Maintenance Programs for MV & HV Power Circuit breakers

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Preface

In a previous article, we overviewed the circuit breaker maintenance practices presently in application, including a listing of some of the important tests in use, with reference to the applicable international standards.

All these tests have to be coordinated and well planned since the collection of data is spread over a relatively long periods of time. In order to achieve these goals, we need to set up a maintenance program.

In the present article you will find a summarized description of a typical maintenance program's structure ***(Fig 1)*** and its main components. We hope it will give maintenance planners managers enough insight to shape their breaker maintenance programs or to initiate one if it does not exist yet.

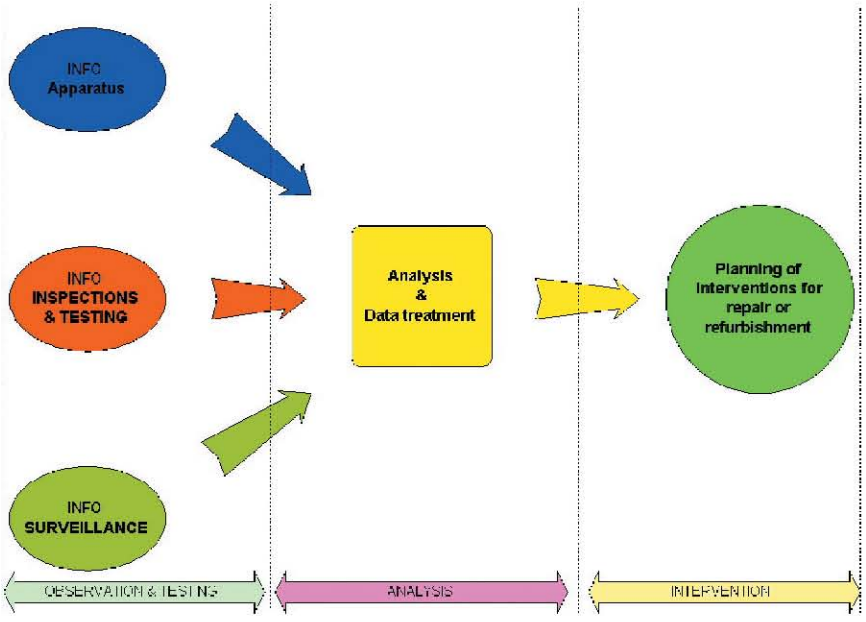

Fig. 1: Maintenance program's typical structure

Introduction

Because of its protective role, the circuit breaker plays an important role in transmission and distribution networks. If it breaks down the impact on the network can be serious. In addition to the damaged equipment, the cost of current interruption can be tremendous, since current interruptions are subject to severe penalty clauses in Electrical energy supplying contracts. Not to mention compromising the substation personnel safety, as they would be at risk of injury.

The best practice to avoid breakdowns then, is to apply proper maintenance. Since the breaker is like a black box, the only way to assess its condition with certainty is to take it apart. This can be a costly business, especially if it is not necessary.

This leads to the necessity of applying a multitude of maintenance actions (inspections and tests), in order to collect enough information on the actual condition of the breaker, which in turn permits a decision to proceed with repairs in time.

Inspection and periodicity Table

Fig. 2: Inspection and periodicity Table

Type	Description	Periodicity
Routine Inspection (RI)	Thermography Visual inspection (insulators, leaks, general condition, etc.) Operation counter Pressure gauges	1 year
Limited Inspection (LI)	In addition to RI it includes: Leaking tests Contact resistance test Timing test	4 years
Provisional Inspection (PI)	In addition to LI it includes: Specific verifications (Heating, wiring, timers, pressure switches, Filters, Safety switches, Fuses, Auxiliary switches, etc.) AC Insulation test Functional test Antipumping test	8 years
Complete Inspection (CI)	In addition to PI it includes: Open inspection of one interrupting module Open inspection of the mechanism any other inspection specific to the type of the breaker	1000 operations

Maintenance Actions

The maintenance of circuit breakers relies then, on the application of a number of actions, called maintenance actions. These actions can range from a simple reading, like an operation counter, to a full inspection including disassembly of a major part, as an interrupter chamber for example.

Fig. 3: Breakers Database

No	TYPE	MANUFACTURER	S/N	TECHNOLOGY	YEAR	SUBSTATION	POSITION	INSTALLATION	KV	A	KA	APPLICATION	K FACTOR
00001	PK4A	DELLE-ALSTHOM	36070R1	AIRBLAST	1970	MAKATA	300-01	1971	330	2000	31	LINE	1
00002	PK4A	DELLE-ALSTHOM	36070R2	AIRBLAST	1970	MAKATA	300-02	1971	330	2000	31	LINE	1
00003	PK4B	DELLE-ALSTHOM	36070R3	AIRBLAST	1970	MAKATA	300-03	1971	330	2000	31	LINE	1
00004	PK4B	DELLE-ALSTHOM	36070R4	AIRBLAST	1970	MAKATA	300-04	1971	330	2000	31	LINE	1
00005	PK4B	DELLE-ALSTHOM	36070R5	AIRBLAST	1970	MAKATA	300-05	1971	330	2000	31	LINE	1

Maintenance actions on circuit breakers are numerous and diverse, but they all serve to keep a close eye on the breaker's condition to correct it before breakdowns occur.

Some of these actions have to be repeated on a periodic basis. The information has to be recorded and analyzed to reach a verdict. ***Fig 2***. Inspections and periodicity table, shows a list of possible inspections classified according to four categories of inspections:

- Routine inspections
- Limited inspections
- Provisional inspections
- Complete inspections

Each family of circuit breakers needs to have its specific list of inspections and periodicities. All these actions need to be planned and coordinated. Setting up a program called "Maintenance Program" does all of this.

Maintenance Program

In essence a maintenance program serves to:

- Coordinate the maintenance actions on a timescale;
- Collect data on the actual condition of the breaker
- Organize the collected data for analysis;
- Analyze the collected data;
- Plan intervention if needed.

Maintenance Program's Elements

In order to reach the above-mentioned objectives, the program has to rely on the following elements:

- Planning;
- Observation & Testing (Data collection);
- Analysis;
- Planning
- Intervention.

Observation:

This is the part that collects information from all sources. The information collected is organized in databases. Some of these databases are described as follows:

Breakers Database ***(Fig 3)***: First of all we need to know our breakers. This is achieved by maintaining a database of installed equipment. This database should contain, in addition to other required information, the following:

- Type;
- Manufacturer;
- Serial number
- Technology (SF6, Air blast, Oil, etc.);
- Year of manufacture;
- Location;

Fig. 4: Tests Database

Name	Description	Breaker Type	Application	Standards
ContactTiming Test	Measures the time from the order initation to contacts close or part	All	Overall breaker operation	IEC
Travel & Velocity Test	Traces travel and velocity curves	All	Overall breaker operation	IEC
Contact Resistance Test	Measures the contact resistance between to parts meant to conduct current	All	Electrical conductivity	IEC
AC Insulation Test	Measures the insulation between open contacts and between line and ground	All	Electrical insulation	
Oil Dielectric Test	Measures the dielectric carachteristics of insulation oil	Oil breakers	Electric Insulation of medium	IEC
Oil gas analysis Test	Measures the gas content in the insulation oil	Oil breakers	General quality of medium	IEC
Water Content Test	Measures the moisture content in the insulation medium	All	General quality of medium	
SF6 By-Products Test	Measures SF6 byproducts level in SF6 insulation gas	SF6 breakers	General quality of medium	
SF6 Mixture percentage Test	Measure the percentage of SF6 in insulation gas mixture	SF6 breakers	General quality of medium	
Auxiliary Circuits Insulation Test	Measures the insulation of the low voltage control circuits	All	Electrical insulation	IEC
First Trip Test	Measures the contact timing at first trip	MV breakers	Breaker operation	
Dynamic Contact resistance Test	Measures the contact resistance continously since the first contact make of a moving contact until the contact's stop	All	State of contact wear-out	
Vibration Test	Measures the vibration signature of a circuit breaker	All	Overall integrity	
X Ray Test	Takes an X-ray photo of the inside of closed subassemblies	All	Breaker integrity	
Ultrasound Test	Cheks for crackes in insulatures	Insulators	Product integrity	
Capacitance Test	Checks the capacitance value on capacitors used on breaker (grading, coupling, etc.)	Capacitors	Product integrity	
Air pressure consumption Test	Measures the air consumption of an operation or cycle of operations	Air blast breakers	Breaker operation	
Infrared Tempurature Test	Measures temperature of parts by infrared device	All	Electrical conductivity	
Tightness Test	Checks the tightness of the insulation medium	All	General quality of medium	

- Electrical characteristics (Voltage, Amperage, Breaking capacity, making capacity, etc.);
- Application;
- Date of installation;
- Various information, proper to the breaker itself.

Tests database ***(Fig 4)***: This database contains a list of required inspections and periodicities (prescribed time periods between successive maintenance actions to be repeated systematically) to be conducted on the breakers.

Collected data database ***(Fig 5)***: This database organizes, for each breaker, the data collected in various inspections, and it may include:

- First test sheets results;
- Inspections results over time;
- Repair interventions;
- Operation Counter
- Pressure gauges readings
- Temperature readings
- Timing readings
- Insulation readings
- Travel Velocity readings
- Contact resistance readings
- Oil quality checks
- Moisture measurements
- SF6 by products measurements
- Contact condition inspection (following a complete inspection for example)
- Incidents;
- Etc.

This information serves primarily to conduct an analysis in order to determine the type and urgency of maintenance interventions. It also serves as historical data for future statistical and durability studies.

Inspection and Tests Planning:

This is the part that organizes and coordinates the inspection sequences so the maintenance people can prepare the required maintenance actions in advance (Purchasing department, Warehouse, maintenance teams, operators, etc.). to increase efficiency in collecting information. The following figure (Fig 6) gives an idea on a possible course of inspection planning.

Fig. 5: Collected data Database

BKR S/N	TYPE	INSPECTION	TEST	RESULTS	DATE	OPERATOR
23458	OIL	IP	ContactTiming Test	Report433	04-Jul-99	LMM
23458	OIL	IP	Travel & Velocity Test	Report434	04-Jul-99	LMM
23458	OIL	IP	Contact Resistance Test	Report435	04-Jul-99	LMM
23458	OIL	IL	AC Insulation Test	Report321	18-May-01	HJE
23458	OIL	IL	Oil Dielectric Test	Report322	18-May-01	HJE
23458	OIL	IL	Oil gas analysis Test	Report323	18-May-01	HJE
23458	OIL	IL	Moisture Content Test	Report324	18-May-01	HJE
36070R1	Airblast	IP	ContactTiming	Report201	09-Sep-02	AKH
36070R1	Airblast	IP	Contact Resistance	Report202	09-Sep-02	AKH
36070R1	Airblast	IP	AC Insulation	Report203	09-Sep-02	CDU
36070R1	Airblast	IP	Moisture Content	Report204	09-Sep-02	CDU
36070R1	Airblast	IP	Auxiliary Circuits Insulation	Report205	09-Sep-02	CDU
36070R1	Airblast	IP	Capacitance	Report206	09-Sep-02	CDU
36070R1	Airblast	IP	Air pressure consumption	Report207	09-Sep-02	CDU
36070R1	Airblast	IP	Infrared Temperature	Report208	09-Sep-02	AKH
36070R1	Airblast	IP	Tightness	Report209	09-Sep-02	CDU

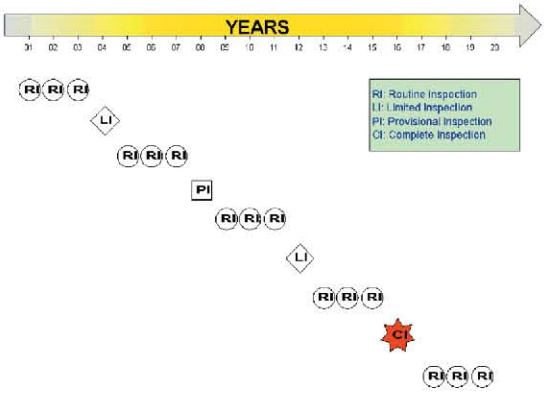

Fig. 6: Planning

BKR S/N	Analysis Report No	Advisory	PRIORITY	DEADLINE DATE	ANALYSIS DATE	ANALYST
23458	Report1	Advisory 1	1	01-Nov-06	07-Jul-06	GHI
23459	Report2	Advisory 2	1	01-Nov-06	07-Jul-06	GHI
23460	Report3	Advisory 3	1	01-Nov-06	07-Jul-06	GHI
23461	Report4	N/A	2	15-Oct-08	07-Jul-06	GHI
23462	Report5	N/A	2	15-Oct-08	07-Jul-06	GHI
23463	Report6	Advisory 3	3	31-Dec-08	07-Jul-06	GHI
23464	Report7	Advisory 110	3	31-Dec-08	07-Jul-06	GHI
23465	Report8	Advisory 2	3	31-Dec-08	07-Jul-06	GHI
23466	Report9	Advisory 34	4	01-Jun-09	07-Jul-06	GHI
23467	Report10	Advisory 1	4	01-Jun-09	07-Jul-06	GHI
23468	Report11	Advisory 22	4	01-Jun-09	07-Jul-06	GHI
36070R1	Report12	Advisory 31	3	31-Dec-08	25-Aug-06	RTY
36070R1	Report13	N/A	3	31-Dec-08	25-Aug-06	RTY
36070R1	Report14	N/A	3	31-Dec-08	25-Aug-06	RTY
36070R1	Report15	N/A	3	01-Jan-09	25-Aug-06	RTY
36070R1	Report16	Advisory 11	7	31-Dec-09	25-Aug-06	RTY

Fig. 7: Analysis Database

Analysis

Teams of highly trained engineers and technicians process all the information gathered in the previous sections and stored into well-organized databases. These teams have the responsibility to reach a verdict based on the available information, and determine the required actions and priorities. This information is put into a specific database, Analysis database ***(Fig 7)*** that is used to prepare interventions.

This database has to contain:

- Breaker serial No, to identify the equipment being analyzed;
- Analysis report No, that details the findings and recommendations;
- Advisory No, if any;
- Priority level of each recommendation;
- Deadline date for the intervention;
- Analysis date;
- Analysts names;
- Various required information, etc.

Advisory:

Advisories are reports that inform the maintenance manager on what to do and on which equipment. It contains, at least:

- A list of concerned breakers;
- A list of actions to do;
- A description of the reasons (reference to Analysis report);
- A list of parts;
- A list of special tools;
- Drawings and instructions;
- Etc.

Intervention:

Once the advisory is initiated, interventions can now be planned.

For example the result of a complete inspection of an interrupter module may reveal a critical condition that may require an intervention program on all similar breakers.

This requires coordination between network administration and maintenance teams. A list of to-do actions, parts and special tools must be determined, not to mention training, quality assurance, budget cost control, etc.

BKR S/N	Action plan	Teams	Schedule	Start date	End date	Completion date	Manager
23458	To do list1	1	Plan1	07-Jul-06	01-Aug-06		ALH
23459	To do list2	1	Plan2	07-Jul-06	01-Aug-06		ALH
23460	To do list3	1	Plan3	07-Jul-06	01-Aug-06		ALH
23461	To do list4	2	Plan4	07-Jul-06	01-Aug-06		ALH
23462	To do list5	2	Plan5	07-Jul-06	01-Aug-06		ALH
23463	To do list6	3	Plan6	07-Jul-06	06-Aug-06		ALH
23464	To do list7	3	Plan7	07-Jul-06	06-Aug-06		ALH
23465	To do list8	3	Plan8	07-Jul-06	06-Aug-06		ALH
23466	To do list9	4	Plan9	07-Jul-06	06-Aug-06		ALH
23467	To do list10	4	Plan10	07-Jul-06	06-Aug-06		ALH
23468	To do list11	4	Plan11	07-Jul-06	06-Aug-06		ALH
36070R1	To do list12	3	Plan12	25-Aug-06	30-Nov-08		GWE
36070R1	To do list13	3	Plan13	25-Aug-06	30-Nov-08		GWE
36070R1	To do list14	3	Plan14	25-Aug-06	30-Nov-08		GWE
36070R1	To do list15	3	Plan15	25-Aug-06	30-Nov-08		GWE
36070R1	To do list16	7	Plan16	25-Aug-06	30-Nov-08		GWE

Fig. 8: Breakers Database

Once the intervention is completed, keeping record of it is crucialmatter. Every corrective action or intervention on the circuit breaker has to be recorded for comparison and future analysis. A part's repetitive failure for example may raise concerns on more critical problem or a design flaw. A breaker's history has to be available for reliability studies; this may influence the future of a circuit breaker family (systematic replacement or refurbishment).

The Intervention database ***(Fig 8)*** keeps record of such information, it must contain:

- The breaker's serial No;
- The action plan and schedule;
- Technical team assigned;
- Start date;
- Deadline end-date;
- Date of completion;
- Manager name;
- Etc.

Conclusion

As we mentioned from the beginning, the present article gives the basics of setting up a maintenance program. Detailed discussion is not relevant here, since we are dealing with a great deal of information. The following figure ***(Fig 9)*** recapitulates briefly as follows:

Information from the breaker's database and Tests database lead to collect information in Data database. This data serves to conduct a thorough analysis, leading to maintenance interventions. Interventions meant to happen before any breakdown occurs.

And last but not least, as it is obvious that any relational database can do the job, we can find many programs on the market that are specifically designed for this purpose. It is the task of specialized personnel to determine the need versus the program's capability in order to reach the perfect choice.

Bibliography

The present article is based on our personal experience with Hydro-Québec's maintenance program model. ■

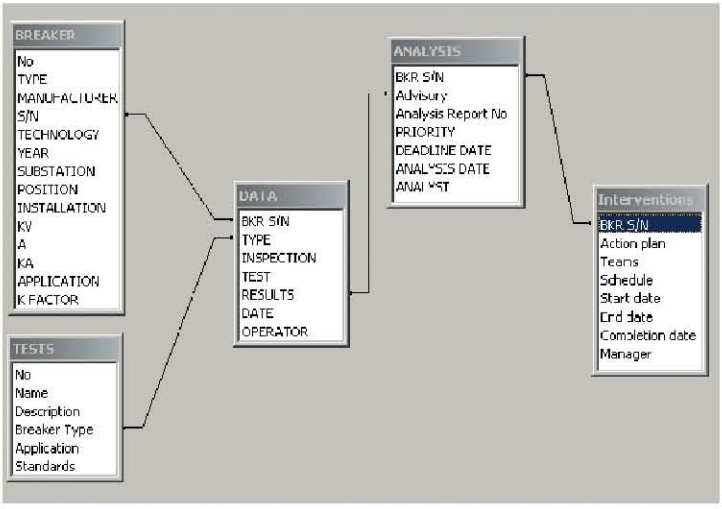

Fig. 9: Breakers Database

About the Authors

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