	7	217	204	94.01
Image	18	11	14	3	1	47	2	4.26
Video	0	0	2	1	0	3	0	0
Total	67	34	186	67	11	365	299	81.92

The real-time access rate of the monitoring device is only 81% on average, and the data availability is not high.

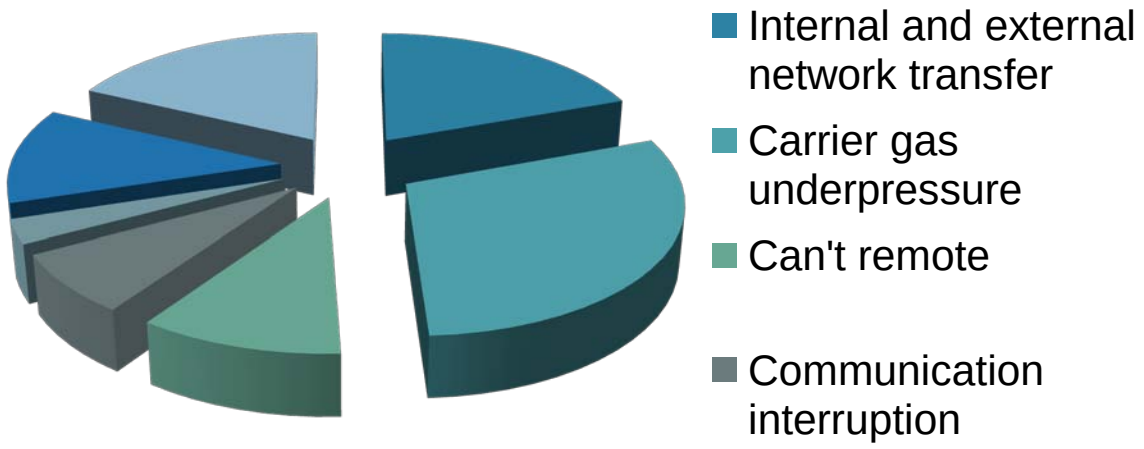
Application analysis of CM

Taking the Transformer Oil Chromatography Monitoring System (DGA) as an example, the operating statistics show that 67 devices are not working properly in a week (in 847 units).

among them:

Internal and external network transfer	13
Carrier gas underpressure	20
Can't remote	7
Communication interruption	5
Current sensor failure	2
Equipment failure	8
other	12

Fault statistics



The quality of condition monitoring devices is generally not high.

Related standard of CM

TC2 Generator: 2 related standards

IEC TS 60034-24:2009

Edition 1.0 (2009-09-16)

Rotating electrical machines - Part 24: Online detection and diagnosis of potential failures at the active parts of rotating electrical machines and of bearing currents - Application guide

IEC TS 60034-27-2:2012

Edition 1.0 (2012-03-22)

Rotating electrical machines - Part 27-2: On-line partial discharge measurements on the stator winding insulation of rotating electrical machines

TC10 Fluids for electro-technical applications: 1 related standard

IEC 60422:2013

Edition 4.0 (2013-01-10)

Mineral insulating oils in electrical equipment - Supervision and maintenance guidance

TC9 Electrical equipment and systems for railways: 1 related standard

IEC 62290：2014

Railway applications - Urban guided transport management and command/control systems - Part 2: Functional requirements specification

Related standard of CM

- IEEE 4 related standards(Including: standards, technical guidelines, recommended guidelines)

  IEEE 1129-1992 - IEEE Recommended Practice for Monitoring and Instrumentation of Turbine Generators

  IEEE 400.3-2006 - IEEE Guide for Partial Discharge Testing of Shielded Power Cable Systems in a Field Environment

  P2797 - Guide for Forecast and Early Warning of Icing on Overhead Transmission Lines in Micro-topographic Areas

  IEEE 1718-2012 - IEEE Guide for Temperature Monitoring of Cable Systems

- CIGRE A total of 26 technical reports related to online monitoring of power equipment：

  2 directly related to the monitoring device (or technology)：Use of Equipment built-in Automatic Testing: Self-Checking and Monitoring with a View to improving Reliability、Guide for Application of Direct Real-Time Monitoring Systems。

  24 related to equipment category: 6 generators, 4 transformers, 3 substations, 4 transmission lines, 2 power quality, 1 switch cabinet, 1 shunt reactor, protection and automation device. 1 high voltage insulation.

Related standard of CM

	Electric generation	Electric transmission	Electric transformation	Electric distribution	Electric consumption
IEC Standard	2	×	1	×	1
IEEE Standard, Recommended practice or Guide	1	3	×	×	×
CIGRE technical report	6	4	8	4	2
China (National Standard)	4	7	6	8	1
China (Industrial Standard)	12	28	41	25	13
China (Enterprise Standard)	2	36	47	5	×

Existing problems of CM

- Lack support of fundamental theories
- Lack system planning
- Lack systematic evaluation
- Lack application strategy
- Lack risk management

These problems restrict seriously the development of power equipment condition monitoring technology!

Objectives

Facing the future development needs, in view of the existing problems, the relevant research on the power system condition monitoring system is carried out according to the following principles:

- **Safe and Reliable**
  - Not change the integrity and normal operation, reliably monitor and record the status parameters and characteristic information, with self-test, self-diagnosis and data upload function.
- **Advanced and Mature**
  - Have measurement digitization, function integration, communication network, and state visualization, and meet the application requirements of easy expansion, easy upgrade, easy modification, and easy maintenance.
- **Flexible and Efficient**
  - Flexible choice according to the importance of the equipment to be monitored, the reliability of the monitoring device, maintenance and input costs
- **Economical and Environmental-friendly**
  - Reduce excessive maintenance of power equipment and extend equipment life

Objectives

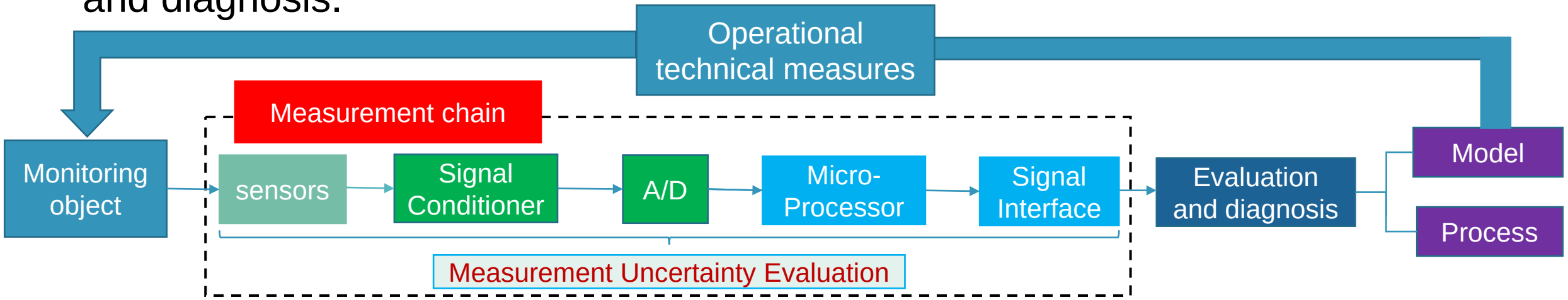
Carry out the construction of relevant standards for power system condition monitoring, which can be realized:

- **Real-time**
  - Master operating condition and status of power equipment
- **Accuracy**
  - Analyze defects and faults in power equipment
- **Prediction**
  - Discover condition change trend of power equipment
- **Economical efficiency**
  - Avoid excessive operation and maintenance for power equipment

Content and Scope

Construction scope:

The power system condition monitoring system is the research object, covering sensors, information collection, information transmission, evaluation and diagnosis.



Construction Content:
Architecture
Measurement model and theory
System relationship with other devices
Evaluation method
Application method

Technical key:
Identification specification
Logical layering
Measurement chain, measurement model and uncertainty analysis
Effective test method for device performance
Reliability Evaluation Based on Time Series
Control Theory

Construction scope

This standard

Condition monitoring basic part:
(1) Basic model
(2) Measurement
(3) Data processing

TC 8
Management of network and de-centralized electricity supply systems

TC 13
electrical energy measurement and control

TC 57
power systems control equipment and systems including EMS, SCADA (Supervisory Control And Data Acquisition), distribution automation, teleprotection, a nd associated information exchange

TC 38
instrument transformers

TC77
electromagnetic compatibility

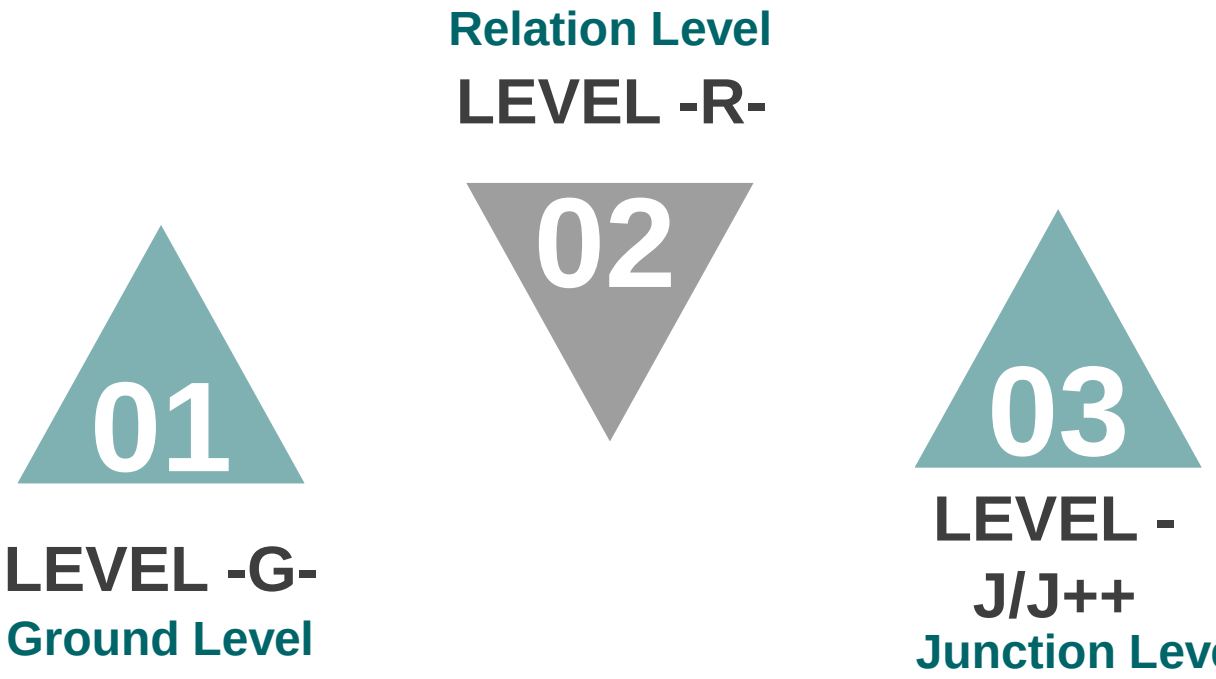
TC 108
safety for communication technology equipment

TC 66
test and measurement, industrial-process control equipment

TC 123
Asset lifetime management

3-Layer Design:

- Ground level: Basic definition, theory and method of condition monitoring system
- Relation level: Relationship between equipment and system in condition monitoring
- Junction level: Specific application of the relationship layer.



Structure of CM System

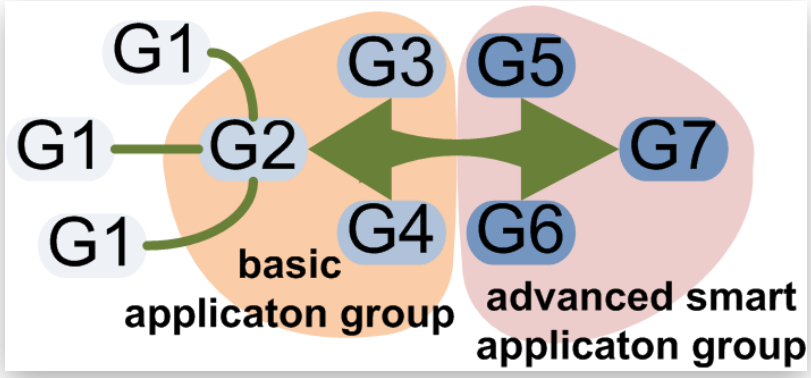
Standard Architecture

“Condition Monitoring” Working Group in China

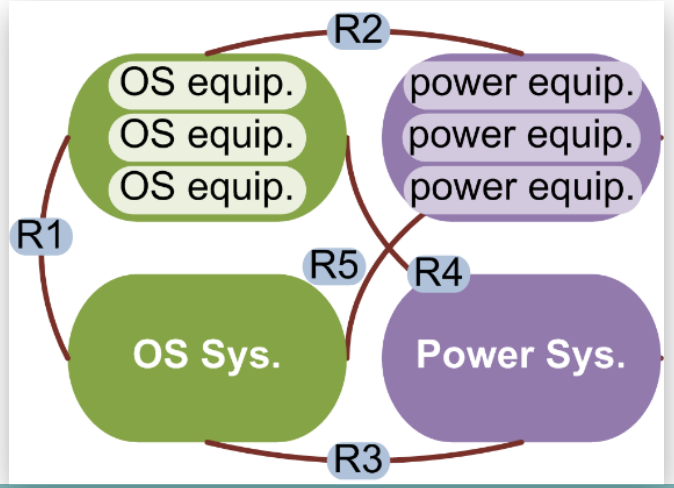
3-Layer Definition:

LEVEL G GROUND LEVEL	G-1 term. & def. G-2 general specification G-3 structure G-4 measurement		G-5 interface G-6 evaluation G-7 stabilization
LEVEL R RELATION LEVEL	R-1 OM equip. R-2 OM equip. R-3 OM sys. R-4 OM equip. R-5 OM sys.	to to to to to	OM Sys. power equip. power sys. power sys. power equip.
LEVEL J/J++ JUNCTION LEVEL	J-1 CH_4 J-2 C_2H_4 J-3 C_2H_2 J-*n* UHF J-*m* U	J-1+ gas dissolved in oil J-*N*+ SF_6 J-*M*+ VOID	J-1++ transformer J-*N*++ GIS J-*M*++ BUS

(Three-layer design and Definition)



Internal supporting links of Level G

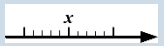
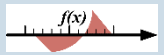
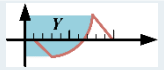
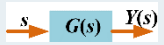


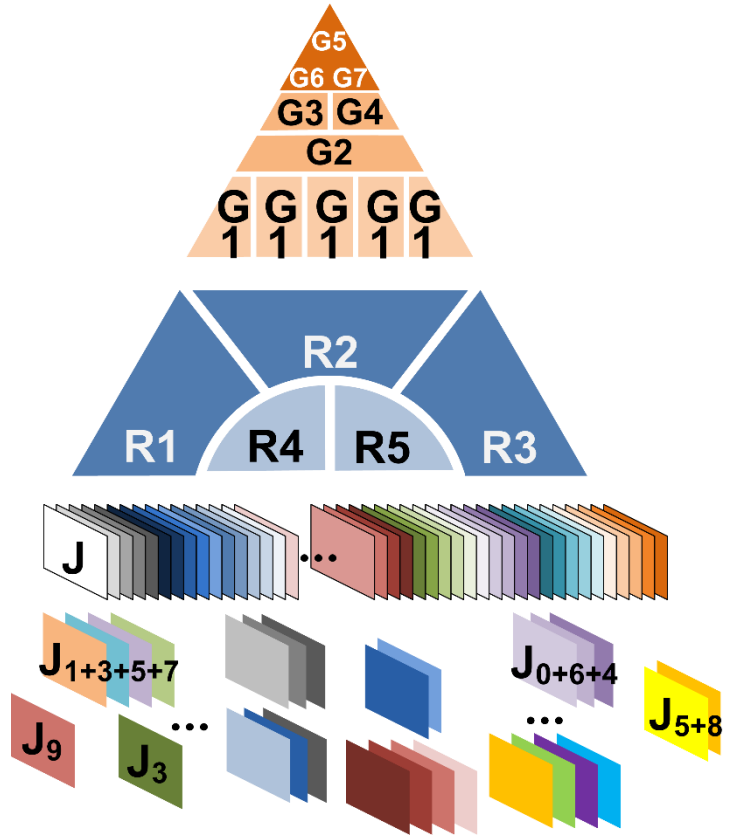
Definitions of dualistic relationships within level R

3-Layer Application:

Mapping mode of Level J/J++

Characterization mode of Level G

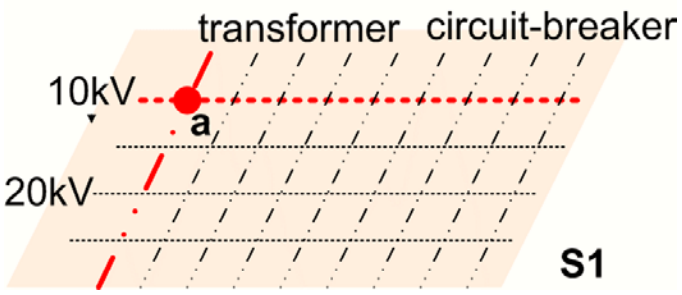
Section	Role	Symbol	Diagram
G1	independent variable	x	
G2	domain of definition	$x \in D$	
G3	function	$f(x)$	
G4	range	$f(x) \in Y$	
G5	translation function	$F(s)$	
G6	open loop function	$G(x)$	
G7	closed loop function	$H(x)$	



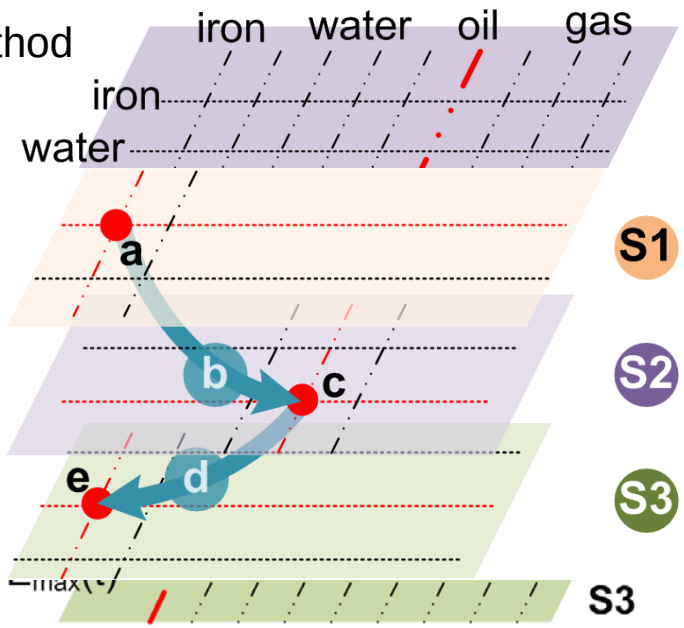
Application of 3-Layer Design

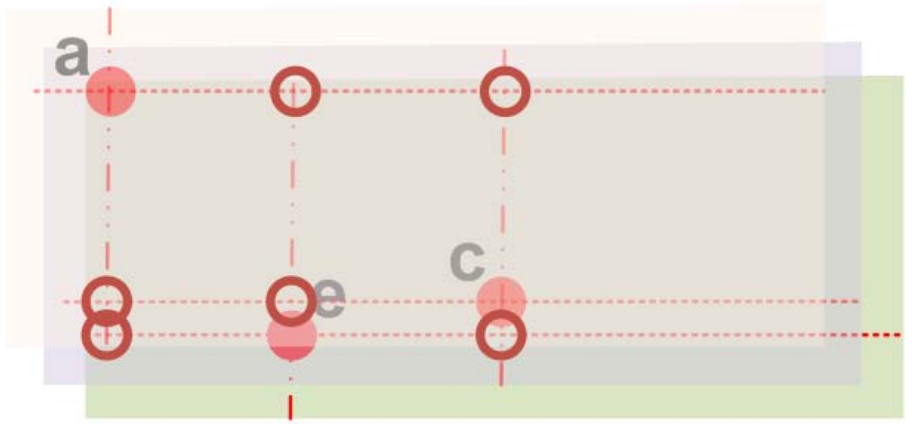
Case study:

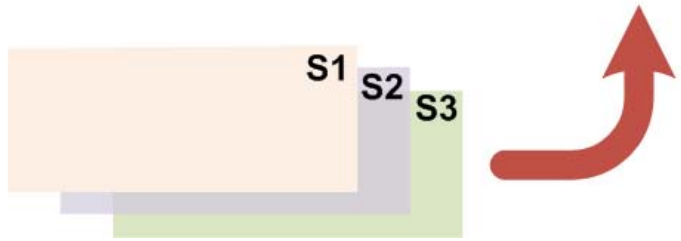
Analysis of Condition Monitoring of Dissolved Gases in Transformer Oil

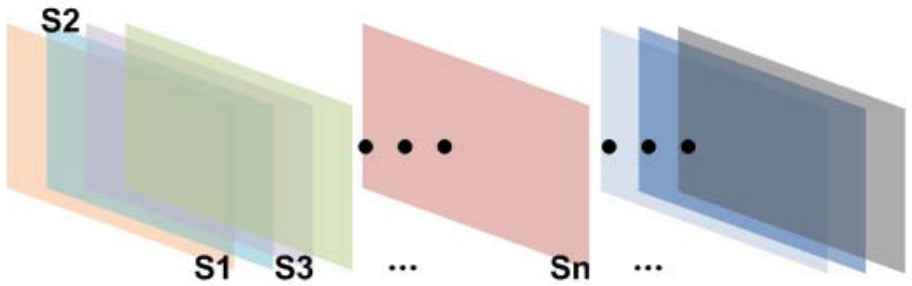


S1: Device layer
S2: Measured object
S3: Measurement method

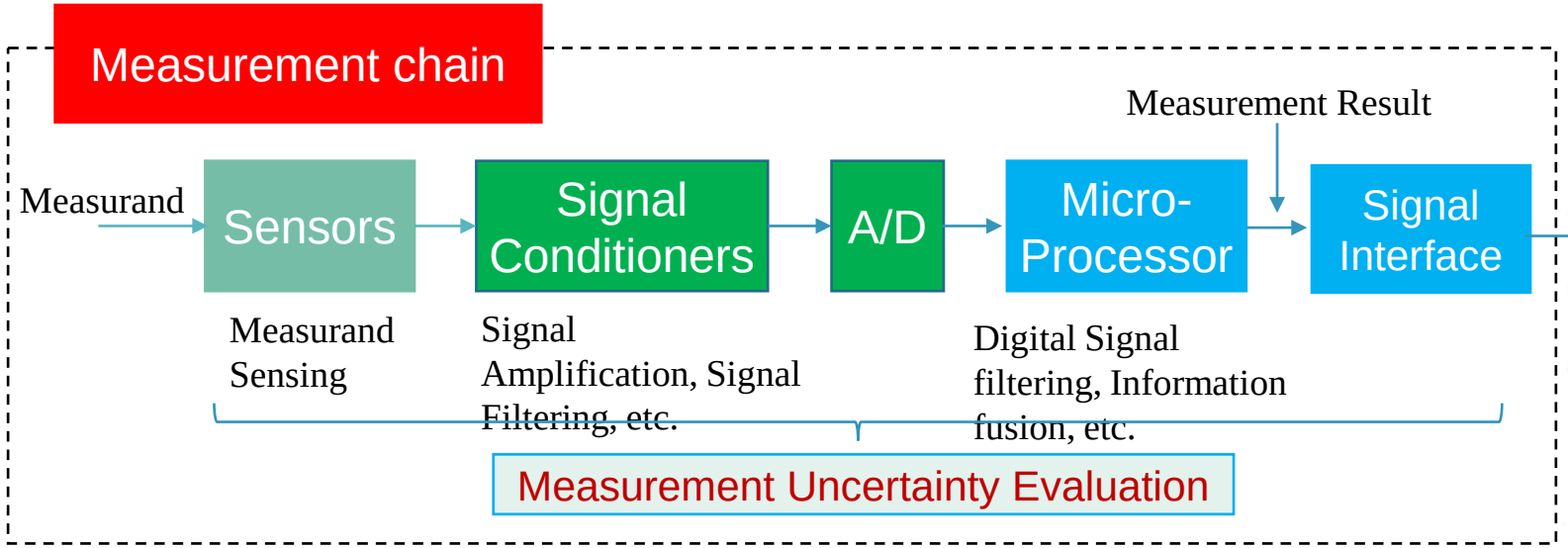


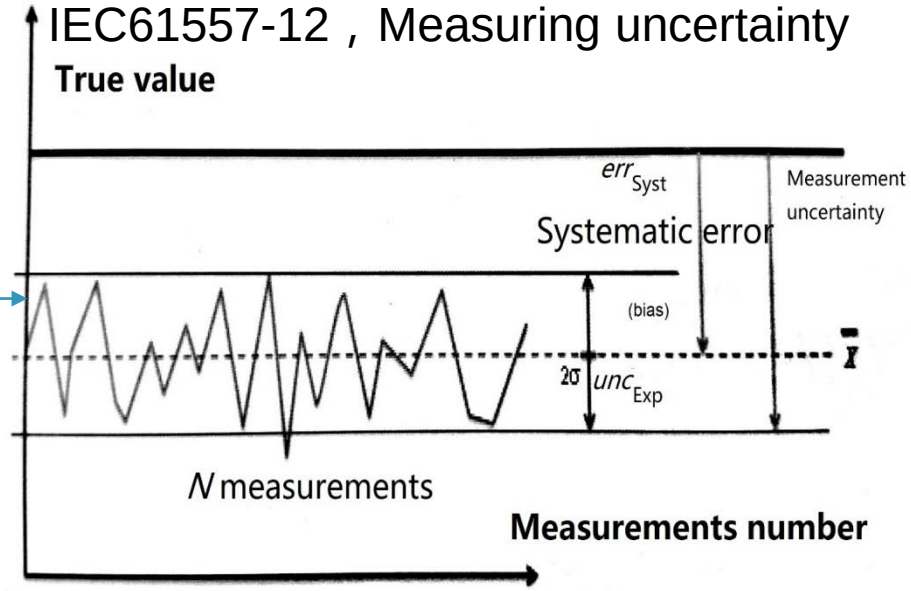






Uncertainty evaluation





- **Error Modeling of Condition Monitoring System**
  - General model of measurement chain for condition monitoring system
  - Abstract Modeling of Errors in Different Links of Measurement Chain
- **Uncertainty evaluation of condition monitoring system**
  - Typical measured probability density distribution law
  - Uncertainty transfer model of measurement chain
  - Measurement Chain Uncertainty Evaluation Method Based on Measurement Uncertainty Guide (GUM)
  - Measurement chain uncertainty evaluation method based on Monte Carlo method (MCM)

Evaluation system based on sequential control

Level 1:Definition of 4-dimensional feature parameters based on time series

$$T = [t_0, t_1, t_2, \ldots, t_N]$$

t_i Time interval

F_i Frequency domain characteristic parameter

A_i Width characteristic parameter

S_i **State characteristic parameter**

Level 2:Evaluation factor modeling

Evaluation factor definition:

(1) Single factor $P_i = f(A_i, F_i, S_i, t_i)$

P_i Function based on swath, frequency domain, running state, time-scale 4D feature parameters , [0,1]

(2) Multi-factor, which can be used to evaluate multiple prices for one device or multiple systems, and the total number of factors is set to M, then:

$$P_{m\times i} = f_m(A_{m\times i}, F_{m\times i}, S_{m\times i}, t_{m\times i})$$

Level 3:Condition monitoring overall quality evaluation

The overall quality evaluation is performed based on the evaluation factors on the time series, and the evaluation model is established by the corresponding overall quality evaluation criteria f'.

(1) Single factor $Q = \int_{MIN}^{N} f'(P_i)\mathrm{d}i$

(2) Multi-factor $Q = \int_{1}^{M}\int_{1}^{N} f'(P_{m\times i})\mathrm{d}i\mathrm{d}m$

Undertaken work

- Collection of relevant standards at home and abroad
- Summary, classification and analysis of existing standards
- Clarification of the existing condition monitoring development and analysis of the application demand
- Proposition of the basic framework of this standard
- Analysis and research on application status of existing condition monitoring system
- Research on system reliability
- Detection of existing equipment

Following work

In-depth research on related sub-topics:

(1) Research based on measurement, including: error theory, adaptation range and limitations of test methods;

(2) System uncertainty research;

(3) Research on evaluation system based on sequential control theory.

Thanks for your listening!