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Predictive Reliability-Centered-Maintenance for Asset Management and Enabling Quick Diagnosis-Response to Events

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***Abstract*— This paper deals with proposition of a maintenance methodology to be utilized in smart grid, which, in turn, may ensure reliability and security levels, minimize operation costs, reduce service interruptions and shortened outage durations. In this way, Reliability-Based-Maintenance (RCM) incorporated with economical rankings to achieve Predictive RCM (PRCM). The proposed methodology takes into account the individual equipments tasks to provide Independent System Operator (ISO) with system security and reliability monitoring tool. It evaluates each equipment condition and impact on the system reliability to manage the overall system maintenance. The methodology categorized the equipments based on their condition into three clusters. These are bad condition which maintenance or replacement is required, medium condition which maintenance should be done and good condition which maintenance is not required. The equipment condition is employed in the scheduling of sufficient generation units by ISO to provide load, which, in turn, may ensure system reliability. The maintenance task could be done based on the importance of each one in respect to system reliability in order to reduce services interruptions. Economical ranking is tackled into the problem formulation to improve the proposed methodology efficiency.**

Keywords- *Predictive reliability-centered maintenance, reliability, ISO, equipment condition*

I. Introduction

The preliminary notion of smart grid is to improve energy efficiency, self-healing concept, and etc [1]. However, a smart grid has several benefits for consumers, utilities, environment and nation. Asset management, reducing service interruptions and shortening outage durations are common benefits for consumers and utilities [2]. Reduction of downtime, caused by equipment failures, could be achieved through deployment of predictive maintenance strategies, which, in turn, enables quick diagnosis and self-healing properties [3].

Planned and scheduled maintenance, called Preventive Maintenance (PM), contributes in reliable power system operation. Moving toward more reliable system besides the need to minimize operation costs speed up the smart grid visualizing. In such framework, all the system issues may be formulated based on the reliability and cost. By taking into account the economical, technical and business factors, PM strategies change to Reliability-Centered-Maintenance (RCM) strategies which successfully consider asset management and service interruption minimization in maintenance problem [4, 5].

The function of an electric power system is to satisfy the system load requirement with a reasonable assurance of continuity and quality. The ability of the system to provide an adequate supply of electrical energy is usually designated by the term of reliability [6]. Some indices are measures of reliability at each load point (load point indices), and of average behavior of the overall system (system indices). The reliability indices are reported in Table 1 [5].

Table 1: Reliability Indices

Load point	System
Failure rate	SAIFI (int/yr.cust)
Outage time	SAIDI (h/yr.cust)
Unavailability	CAIDI (h/int)
Energy not supplied	AENS kWh/yr.cust)

An electricity market as a framework for smart grid includes a market operator, Independent System Operator (ISO), sellers and buyers. While market operator manages the financial transactions and implementation of market rules, sellers and buyers negotiate in the market to achieve their goals. ISO manages the network and involved constraints to satisfy common system goals. ISO do this task in such a way that players attain their individual goals [7]. In this way the ISO should tackles the desired plans of players into the operational scheduling. This concern addresses in several papers by coordination between system operator, transmission owners, producers and consumers [8-9]. Ref. [8] introduces a method based on game theory for maintenance scheduling in the layer of producers. In this method each producer manages its outage by considering the rivals reaction. Neglecting overall supervision over the security and reliability issues, limits application of this methodology. Conejo et al. [9] introduces a mechanism based on incentive/disincentive for power producers and the ISO to achieve the final maintenance plan for a year ahead. This methodology takes into account maximum producers profit and a fair degree of reliability in each week of the year in maintenance problem. This paper introduced as an attempt to deal with maintenance in smart grid in some researches.

Generally, all of the installed electrical equipments in power supply systems are reaching the end of their technical and economical service life. In other hand, purely technical aspects of maintenance affect competition environment. ABB suggests several steps to provide effective asset management in corporation with self-healing properties. In other words, ABB takes into account these steps in maintenance planning to speed up smart grid visualization. Two of these steps are [10]:

1- Condition assessment of equipment
2- Technical and economical ranking based on condition and importance (RCM method).

Technical and economical ranking could be effectively employed to achieve a PRCM, which, in turn, enables quick diagnosis and self-healing properties [11]. In other words, by moving from a reactive to predictive RCM strategies, one can assess and manage the health of assets to extend lifecycles, reduce maintenance costs and service interruptions, ensure return of investment, and shorten outage durations. These are the main objectives of smart grid. Therefore this paper combined RCM with condition-based maintenance to coordinate system operator, the transmission companies, the producers and the consumers in order to enable smart grid. In this way importance of each equipment is considered in the problem formulation. In other words, the employed strategy provides the ISO with a comprehensive framework to manage the system considering individual and overall goals.

The rest of this paper organized as follows. Section 2 describes the RCM considering technical ranking. In section 3 simulation results are explained in details, and finally section 4 concludes the paper.

II. Reliability-Centered Maintenance

RCM is an engineering process used by some industries to optimize PM. RCM defines as an employed procedure to determine the maintenance requirements of any physical asset in its operating context. RCM aids to establish system boundaries and develop a critical equipment list. If an equipment performs a function that ensures continued power production, or its failure affects continued power delivery, deemed to be critical. For each critical equipment, a Failure Modes and Effects Analysis (FMEA) is performed to:

1- Identify each failure mode and probability of occurrence
2- Evaluate the importance of each failure mode

The failure modes with great importance, obtained by FMEA, considered to be functional. Fault Tree Analysis (FTA) is an effective method through which field data can be used to determine importance of each failure mode. In other word, a maintenance schedule should takes into account the initial operation of system/equipment [12]. Here it should be noted that maintenance-based solution could not be employed for every failure mode. If a maintenance action addressing a significant failure mode is not available or is not cost effective, and the failure cannot be tolerated, then a design modification is recommended [11].

The RCM strategies classify to three categories as follows [11].

1- Hard-time maintenance which is predetermined scheduled maintenance for the failure modes.
2- On-condition maintenance which requires scheduled inspections or tests to measure deterioration of an item.
3- Condition monitoring for those failure modes that require unscheduled tests on components which failure could be tolerated during operation.

Utilization of on-condition maintenance besides calculation of failure modes importance could provide an appropriate platform to analysis the equipment maintenance condition. This could aid the continued power delivery while taking into account asset management, minimum interruptions service and minimum outage durations.

III. Simulation and Results

Stockholm city supplies about 450000 customers and belongs to Birka Energi, which is the utility in Sweden with the greatest number of customers [13]. The reduced version of this grid was analyzed by Bertling et al. [5]. The intact version of this grid is considered in this paper.

NEPLAN software is employed to examine the mentioned RCM strategy in the Stockholm urban network. The reduced version of the grid is taken from [5] and illustrated in Figure 1.

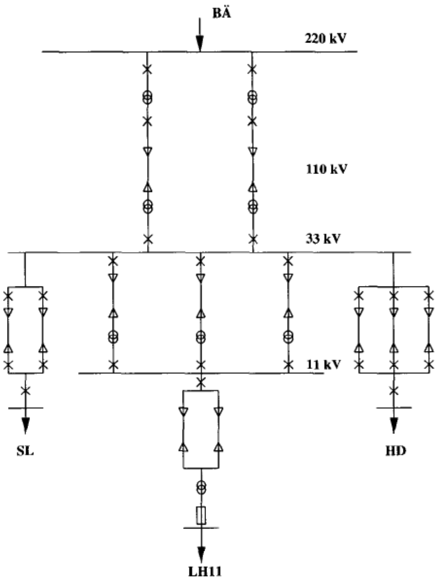

Figure 1: Stockholm reduced model

Reliability analysis indicates that there are 711 probable faults in the system. Among them, 611 faults recognizes as critical faults. According to the component fault analysis and RCM condition, the equipments are categorized as three groups. These groups are:

1- Good condition identified by green color which require no maintenance
2- Medium condition identified by yellow color which should be considered for maintenance
3- Bad condition identified by red color which must be replaced.

Figure 2 demonstrates the status of all the buses, lines, transformers and protection devices based on their RCM condition. According to the importance of each equipment the operational planning should be scheduled. This may be done in corporation with the ISO.

Figure 3 demonstrates the condition-importance plot of the grid in the circuit breakers. It could be clearly seen that there are two elements with high importance which are related to the common fault modes. Multiple circuits transmission lines is used in the areas with developed economy and a large population, such as Japan and part of Europe, because of the scarcity of land and the high proportion of transmission line cost in the total cost. Common mode faults occur on this transmission lines. Figure 4 demonstrates the failure rate and outage time

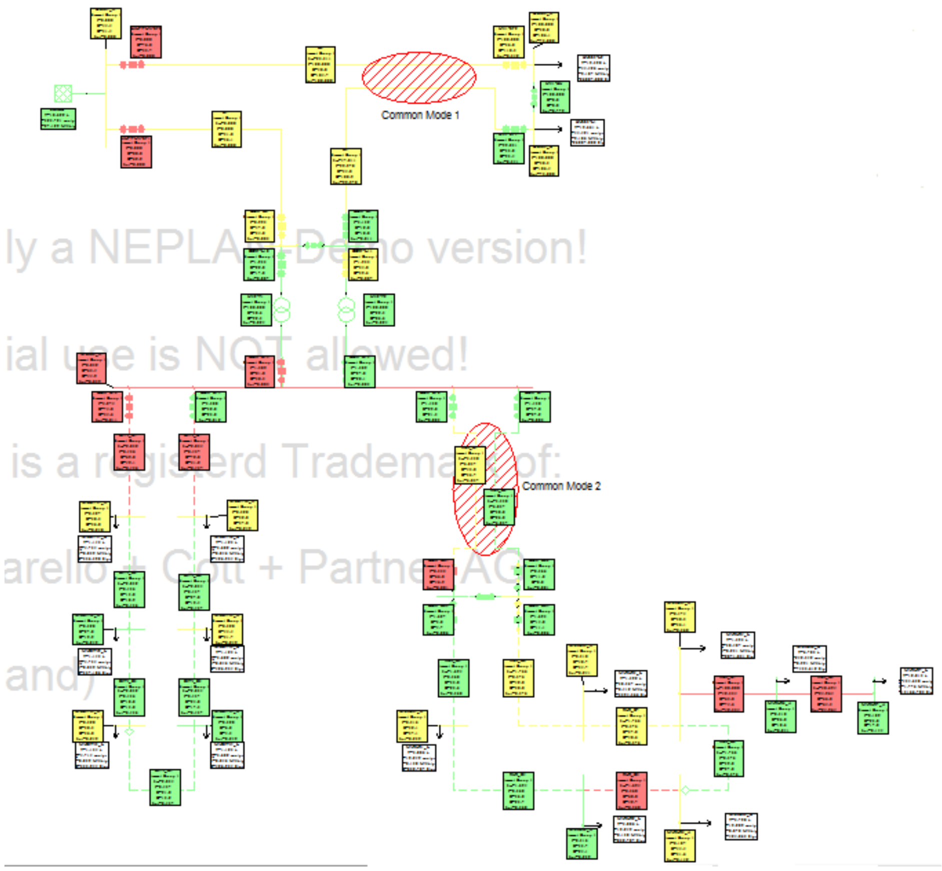

Fig. 2: categorized Stockholm intact model

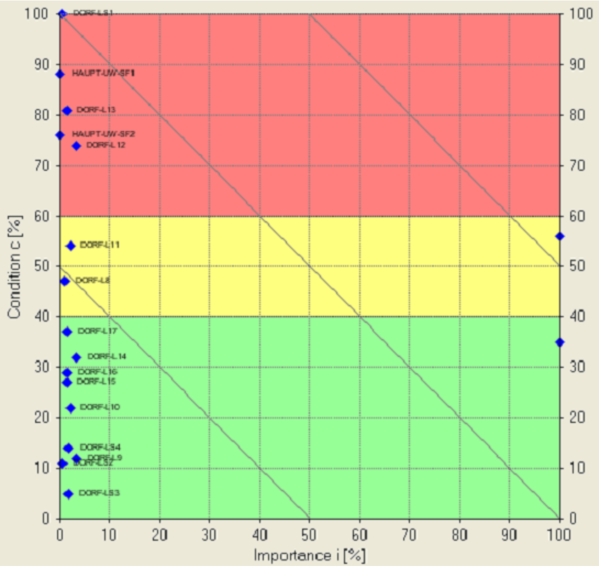

Fig. 3: condition-importance plot

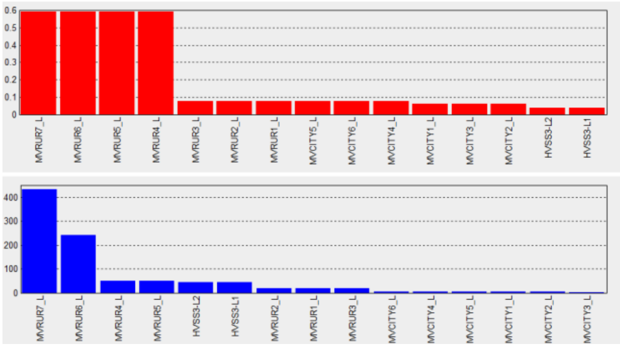

Fig. 4: load-point indices; a) failure rate, b) outage time

related to the existing loads.

IV. Conclusion

Developing an intelligent/predictive platform for equipment maintenance in an electric power system could speed up visualization of smart grid technology which, in turn, reduces service interruptions, shortens outage duration and manages assets.

In this paper RCM methodology incorporated with equipments condition and importance ranking to achieve a reductive maintenance scheduling. Efficiency of the proposed method is examined on an urban network and analyzed by means of load point indices. Simulation results reveal that the condition-importance plot could be employed by ISO, producers, transmission managers and other players to reduce service interruptions and shorten outage while system reliability is guaranteed. Minimizing maintenance cost should be done by employing of economical ranking.

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