OPTIMIZING MAINTENANCE AND IMPROVING OPERATION OF DISTRIBUTION NETWORK BASED ON "SCADA" APPLICATION PROGRAM

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ABSTRACT

Alexandria Electricity Distribution Company (AEDC) applied a SCADA system for network automation called Distribution Management System (DMS). Collected information from DMS gives a big advantage for any programmer to develop application programs based on this data and get valuable results from them.

This paper presents a computational program developed to help the network operator to keep Medium Voltage (MV) Circuit Breakers (CBs) working safely by warning him when a breaker is near or at full duty cycle. Timing parameters are user-defined according to CB type (Minimum Oil, Air Blast, Sulfur Hexa Fluoride [SF6] or Vacuum) and the number of operations according to each CB's maintenance type (counting the number of tripping times under short circuit condition, number of switching under load condition and number of switching under mechanical operating condition).

The function of this program is to not only warn the operator that a breaker needs maintenance but also to create a history for each MV cable in the loop of each CB. The history contains number of cable's faults, number of repairing joints, number of HV tests applied on it and its recommended loading level according to this information.

There is a third function for this program. It can be used as an indication for power quality level of service on MV network. The program calculates the interpretation time due to CB tripping or switching off operation and isolation for its load area and the value of the interrupted power during isolation period as well control actions, total number of switching operations for each MV CB in a definite period. Then it has to apply the results on the standard equations forms to get the required indices.

DMS has "UNIX" as operating system and "Sybase" as system database while the computational program is implemented using File Transfer Protocol (FTP), Java programming language and Access database program under Microsoft Windows.

INTRODUCTION

AEDC is a government-owned utility serving Alexandria Governorate with electrical power supply through 20 & 11 KV Medium Voltage (MV) network. AEDC is serving about 1.819 Million customers. Peak load of Alexandria was 1798 MW. Sold energy was about 5890 Million KWHr (2005/2006).

Network automation has been applied since 1997. There are 24 Substations (S/Ss), 104 Distributors (DPs) and 200 Distribution Rooms or Kiosks (as a pilot project) under automation. DMS consists of three Distribution Control Centers (DCCs) and a Supervisory Control Center (SCC).

Each DCC provides controlling and monitoring of a definite part of the electrical network with no overlapping for decision responsibility using a special communication protocol over radio communication links through Remote Terminal Units (RTUs). DCC is acting to fully collection and processing for all acquired data, as well issuing controls for the entire area of responsibility.

Additionally, SCC provides for overall monitoring, without control, of Alexandria electrical network. It has access to real-time data and display for all DCCs. It provides reporting capabilities that merge data from all DCCs.

The result of applying automation is great. Detection of faulty MV cables, sending information immediately to DCC, the action of isolating the faulty cable and restoring power supply to the isolated loop within few minutes are some of the advantages. Saving in time increases the sold energy and improves the power quality as new advantages. There are other advantages like improving voltage quality and loading levels of MV cables, saving in working teams and transport facilities due to remote operation, decreasing the routine maintenance programs and scheduled network partial isolation.

There is a continuous check for quality of information, which has been collected from DMS under normal condition and under unexpected events. The quality of information depends on many factors. The main factors are:

1- Control system hardware and software in Master Station and at Remote End.
2- Remote end switchgear equipment.
3- Database and its updating regulations.
4- Communication link availability.

There is a big effort to manage with them to keep the quality of information under all possible single hardware and/or software failures by using redundancy and fault tolerance technique without affecting the system performance and keeping it in the highest level of accuracy and availability under the same level of security. System is covered by a supervision and maintenance programs which insured about 99.98% system availability with no major problem causing failover of the system. Availability of communication is very high and stable (99.94% at least) as per reporting records.

METHODOLOGY

Circuit Breakers (CBs) are very important element in the power system. They are used to switch other equipment in and out of service. CBs need to be reliable since their incorrect operation can cause major issues with power system protection and control.
In case of shortage of information about CBs working condition, unnecessary maintenance program may be applied on some CBs in S/Ss or DPs. It costs a lot of money and causes an interruption for power supply.
This computational program offers accurate information to help decision makers to start the required maintenance on time. The program has three functions through three modules. It starts when any CB opened. It takes information from DMS database files same as "Historical Alarms and Event Browser" file (real time). Then it starts to record the results in specified tables to give an indication for each function of it.
The first function is to count the number of switching operations for each MV CB. According to coming alarms, the program has to identify the cause of CB opening.
There are three causes:
- First one is due to tripping by protection (Over current and/or earth leakage).
- Second is due to normal switching operation (current within the normal operating range for CB), or tripping by under frequency protection.
- Third is due to testing CB to check its functionality and its response to the protection system (CB truck in test position).

The program has to count the number of switching operations in different tables according to the cause of it. If the number in a table reaches the limit according to CB type and manufacturer's instructions, an alarm appears as a warning to the operator to call the maintenance team for checking that CB and maintaining it as required. Counter will be reset automatically; if the maintenance was done and warning alarm would be cancelled.
The second function is to create a history for the operating criteria for each MV cable in the distribution network. This history contains cable's configurations, its normal loading level, number of failures of its insulation during service, HV tests on it, repairing joints and the recommended loading level according to this history. This can be done by identifying the cause of tripping from protection alarms, and then the program has to check the loop and create a list for cables and kiosks connected to that CB. This will be done automatically from "Network Connectivity" file. Then according to the testing results, the faulty cable can be identified and repaired. This information will be recorded manually to get the "Cable History Report".
If the tripping is due to false operation of protection system, it will be recorded in a table and give a report to check protection equipment for that feeder.
The third function is to measure power quality of service at MV Bus Bar (BB) for each S/S or DP of the distribution network. Service quality can be measured by indices depend on electrical power and energy such as ASIDI (Average System Interruption Duration Index) and ASIFI (Average System Interruption Frequency Index).
This can be calculated according to the available loading information from DMS and according to the standard specifications of power quality of service indices which are defined according to loading (KVA) information.

COLLECTED INFORMATION FROM DCC

The available information includes:

1- Distribution Control Center name (East, Middle or West).
2- Location of the CB (Name of S/S or DP).
3- CB's feeder name.
4- Type of CB (Minimum oil, air blast, SF6 or Vacuum).
5- Date (dd/mm/yyyy) and time (hh:mm:ss:ms) of switching operation for a CB.
6- Date and time of power restoration for each part of the loop connected to that CB.
7- Cause of switching operation (Tripping by protection, Normal switching operation or Testing).
8- Pre-operation / Pre-fault current of CB's feeder.
9- BB voltage.
10- Connected MV cables to the tripped CB.
11- Connected Kiosks to the tripped CB.
12- Load of each power transformers at each S/S.
13- Load of each incoming feeder at each DP.
14- Total load of the site (S/S or DP).
15- Total load of the network.

I- CIRCUIT BREAKER MONITORING (CBM)

First module starts when any CB opened either normally by operator (Locally or remotely) or forced by protection. All information about CB location, CB name & CB type will be taken from system database and recorded in a specified table.
If protection alarm (over current earth fault) appears in the same time, it means "Case of CB tripping". Counter starts to count "CB Trip, electrical & mechanical operation" in that table.
If there is no alarm associated with CB opening event, the program has to check CB position (Service/Test position) by checking CB truck position in case of draw-able CB or check BB isolators status (Close/Open) in case of fixed CB.
If CB is in service position, it means "Case of normal switching operation" or tripping by under frequency protection, i.e. current within the normal operating range for the CB. Counter starts to count "electrical and mechanical operation" in the same table.
In case of CB testing or protection devices check for a feeder, CB is in test position or BB isolators are opened according to CB type. CB open event will be considered as only mechanical operation. Counter starts to count "mechanical operation" in the same table.
If a counter in any table's column (tripping, electrical or

mechanical) reaches the limit according to CB type and instructions of the manufacturer, an alarm will appear as a warning to the operator to call the maintenance team for checking that CB and maintaining it

If the maintenance was done, then the operator has to click the button "Maintenance was done" for checking the maintenance action, then the counter will be rested and warning alarm will be cancelled automatically.

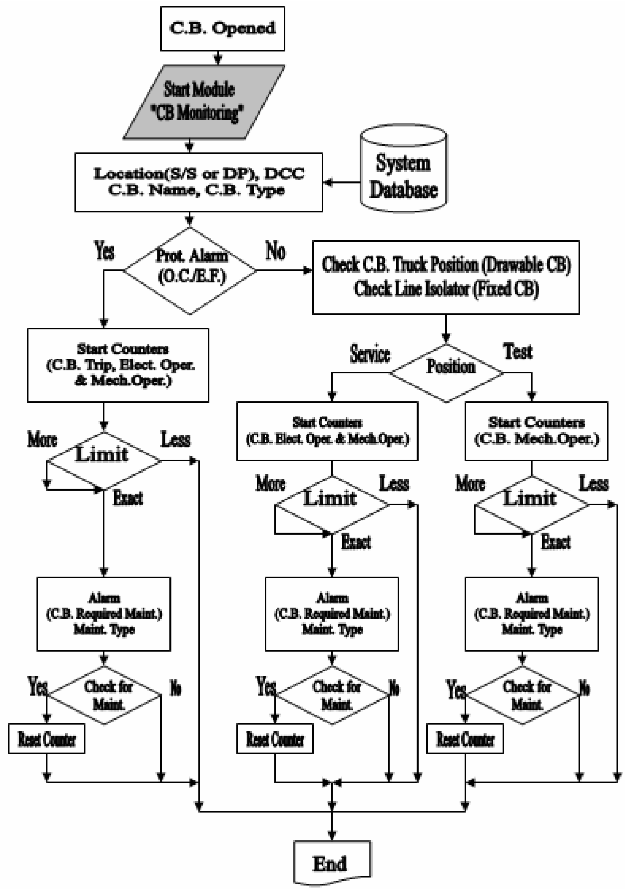

Figure (1) - Flow Chart of Circuit Breaker Monitoring (CBM)

II- CABLE HISTORY REPORT (CHR)

Second module creates a history for each MV cable in the distribution network. It starts When a CB opened and protection alarm appears. A list of cables and kiosks which are connected to that CB is called from "Network Connectivity" file. According to identification of the tripping cause, the module will run as:

1- Case of "Faulty Cable"

The module has to check the list of cables connected to that CB. This will be done automatically. Then according to the testing results, the faulty cable can be identified and repaired. This information will be recorded manually to fill the table of "Cable History Report" by these events. Cable history table contains cable's configurations (type, length, cross section, normal loading level, ..) from system database and number of failures of its insulation during service, high

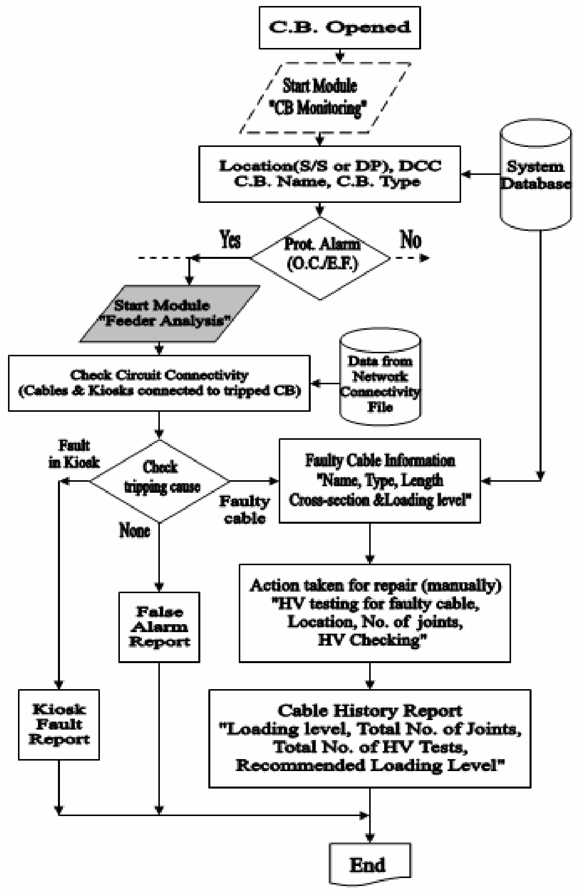

Figure (2) - Flow Chart of Cable History Report (CHR)

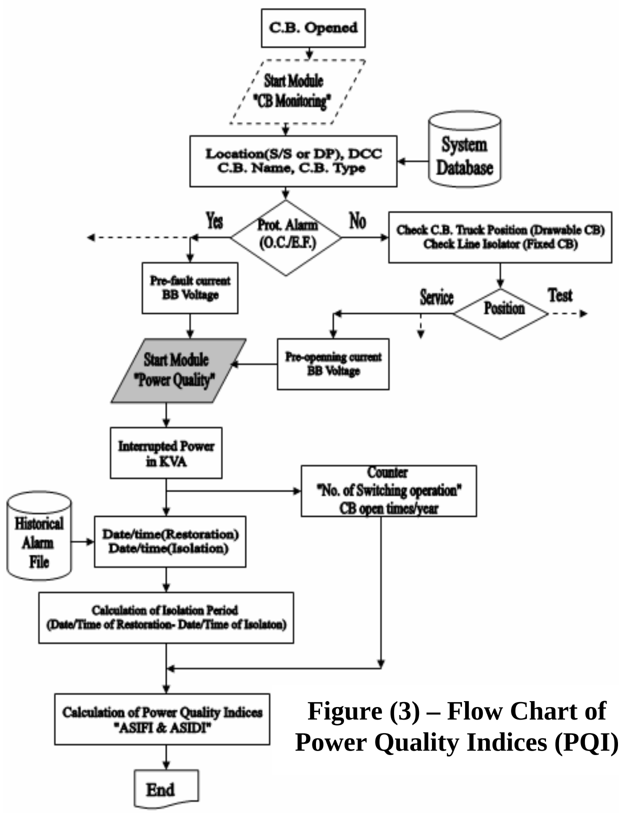

Figure (3) – Flow Chart of Power Quality Indices (PQI)

voltage tests on it, repairing joints and the recommended loading level according to this history (added manually).

2- Case of "Fault in a Kiosk"

If the testing result shows that the tripping is due to faulty component in a kiosk (isolator, distribution transformer, capacitor bank ...), "Kiosk Fault Report" will be filled according to the cause of kiosk's fault and the action taken for repairing it**.**

3- Case of "False Alarm"

If the testing result shows no fault in the loop components, so the tripping is due to false operation of protection device, it records the condition in a table called "False Alarm Report" and gives a report to check protection equipment for that feeder.

III- POWER QUALITY INDICES (PQI)

The third module calculates some of power quality indices at MV BB for each S/S or DP of the distribution network such as ASIDI and ASIFI. Program calculates those according to (IEEE 100, IEEE 493 & IEEE 1366) standards as:

$$\mathbf{ASIDI = (\Sigma\ r_i L_i) / (L_T)}$$
$$\mathbf{ASIFI = (\Sigma\ L_i) / (L_T)}$$

Where:
L_i = KVA load interrupted for each interruption level.
L_T = Total connected KVA load served.
r_i = Restoration time for each interruption event.
i = an interruption event.

Calculation starts when a CB opened as:

1- KVA load Interrupted of any BB at S/S or DP.
= [(pre-fault or pre-opening current) * (BB voltage)].
2- Restoration Time.
= (date & time for power restoration for the isolated area - date & time of tripping or switching off operation).
3- Number of Switching Off times for each CB / (S/S) or (DP) / year will be counted by the program.
4- Total connected KVA load served for each BB (incoming feeders) / (S/S) or (DP), total power of each (S/S) or (DP) and total power of the network.

APPLIED EXAMPLE

In order to illustrate this application program and getting valuable results, an example applied to "Middle" DCC network. It has 8 S/Ss, 24 DPs and 81 kiosks under control.
Figure (4) shows typical two reports. The first contains a list of CBs which need maintenance according to manufacturer instructions and tripping counter of the program. The second contains CBs monitoring report for a S/S "Mostafa Kamel" including the different counting

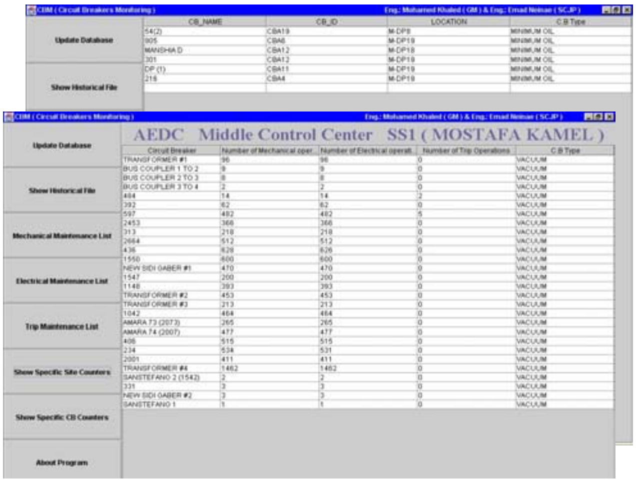

Figure (4) – Program's Reports about CBM

results for each feeder's CB (tripping, electrical & mechanical) and CB's type. Results were great. Reducing cost and saving power due to limiting the interruption of power supply for many customers' areas by postponing unnecessary predictive maintenance actions (inspections). Maintenance actions on time include corrective actions (repairs) and checking of cables history are reducing failure rates and therefore reliability indices are improved. It saves maintenance efforts. Risk of failure's level comes down and interrupted power rates are decreased which means better service quality, more sales and better customer's relation

CONCLUSION

Results of implementation of this computational program on MV network of Middle DCC areas has proven that it is a valuable and powerful tool to manage maintenance action, improves the operation of distribution network, decreases the risk of failure of network equipment and improves power quality indices. The program has been applied on the other network portions at "East" and "West" DCCs to cover the complete area of Alexandria distribution network.

10- REFERENCES

Documents:
[1] Annual Technical & Commercial Reports of AEDC.
[2] Software manual –Vol. 1, 12-17& Vol. 2, 233-240.

Published researches:
[3] A.Baset & M. Khaled, 2001, "DMS improving power quality" 8 th MEPCON Conf., Helwan Univ. Cairo, Egypt.
[4] A.Baset & M. Khaled, 2002, "Cost Benefit for DMS" Med Power Conf., Athens, Greece.

Books:
[5] Bruce Eckel, "Thinking in Java", Second edition..
[6] Kamila Yousef, 2006, "Electrical power reliability indices and customer services", Egypt