Study Committee B3

Substations and Electrical Installations

B3-10259

Condition Assessment of Substation Apparatus – The Challenges of Turning Dreams into Reality

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Motivation

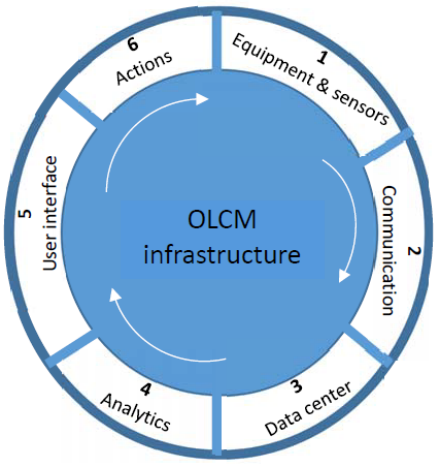
- Strong pressure on financial, material and human resources
- Expectations for very high network availability
- Room for improvement in maintenance strategies and practices
- Reassigned human resources used for failure finding activities to fix a larger number of anomalies
- Valorize the great quantity of data available by converting it to relevant information

Approach

- Gradual implementation of an On-Line Condition Monitoring complete infrastructure
- Retrieve as much data as possible from existing sensors (relays, event recorder, etc.)
- Develop efficient analytics, warning management and user interfaces
- Install selected sensors on new equipment's where there is still "a gap " and retrofit sensors on existing equipment only for the most critical applications

Apparatus monitored

- Power Transformers
- Circuit Breakers
- Disconnectors
- Instrument Transformers
- Battery and battery chargers
- AC filters
- Other apparatus to come



On-Line Monitoring Profitability Evaluation

Advantages / Activities	1 Condition Assessment	2 Optimal Use	3 Reliability
A Operation	A1 Major failures converted to minor failures due to early detection of abnormalities	A2 Better utilization in degraded mode and reduction of outage duration	A3 Reduction of major failure and its consequences; reduction of forced outages
B Sustainability	B1 Replacement of equipment a short time before it fails	B2 Extending the life of old equipment	B3 Identification of problematic equipment families and prevention of early degradation
C Maintenance	C1 Systematic maintenance: Reduction of the need for condition assessment tasks	C2 Conditional maintenance: Reduction of the time necessary to fix anomalies	C3 Corrective maintenance: less corrective and more conditional maintenance

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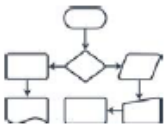
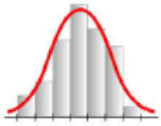
Analytic techniques

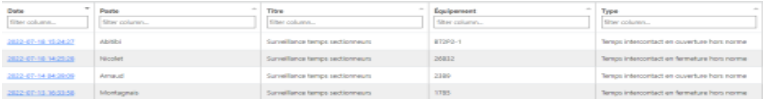
Expert rules	Statistical rules	Artificial Intelligence
		
Rules established by physical models or by experts to identify any deviation from normal behavior	Rules established with data gathered on the same or similar apparatus to identify any deviation from normal behavior	After a learning phase to gather input and output data, the calculated and the real output are compared to identify any deviation from normal behavior

Objectives

- Minimize potential “false positives”: problems falsely detected on healthy equipment
- Eliminate almost all possible “false negatives”: problems not detected on ailing equipment
- When abnormal behavior is detected, a “warning” is generated and announced to pre-identified users by SMS or email
- Acknowledgement feature is also essential to ensuring follow-up of anomaly detections and resolutions.
- A set of visualization tools for in-depth analysis that helps users evaluate the seriousness and urgency of a situation
- Decision about the case is archived: Continue operation, mitigation measures, false positive
- Continuous improvements to analytics should include analysis of all false-positive and false-negative cases generated.

Information structure

For the whole system

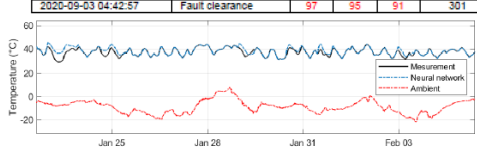


For an **installation**

ID	Last operation						Wear (%)	Operation Counter
	Open			Close				
	Date	Timing(ms)	Status	Date	Timing(ms)	Status		
25-28	2020-06-29 14:27:24	51	Success	2020-06-29 17:29:05	110	Success	2,7484	35
25-29	2020-07-17 10:13:36	42	Success	2020-07-17 12:36:31	97	Success	1,2186	10
25-30	2019-11-19 15:17:20	48	Success	2019-11-21 16:32:26	99	Success	0,0046	20
25-31	2021-10-27 07:10:17	54	Success	2021-10-27 07:10:22	107	Success	5,3479	16
25-32	2018-07-02 15:20:21	50	Success	2018-07-02 15:28:42	106	Success	0,3606	80
25-33	2021-06-19 06:25:35	46	Success	2021-06-19 06:25:40	106	Success	4,2264	4
25-35	2020-11-06 16:19:20	49	Success	2020-11-06 16:19:25	97	Success	3,9886	12
25-36	2020-10-07 08:01:34	48	Success	2020-10-07 08:00:50	108	Success	1,8393	20
25-37	2020-01-12 04:47:57	47	Success	2020-01-12 08:34:32	106	Success	1,4254	6
25-38	2021-10-27 11:09:32	53	Success	2021-10-27 11:09:54	105	Success	2,9328	5
25-39	2019-11-01 09:22:18	78	Success	2020-08-12 13:27:30	91	Success	5,7091	5
25-40	2021-10-20 08:55:23	76	Success	2021-10-20 08:55:28	121	Success	0,0002	7
25-41	2018-01-23 23:50:40	47	Success	2018-09-12 15:04:00	101	Success	0,0104	10
25-42	2021-09-12 15:03:45	62	Success	2021-09-12 15:04:00	89	Success	14,211	18
25-43	2021-09-14 21:44:13	52	Success	2021-09-14 21:44:28	91	Success	1,6854	5

For an apparatus

Date	Type of open operation	Timing (ms)			Dead time (days)
		θA	θB	θC	
2021-09-12 15:03:45	Fault clearance	55	62	62	0
2021-09-12 15:03:39	Fault clearance	59	58	58	17
2021-08-26 05:49:39	No-load	74	74	74	11
2021-08-15 02:04:47	Fault clearance	242	237	240	346
2020-09-03 04:43:18	Fault clearance	59	59	60	0
2020-09-03 04:43:02	Fault clearance	59	63	63	0
2020-09-03 04:42:57	Fault clearance	97	95	91	301



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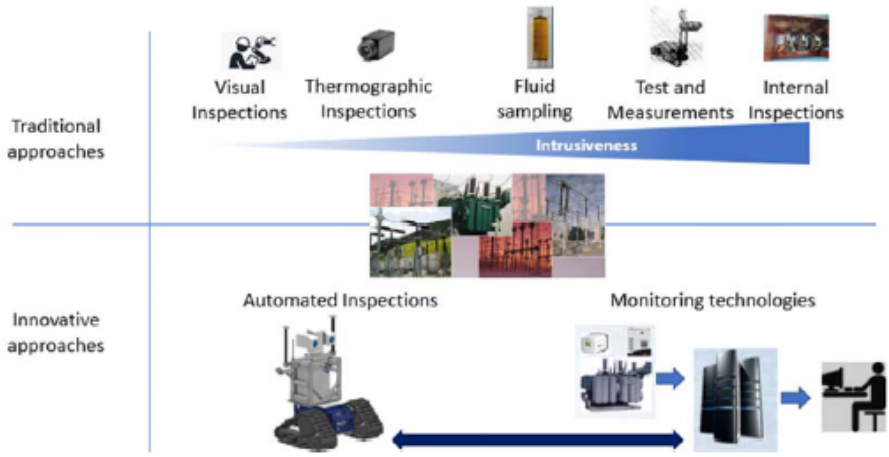
Ongoing development

- Visual and Thermographic Automated Inspections
- In complement to monitoring technologies



Sensor and thermography automatic readings

Conclusion

- The new applications which have been implemented were, not so long ago, merely the stuff of engineers' dreams.
- Monitoring infrastructure is gradually being implemented, but sensors and communication elements are costly and limit the extent and speed of OLCM implementation.
- Whenever possible, the use of existing sensor infrastructure and data is advantageous as it requires smart utilization but only minimal investments.
- Analytics (including warning management) is a key component that needs to be constantly improved to minimize "false positives" cases and to eliminate almost all possible "false negatives" cases.
- The authors believe that despite the achievements described in this paper, our industry is only at the dawn of great changes.
- In a near future, it will be certainly possible to generate automatic outages and work orders using advanced algorithms.