A Reliability-Oriented Outlook on the Critical Components of Power Distribution Systems

Payman Dehghanian, *Student Member, IEEE,* and Mahmud Fotuhi-Firuzabad, *Senior Member*, *IEEE*

Abstract**-- Critical components of a system denote to those which have considerable influences on its both technical and economical performance. This paper is concentrated on the identification of critical components in power distribution systems, more from a reliability viewpoint, to be planned for maintenance schedules. A new straightforward scheme is proposed based on the common load point reliability indices which can easily get through the components prioritization. The presented scheme can then mathematically find the most critical ones to be put under reliability centered maintenance (RCM). Since the maintenance plans are then applied where necessary, the proposed method helps in more effectively reaching the benchmarked reliability indices of a distribution utility, with the minimum costs and the maximum benefits. The effectiveness and applicability of the offered scheme are finally reflected in its application on a real distribution system, i.e. Swedish distribution network belonging to the BIRKA Nat distribution system in the Stockholm City area.**

Index Terms**-- Critical components; reliability centered maintenance (RCM); reliability indices, power distribution systems.**

NOMENCLATURE

Subscripts are listed below for quick references.

Variables

$CF_{m,des.}$	Desired criticality factor of the load point *m*.
$CF_{m,i}$	Criticality factor associated with the i^{th} component and for the load point *m*.
$CF'_{m,i}$	Cumulative criticality factor associated with the i^{th} component and for the load point *m*.
$EENS_{m,des.}$	Desired value of EENS index.
$EENS^{2}_{m,i}$	EENS index for the load point *m* in the 2nd scenario on the i^{th} critical component.
LOE_m	Loss of energy at the load point *m*.
$LAIDI_{m,des.}$	Desired value of the LAIDI index.
$LAIDI^{2}_{m,i}$	LAIDI index for the load point *m* in the 2nd scenario on the i^{th} critical component.
$LAIFI_{m,des.}$	Desired value of the LAIFI index.
$LAIFI^{2}_{m,i}$	SAIFI index for the load point *m* in the 2nd scenario on the i^{th} critical component.
U_i^1	Un-served energy associated with the i^{th} component in the first scenario.
U_i^2	Un-served energy associated with the i^{th} component in the 2nd scenario.
U_m^1	Un-served energy index associated with the load point *m* in the first scenario.
U_m^2	Un-served energy index associated with the load point *m* in the 2nd scenario.
$\lambda_i^{new}, \lambda_i^2$	Possible minimum failure rate of component *i* in the second scenario.
$\lambda_i^{now}, \lambda_i^1$	Failure rate of component *i* when it is in the first scenario.
λ_m^1	Failure rate index associated with the load point *m* in the first scenario.
λ_m^2	Failure rate index associated with the load point *m* in the 2nd scenario.

Parameters

L_{a_i}	Average load of the i^{th} load point.
N_i	Total number of customers in i^{th} load point.
r_i^1	Repair time associated with the i^{th} component in the first scenario.
r_i^2	Repair time associated with the i^{th} component in the 2nd scenario.
r_m^1	Repair time index associated with the load point *m* in the first scenario.
r_m^2	Repair time index associated with the load point *m* in the 2nd scenario.
α	The importance factor of LAIFI.
β	The importance factor of LAIDI.
γ	The importance factor of EENS.
μ	A conservatively defined coefficient of critical component determination process.

Sets

J	Set of components within the boundary.
K	Set of critical components under study.
N	Set of load points within the boundary.

Abbreviations

CF	Criticality factor.
COMP	Component.
EENS	Expected energy not supplied.
LP	Load point.
RCM	Reliability centered maintenance.
LAIDI	Load point average interruption duration index.
LAIFI	Load point average interruption frequency index.

The authors are all with the Center of Excellence in Power System Management and Control, Sharif University of Technology, Tehran, Iran. (e-mails: payman.dehghanian@ieee.org; fotuhi@sharif.edu).

I. Introduction

RELIABILITY has been so far regarded as an incontrovertible concern in the power system operation, management and control. The reason is due to the drivers such as globalization and increased deregulation together with the technological changes which have forced many distribution utilities world-wide to provide the customers with the reliable and high quality electricity as cost-effective as possible. This has forced the distribution utilities to reconsider how they conduct their business and specifically their maintenance plans, at the point of focuses in this paper [1]-[3].

It falls within the realm of reliability centered maintenance (RCM) to deal with the indispensable balance between reliability requirements and maintenance costs. RCM places a strong emphasis rather on the system function continuation vs. the traditional maintenance approaches that were on the basis of equipment and subcomponents preservation. In this respect, the maintenance personnel are instructed to concentrate on some critical components of significant contribution to the operation of the distribution system [1]. As a result, the resources are not getting distracted by maintenance activities of neither only marginal benefit to the organization nor negligible effects on the system performance. Such components are so called non-critical. Consequently, RCM results in a tight association between the component function, maintenance cost, and the customer expectation and the consequence worth [1], [4].

The number of researches on power system components' maintenance has seen a tremendous growth since the maintenance participation in the total operation costs and benefits in power system has been substantially confirmed [2]-[5]. RCM has been placed under execution on some special types of components in some papers [6]-[9]. Nevertheless, none has put considerable effort to find the most critical components, individually in a distribution network, regarding them in a whole system and with different aging conditions and accordingly various failure rates.

The proposed algorithm in this paper, takes the reliability targets as its inputs and sheds lights on the RCM process in such a way that it would be able to comply with the desired technical and economical goals. This is done via the identification of some critical components in the network. In this response, the rest of the paper is organized as follows. The crucial concept of the RCM process is first introduced in Section II, where some technical challenges and necessary considerations are discussed. The proposed methodology on critical component identification, as the first and fundamental step of the RCM process, is pursued in Section III. Section IV demonstrates the paper case study and Section V summarizes the concluding remarks.

II. Reliability Centered Maintenance Framework

RCM has been generally reported to be composed of the following main steps [10]-[12]:

- **Step 1:** System's/components' data and information preparation for both technical and economic studies.
- **Step 2:** Outlining the desired perspectives from both technical and economical viewpoints.
- **Step 3:** Identifying system most critical components from a reliability point of view.
- **Step 4:** Failure mode/cause analysis.
- **Step 5:** Maintenance strategy allocation in response to the critical failure causes.
- **Step 6:** Performing the common cost/worth analysis on the maintenance strategies to be applied on the most critical components.

The utility's desired perspective is born from the system reliability point of view. The process is done via determining some favorable values of reliability indices associated with the under studied load points of the power distribution system. Some common reliability indices, e.g., outage duration, outage frequency, and energy not served, can be selected as the point of focuses. The targets must be determined such that their possibility of being reached would be principally feasible. Otherwise, it possibly leads to some overestimations or underestimations in the maintenance scheduling and system reinforcing policies.

III. Critical Component Identification

Nowadays strategically-oriented maintenance policies never admire the indiscriminate looking to the numerous distribution network components regardless of their participation to the overall reliability indices [13]. It has been assigned twice importance since the economical drivers put some financial constraints to do this. Some recent efforts have been devoted to the critical component identification in reliability centered maintenance of power distribution systems. In [14], a component reliability importance index is presented based on its contribution in total interruption costs over a specific time interval. But the need for the acquisition of the information about the value of lost load for different type of customers has put the index under a rigorous limitation. Practically approached, reference [15] did a great deal in this context. The exploited method is based on the analytical hierarchical process (AHP) which can easily get through the qualitative aspects as well as the quantitative ones interrelated with the decision making process. Besides, fuzzy sets theory is incorporated in the process of critical component determination to overcome some insufficiently precise data, descriptive language, uncertain knowledge and experts inaccurate judgments and subjective comparisons [16]. References [15], [16], however, are suggested to be involved more in the resource allocation decision makings.

In this paper, each system component is considered to be in two different scenarios; in the first scenario, all the system components are assumed to be in their operational states. In this scenario, the mean value of failure rate in the useful lifespan ($\lambda = \lambda_{ave}$) is assigned to the components. It holds as the system base case condition. The other scenario associates with the case where each under-focused component is assumed as to be in brand new, while all the other system components are at their operational states. This sets the under-focused component's failure rate equal to that of the new one ($\lambda_{new}=\lambda_{min}$), and leads to all the other components possess the failure rates equal to the average in their useful lifetimes ($\lambda=\lambda_{ave}$). As can be easily inferred, the first scenario has to be framed once while the latter needs to be constructed as much time as the number of system components. Putting the first scenario under experience, following the above-mentioned instructions, and benefiting from equations (1)-(3), the reliability indices of the studied load point, which reasonably has to be the most important load point form the utility's point of view, can be achieved.

$$\lambda_{LP}=\sum_{i=1}^{n}\lambda_i \quad \lambda_m^1 \quad \text{LAIFI} \tag{1}$$

$$U_{LP}=\sum_{i=1}^{n}\lambda_i r_i \quad U_m^1 \quad \text{LAIDI} \tag{2}$$

$$r_{LP}=U_{LP}/\lambda_{LP}=r_m^1 \tag{3}$$

Putting the second scenario into execution, and performing a same procedure for each component, the load point reliability indices would be achieved. Having obtained these indices, the contribution of each component in the reliability indices are assessed through (4)-(6).

$$\Delta\text{LAIFI}_{m,i}=\text{LAIFI}_{m,base}-\text{LAIFI}_{m,i}^2 \tag{4}$$

$$\Delta\text{LAIDI}_{m,i}=\text{LAIDI}_{m,base}-\text{LAIDI}_{m,i}^2 \tag{5}$$

$$\Delta\text{EENS}_{m,i}=\text{EENS}_{m,base}-\text{EENS}_{m,i}^2 \tag{6}$$

An effective weighted combination of the above-introduced reliability indices is then set to be the criticality factor by which components' criticality in reliability would be identified. This factor is introduced as follows.

$$CF_{m,i}=\alpha\frac{\Delta\text{LAIFI}_{m,i}}{\text{LAIDI}_m^1}+\beta\frac{\Delta\text{LAIDI}_{m,i}}{\text{LAIDI}_m^1}+\gamma\frac{\Delta\text{EENS}_{m,i}}{\text{EENS}_m^1} \tag{7}$$

The survived point is that coefficients α, β, and γ are set by the distribution utility itself as the weighting factors reflecting the importance of reliability indices. The criticality factors are consequently prioritized in descending order of importance. The higher criticality factors are attributed to the most critical components of the distribution system. The process can be followed step by step in Fig. 1.

The next is to find the essential number of the achieved critical components to be taken into consideration in the RCM process. In response, the cumulative criticality factor associated with each component is proposed to be calculated, as shown in Table I. To this end, a satisfaction level is considered to judge about the total number of components that has the criticality above the threshold, i.e. $CF_{m,des}$. The level of satisfaction holds to be the criticality factor associated with the case where the reliability indices of LAIFI_i, LAIDI_i, and EENS_i are all equal to their desired values which have been decided before ($\text{LAIFI}^m_{des.}$, $\text{LAIDI}^m_{des.}$, $\text{EENS}^m_{des.}$). As soon as the constraint introduced in (8) is satisfied, the number of critical components would be found.

$$CF'_{m,i}\geq\mu\ CF_{m,des.} \qquad \mu>1 \tag{8}$$

TABLE I
CRITICAL COMPONENT IDENTIFICATION IN THE TEST SYSTEM

System Components	Criticality Factor	Cumulative Criticality Factor
COMP.1	$CF_{m,1}$	$CF'_{m,1}=CF_{m,n}+\ldots+CF_{m,3}+CF_{m,2}+CF_{m,1}$
COMP.2	$CF_{m,2}$	$CF'_{m,2}=CF_{m,n}+\ldots+CF_{m,4}+CF_{m,3}+CF_{m,2}$
COMP.3	$CF_{m,3}$	$CF'_{m,3}=CF_{m,n}+CF_{m,n-1}+\ldots+CF_{m,4}+CF_{m,3}$
COMP.4	$CF_{m,4}$	$CF'_{m,4}=CF_{m,n}+CF_{m,n-1}+\ldots+CF_{m,4}$
.	.	.
.	.	.
.	.	$CF'_{m,n-1}=CF_{m,n}+CF_{m,n-1}$
COMP.n	$CF_{m,n}$	$CF'_{m,n}=CF_{m,n}$

The noteworthy is that the coefficient μ is adjusted in response to the fact that the variation in system reliability indices is not necessarily in a linear relationship with the corresponding variation in the component failure rates. The value of this satisfaction index (μ) could be determined on the basis of a utility's knowledge and awareness of the constituent components. Fig. 2 traces the above-scrutinized path toward finding the most critical components of a power distribution system.

IV. AN ILLUSTRATIVE STUDY

A. System Description

The proposed algorithm has been applied to a real distribution system, i.e., the Birka Nat distribution system, in the Sweden and provides about 450,000 customers with electrical power. It is delineated in Fig. 3.

The network customers are represented via two 33-kV load points, i.e. Hogalid station (HD) and Statens Jarnvagar railway line (SJ), and one 11-kV load point, referred to as Liljeholmen station (LH11). LH11 serves a total of 14,300 customers. The load point HD provides a total of 23,400 customers and meanwhile, the load point SJ supplies a railway as its sole customer [10].

LH11 seems to be the most important load point of the at hand network since it shows a fair spread for different types of customers. On the contrary, HD is dominated by residential customers and SJ is the sole responsible for a commercial customer i.e. the railway. Hence, the RCM process has to be conducted on the system most important load point. As a result, the proposed RCM scheduling procedure is guided in such a way that can effectively improve the LH11 reliability indices. The same procedure has to be experienced on the other system load points and in accordance with their importance priorities in the utility's perspective, too.

B. System Reliability Goals/Targets Determination

As an assumption, it is considered that the Birka Nat utility has determined some pre-set reliability based targets, hoped to be met through reinforcement policies, operational schemes, and maintenance process. The utility reliability centered perspectives are as specified in Table II. These reliability indices are determined by the utility's experts and experienced managers possessing a considerable insight into to the system past performance and the utility's available financial resources [10].

C. Critical Component Identification

The proposed analytical approach on the criticality evaluation of the system components is followed through their contribution assessment on the load point reliability indices. To this end, and starting from the first component, C14, which is a 33 kV bus bar, the reliability analysis is done as shown in Tables III and IV. These two tables are completed regarding the under-focusing component respectively in the first scenario (as well as the others in their operational conditions) and in the second scenario (as

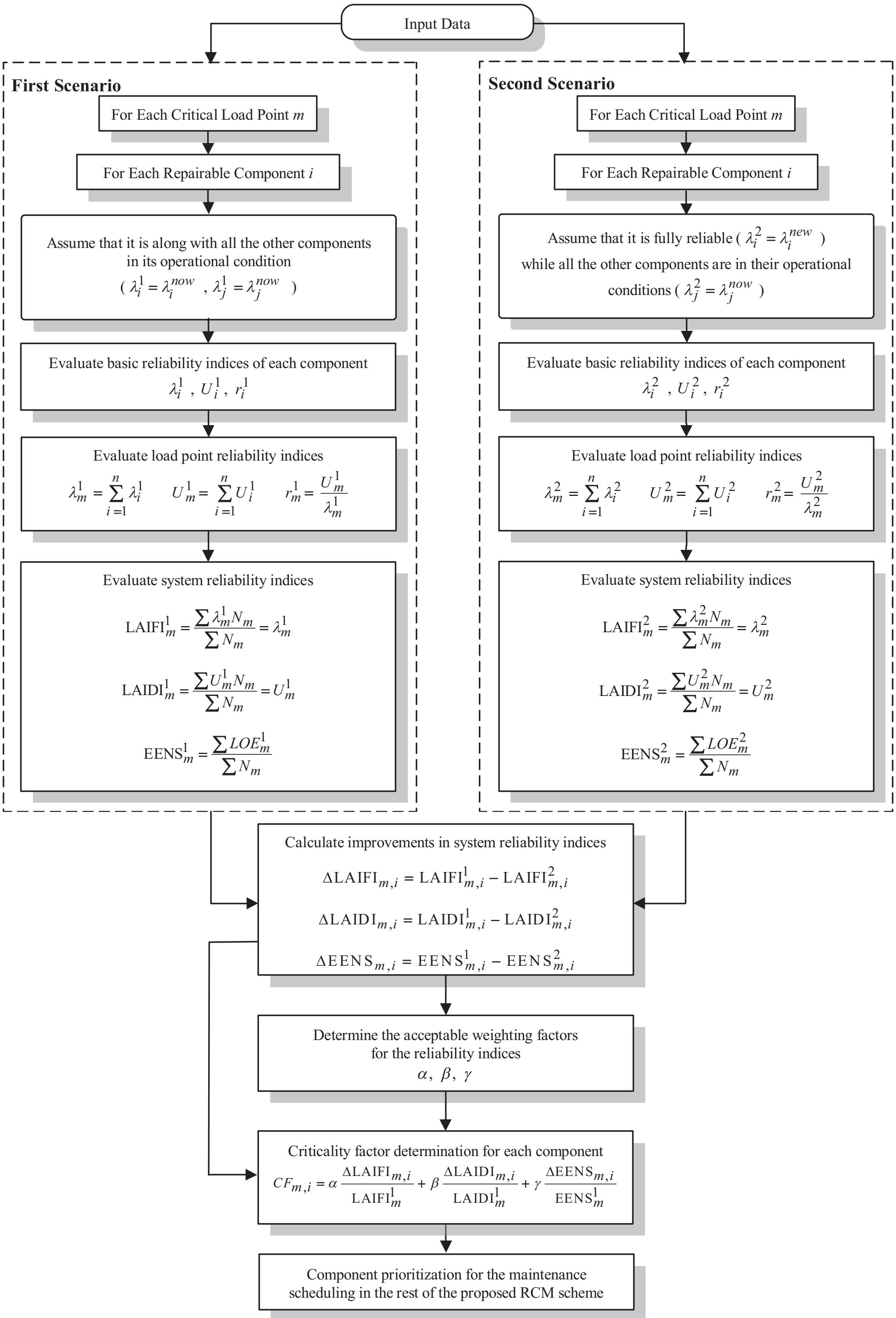

Fig. 1. Critical component identification process.

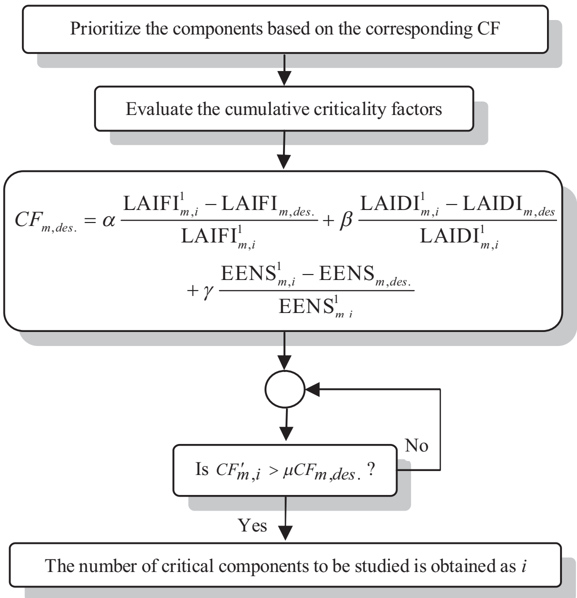

Fig. 2. Process of determining the number of critical components to be employed in RCM analysis.

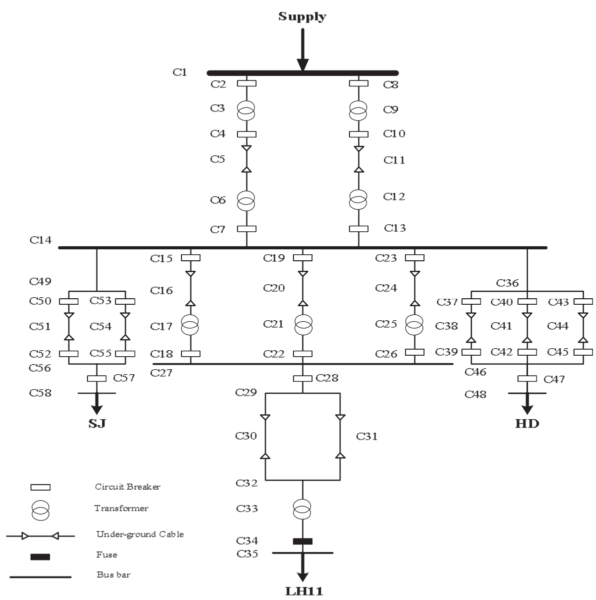

Fig. 3. The Birka distribution system of Stockholm City conducted as the paper case study [10].

good as new). The former is required to be calculated once since it belongs to the case where all the components are in their operational conditions and so is remained unchanged through the scenarios. Having found the load point indices for the criticality assessment of C14, Table V would be framed and the component contribution to the load point indices could be reached. It is noteworthy that the average load of the LH11 load point is assumed to be 28 MW and the total number of its customers is set as 14200 [10].

It is also supposed that the required coefficients of α, β, and γ for calculating the corresponding criticality factor is predetermined by the utility itself respectively as 2, 4, and 4. The criticality factor could be achieved as 0.0035. A similar procedure has to be conducted for the other system components. Hence, the obtained results prioritized based on the components criticality factors are presented as shown in Table VII. As a result, the system critical components are recognized and so can the maintenance process concentrated on them. As can be easily traced, transformer C33, as well as the cables C30 and C31, and breaker C28 are the most critical components of the at hand system.

Now, a question arises which concerns the fact that how many of the identified critical components are of considerable impacts on the system reliability. In this respect, the cumulative criticality factors associated with the system components are proposed to be evaluated as presented in Table VII. As soon as the satisfaction constraint is met, the favorable number of critical components would be then reached. The satisfactory constraint is set to be the desired criticality factor assigned to a system condition in which the utility's reliability targets and perspectives have been all met. Table VIII addresses the desired reliability indices and consequently the desired criticality factor as the qualification criterion of the critical component identification process.

TABLE II
THE RELIABILITY INDICES AS THE UTILITY PERSPECTIVE TO BE MET THROUGH THE MAINTENANCE SCHEME

Reliability Indices	**$\text{LAIFI}_{\text{LH11,des.}}$ (int. /yr.)**	**$\text{LAIDI}_{\text{LH11,des.}}$ (hr. /yr.)**	**$\text{EENS}_{\text{LH11,des.}}$ (kWh. /yr. cust.)**
Target Value	0.85	4.7	9.5

TABLE III
LOAD POINT RELIABILITY INDICES FOR C14 IN THE FIRST SCENARIO

Load Point LH11			
Components	λ	r	u
C14	0.002	1	0.002
C_{eq1} (C15-C26)	0.230	2.79	0.641
C27	0.002	1	0.002
C28	0.140	2	0.28
C_{eq2} (C30-C31)	0.990	12	1.189
C33	0.420	6.5	2.730
C34	0.130	3	0.390
C35	0.010	1	0.010
Load Point Reliability Indices	1.033	5.075	5.240

TABLE IV
LOAD POINT RELIABILITY INDICES FOR C14 IN THE SECOND SCENARIO

Load Point LH11			
Components	λ	r	u
C14	0.001	1	0.001
C_{eq1} (C15-C26)	0.230	2.79	0.641
C27	0.002	1	0.002
C28	0.140	2	0.28
C_{eq2} (C30-C31)	0.990	12	1.187
C33	0.420	6.5	2.730
C34	0.130	3	0.390
C35	0.010	1	0.010
Load Point Reliability Indices	1.032	5.079	5.240

TABLE V
LOAD POINT RELIABILITY INDICES IN BOTH SCENARIOS

	$\text{LAIFI}_{\text{LH11,base}}$ (occ. /yr.)	**$\text{LAIDI}_{\text{LH11,base}}$ (hr. /yr.)**	**$\text{EENS}_{\text{LH11,base}}$ (kWh. /yr. cust.)**
1st Scenario	1.03307	5.24319	10.3387
2nd Scenario	1.03207	5.24219	10.33672

TABLE VI
C14 CONTRIBUTION IN THE LH11 LOAD POINT RELIABILITY INDICES

$\Delta\text{LAIFI}_{\text{LH11,C14}}$ (occ. /yr.)	**$\Delta\text{LAIDI}_{\text{LH11,C14}}$ (hr. /yr.)**	**$\Delta\text{EENS}_{\text{LH11,C14}}$ (kWh. /yr. cust.)**
0.001	0.001	0.002

TABLE VII
CRITICALITY ASSESSMENT OF THE SYSTEM COMPONENTS WITH RESPECT TO THE LOAD POINT LH11

System Components	LAIFI	LAIDI	EENS	Criticality Factor	Cumulative Criticality Factor
C33	0.963	4.788	9.44	0.830	2.639
C30	1.012	4.99	9.836	0.430	1.809
C31	1.012	4.99	9.836	0.430	1.379
C28	0.963	5.103	10.06	0.349	0.949
C34	0.993	5.120	10.10	0.260	0.600
C18	1.025	5.220	10.29	0.052	0.339
C22	1.025	5.220	10.29	0.052	0.288
C26	1.025	5.220	10.29	0.052	0.236
C15	1.026	5.220	10.30	0.044	0.185
C19	1.026	5.220	10.30	0.044	0.141
C23	1.026	5.220	10.30	0.044	0.097
C17	1.031	5.240	10.33	0.014	0.053
C21	1.031	5.237	10.33	0.014	0.039
C25	1.031	5.240	10.33	0.014	0.025
C14	1.032	5.240	10.34	0.0035	0.011
C27	1.032	5.242	10.34	0.0035	0.0073
C35	1.032	5.240	10.34	0.0034	0.0038
C16	1.033	5.240	10.34	0.00013	0.00039
C20	1.033	5.240	10.34	0.00013	0.00026
C24	1.033	5.240	10.34	0.00013	0.00013

TABLE VIII
DESIRED CRITICALITY FACTOR AS THE QUALIFICATION CRITERION FOR THE CRITICAL COMPONENTS SPECIFICATION

Reliability Indices	LAIFI (occ. /yr.)	LAIDI (hr. /yr.)	EENS (kWh. /yr. cust.)	$CF_{LH11,des}$
Base-Case	1.033	5.243	10.339	1.093
Desired-Case	0.85	4.7	9.5	

According to the proposed inequality constraint and assuming the μ coefficient to be defined as 1.2 via the utility experts and in accordance with their knowledge and experiences, the constraint would be embodied as introduced in the following.

$$CF'_{LH11,i} \geq 1.2\ CF_{LH11,des.} = 1.312$$

As can be seen, the first three components are selected as the system critical components to be further scrutinized.

The noteworthy is that the components of less assigned criticality in the proposed analysis in accordance with a specific load point may be the most critical for the other load points of currently less importance. So, maybe they will be devoted more maintenance consideration in the associated analysis concerning those load points.

V. CONCLUSION

In this paper, some useful discussions were first conducted on the determination of the target reliability indices as the benchmarking values in distribution utilities. RCM, as a means of reaching a desired level of reliability, was under discussion in this paper. Having scrutinized the proposed algorithm to find the most critical components of a distribution system, as the first and essential step of RCM, reliability was, thus, incorporated in the maintenance process. As a result, the components priorities to be managed through RCM were found. The proposed method was applied to the Stockholm city distribution test system, i.e. the BIRKA system, and proved its straightforward path by then. The most critical components of the test system were identified as a transformer and two underground cables. These critical components can be accordingly put under the rest of RCM process. The proposed method would mainly help the distribution asset managers to get the most of the RCM scheme.

REFERENCES

[1] J. Moubray. *Reliability-centered Maintenance*. Butterworth-Heinemann, Oxford, 1991. Reprint 1995.

[2] F. Yong, *et.al.*, "Security-Constrained Optimal Coordination of Generation and Transmission Maintenance Outage Scheduling," *IEEE Trans. Power Syst.*, vol.22, no.3, pp.1302-1313, Aug. 2007.

[3] A. J. Conejo, R. Garcia-Bertrand, and M. Diaz-Salazar, "Generation maintenance scheduling in restructured power systems," *IEEE Trans. on Power Syst.*, vol. 20, no. 2, pp. 984- 992, May 2005.

[4] A. M. Smith and G. R. Hinchcliffe, *RCM—Gateway to World Class Maintenance*, Butterworth-Heinemann, Oxford, 2004.

[5] W. Li and J. Korczynski, "A reliability-based approach to transmission maintenance planning and its application in BC hydro" *IEEE Trans. Power Del.,* vol. 19, no. 1, pp. 303- 308, Jan. 2004.

[6] Z. Xiang, *et.al.*, "Reliability centered asset management for MV deteriorating electrical equipment based on Germany failure statistics," *IEEE Trans. Power Syst.*, vol. 24, no. 2, pp. 721-728, 2009.

[7] D. W. Holladay, B. D. Dallman, and C. H. Grigg, "Reliability centered maintenance study on voltage regulators," 11*th Int. Conf. on Transm. & Dist. Const., Oper., and Live-Line Maint., ESMO 2006*, Oct. 2006.

[8] C. Ting, L. Chen-Ching, and C. Jong-Woong, "Implementation of reliability-centered maintenance for circuit breakers," *IEEE Power Eng. Soc. General Meeting,* vol. 1, pp. 684- 690, 12-16 June 2005.

[9] S. Costa, A. F. Brandao, "Optimization of the maintenance of oil- filled power transformers based on reliability criteria," *IEEE Transm. Dist. Conf. and Exp.: Latin America,* pp. 297- 301, 8-11 Nov. 2004.

[10] L. Bertling, "Reliability centered maintenance for electric power distribution systems," Doctoral dissertation, Sch. Elect. Eng., KTH, Stockholm, Sweden, 2002.

[11] W. Reder and D. Flaten, "Reliability centered maintenance for distribution underground systems," *IEEE Power Eng. Soc. Summer Meeting,* vol. 1, pp. 551-556, 2000.

[12] P. Dehghanian, *et.al.*, "Incorporating Probabilistic Cost/Worth Analysis in Maintenance Prioritization of Power Distribution Components," *12th Int. Conf. on Probabilistic Methods Applied in Power Syst., PMAPS2012, Istanbul, Turkey, 2012*.

[13] P. Dehghanian, *et.al.*, "A comprehensive scheme for reliability centered maintenance in power distribution systems-Part I: Methodology," *IEEE Trans. Power Del.*, 2012, to be published.

[14] P. Hilber, *et.al.*, "Multi-objective optimization applied to maintenance policy for electrical networks," *IEEE Trans. on Power Syst.*, vol.22, no.4, pp.1675-1682, Nov. 2007.

[15] P. Dehghanian, *et.al.,* "An approach on critical component identification in reliability centered maintenance of power distribution systems based on analytical hierarchical process (AHP)," *21th Int. Conf. and Exh. on Elec. Dist., CIRED2011,* Germany, June.2011.

[16] P. Dehghanian, *et.al.,* "Critical component identification in reliability centered asset management of distribution power systems via fuzzy AHP," *IEEE Systems Journal*, in Press, 2012.

BIOGRAPHY

Payman Dehghanian (S'11) received the B.Sc. and M.S. degrees both in Electrical Engineering respectively from University of Tehran, Tehran, Iran, in 2009, and Sharif University of Technology, Tehran, Iran, in 2011. He is also a member of IEEE Power and Energy Society (PES) since 2012. His research interests include power system reliability, reliability centered maintenance, and asset management.

Mahmud Fotuhi-Firuzabad (SM'99) is presently a professor and Head of the Electrical Engineering Department at Sharif University of Technology, Tehran, Iran. Dr. Fotuhi-Firuzabad is a member of center of excellence in power system management control. He serves as the Editor of the IEEE TRANSACTIONS ON SMART GRID and as the Guest Editor-in-chief of a Special Issue (Microgrids) of the IEEE TRANSACTIONS ON SMART GRID. He is also an Honorary Professor in the Universiti Teknologi Mara (UiTM), Shah Alam, Malaysia.