Performance Evaluation of Power System Network By Minimal Path Set Approach

Conference Paper · December 2017

Ramanjan Prasad Repana
Vignan Institute of Technology & Science

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Special Issue 1, December 2017)

Performance Evaluation of Power System Network By Minimal Path Set Approach

[1]T.Rama Subba Reddy, [2]G.Durgasukumar and [3]R.Ramanjan Prasad

[123]*Electrical Engineering Department, VITS, Desumukhi, Hyderabad*

Abstract— Power system is a combination of elements which are arranged in a particular fashion. Performance of the system is indicated by its reliability which is the ability of performing its intended function. This paper proposes the minimal path set approach, which is a simple and straight forward. A simple algorithm is developed for the generation of the minimal path sets, in a monotonically increasing order of cardinality. However, as the number of minimal path sets increases the terms to be evaluated increases rapidly. Due to this the computational effort rounding off and truncation errors increases. So, to determine the 'exact' reliability of a system, in this algorithm the minimal paths which give required reliability are determined. When the desired reliability is achieved, the algorithm terminates when the minimal pathsets of higher cardinality is obtained, with a considerable saving in the computational effort. The reliability of a two power systems models that consists of 5 bus and 8 bus power systems networks is presented in this paper.

Keywords- Reliability, minimal pathset, minimal cutest, RLG, MNV, NV

I. INTRODUCTION

There are several algorithms reported in the literature for the generation of the minimal pathsets [2,7,11,14,18, and 20]. Some algorithms generate the minimal path sets in terms of the labels of the elements, where as some algorithms generate the minimal pathsets in terms of the nodes of the RLG. Substituting the numerical values of the component reliabilities, the numerical value of the system reliability can be obtained. Algorithms such as [9, 18] generate the minimal pathsets in the ascending order of cardinality. It is preferable to obtain the minimal pathsets in a monotonically increasing order of cardinality. Many algorithms such as [1,19,20] prefer to order the nodes of the RLG in a particular manner, viz., source node is labeled 1 and the sink node is labeled N, the number of nodes. A majority of the algorithms generate the minimal pathsets from a given node (source node) to another specified node (sink node), i.e., between a specified node pair. A few algorithms like [17] generate the minimal pathsets and the minimal cutsets simultaneously. the cutest approach is superior computationally to the pathset approach, yet, the generation of the minimal cut sets is not as simple as the generation of the minimal pathsets. The salient features of the proposed method are: i) a simple search is used ii) the minimal paths are generated in a monotonically increasing order of cardinality between the node pair: source node, s, and the sink node,t, in terms of the nodes. iii) the ordering of the nodes is arbitrary. iv) the elements may be directed or undirected, except those emanating from the source node and those terminating on the sink node. In this paper simple algorithm to obtain the node vectors and the minimal path node vectors in a monotonically increasing order of cardinality is presented. While the maximum cardinality of a minimal pathset is one less than the number of nodes, the maximum number of elements (nodes) in the minimal path node vector may be equal to the number of nodes.

II. PROPOSED METHOD

In the graph theoretic sense, a minimal pathset is defined as the set of elements, the success of which ensures the success of the system, contributing to the overall reliability of the system. The minimal pathsets are those which establish the connectivity between the source and the sink-nodes of the Reliability Logic Graph (RLG). If the nodes encountered from the source node to the sink node are taken in order we obtain the minimal path node vectors, MNV's. As already discussed, examination of the MNV's reveals that the first element is the source node and the last element is the sink node, with the node in the k^{th} column(k = 2,3,…,) having connectivity with the nodes in the (k-1) and (k+1) columns. Each minimal pathset is defined by a unique row vector, with no node occurring more than once. This idea is made use of to obtain the MNV's corresponding to the minimal pathsets in a monotonically increasing order of cardinality. The procedure can be summarized as follows:

Initially, we generate a node vector NV, of nodes, the first element being the source node and the second element the sink node. Then, we examine whether there is a direct connection between the source nodes and sink node, from the connection matrix. If there were to be a connection, a minimal path of cardinally one is generated and is listed in the set of the minimal path node vectors (however, it is rather rare). On the other hand, if there were to be no direct connection between the source and the sink nodes, the sink node is moved to the n^{th} column (n = 3,4….,N), leaving the $(n-1)^{th}$

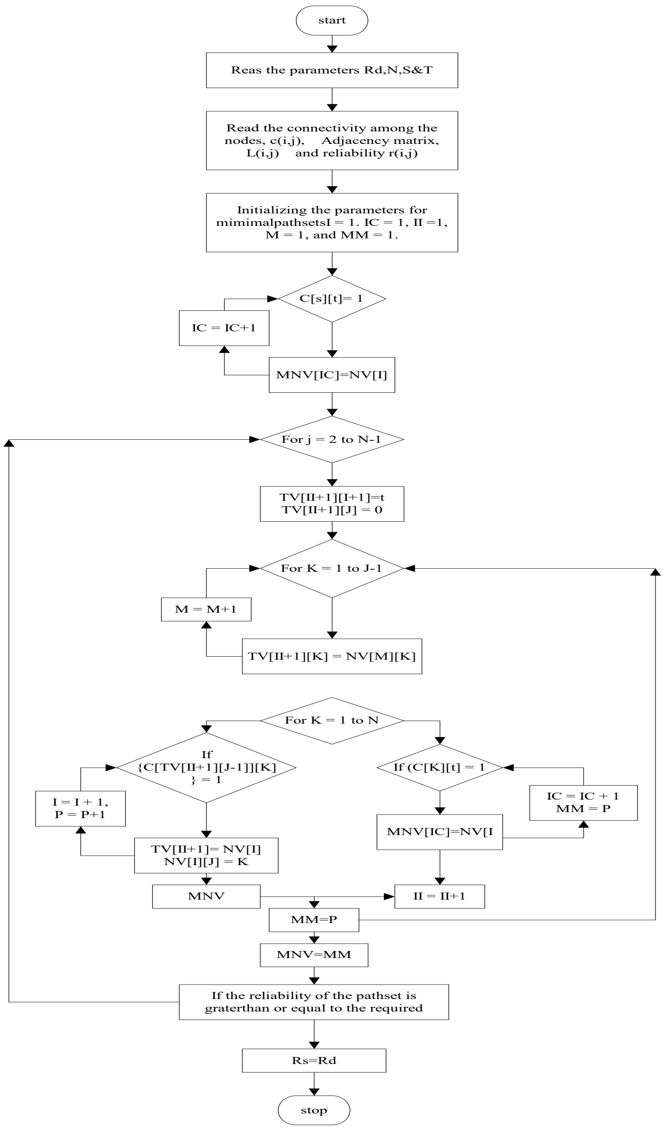

Fig .1 Flow chart

column blank, to be filled by the nodes to which the node in the $(n-2)^{nd}$ column is connected, provided that the node had not already occurred. If there were to be connection between the node that is currently entered in the $(n-1)^{th}$ column and the sink node, a minimal path vector is generated, else, this vector is retained for further consideration. If the sink node is moved to the k^{th} column, all the node vectors with the sink node in the $(k – 1)^{th}$ column are expanded as per the procedure explained. The process is repeated till all the vectors having the sink node as the $(N-1)^{th}$ element are considered. Once these minimal path vectors are obtained, the minimal pathsets can be obtained by replacing the consecutive node pairs starting with the source node and ending with the sink node, by the element connected between the node-pair. The flow chart of the proposed method is as shown in fig.1

III. IMPLEMENTATION

First a node vector NV(1) is generated with the first element as the source node. It is examined, if there is connectivity between the source node and the sink node. If there were to be a connection, a minimal path is generated in terms of the nodes. Since there is no direct connection with the sink node, second column is filled by the node which is connected to the source node. Thus NV(1) is expanded as NV(2) = [1 2]. The current node 2 is connected to the sink node, i.e., node 4. So, it gives rise to the minimal path node vector MNV(1)= [1 2 4], which is translated as the minimal path {A B}. In a similar way NV(3) is generated as [1 3], which gives rise to the minimal path node vector, MNV(2)=[1 3 4], which is translated as the minimal path {D E}. These are the two minimal paths of cardinality two.

Now, we expand NV (2) as NV(4) = [1 2 3]. Since there is a connectivity between the current node 3 and the sink node 4, the minimal path node vector MNV(3)= [1 2 3 4], which is translated as the minimal path {A C E} is generated. Similarly, NV(3) is expanded as NV(5) = [1 3 2], which gives rise to the minimal path node vector MNV (4) = [1 3 2 4] or equivalently the minimal path {DCB}. Since the number of elements in each of the Node vectors is equal to 4, which is the number of total number of nodes, no more expansion is possible and all the minimal pathsets are generated.

Model.1: To demonstrate the applicability of the algorithm, two power system networks with 5 buses and 8 buses is shown in figs 2 and 4 are considered. The corresponding RLG of these systems are shown in fig 3 and 5.The component reliabilities are assumed arbitrarily as shown in RLG's.An 8-node, 12-element network shown in Fig.2 is considered. Seven cases are considered. 5 nodes and 7 links in which node 3 as source node and node 5 as sink node as shown in fig.2 and line diagram as shown in fig.3.

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Special Issue 1, December 2017)

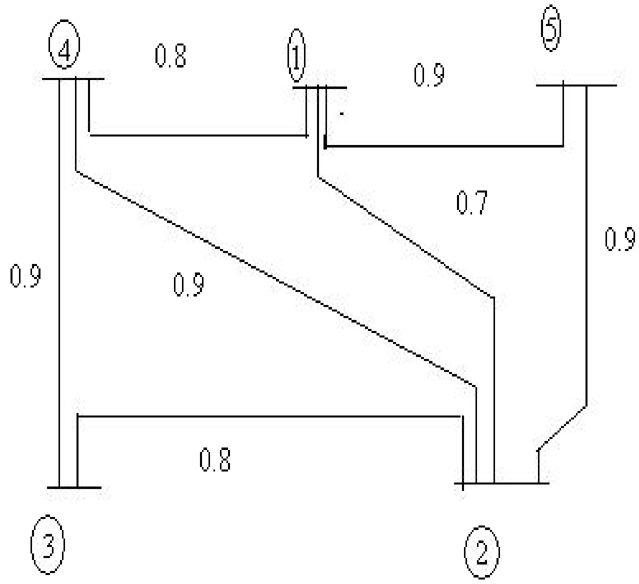

Fig.2 Five bus power system model

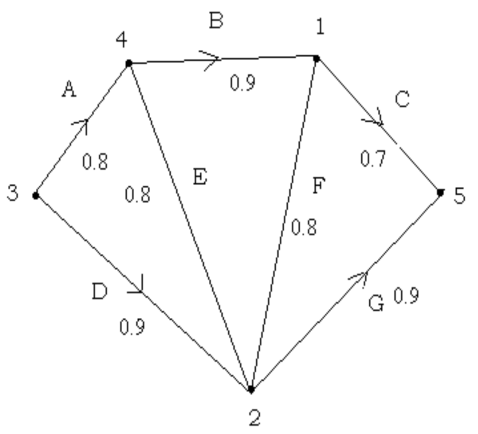

Fig.3 Line diagram

the step by step implementation of the above algorithm let us consider the 5-node,7-element RLG shown in Fig.3

Step.1: R_d = 0.99 (it will be shown that, this reliability cannot be achieved even by considering all the minimal pathsets)

Step.2: N = 5

Step.3: s = 3, t = 5

Connection matrix (To → 1 2 3 4 5; From ↓ 1–5):

$$C = \begin{bmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 & 1 \\ 0 & 1 & 0 & 1 & 0 \\ 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Step.4:

Adjacency matrix (To → 1 2 3 4 5; From ↓ 1–5):

$$L = \begin{bmatrix} 0 & F & 0 & 0 & C \\ F & 0 & 0 & E & G \\ 0 & D & 0 & A & 0 \\ B & E & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Reliability matrix (To → 1 2 3 4 5; From ↓ 1–5):

$$R = \begin{bmatrix} 0 & 0.7 & 0 & 0 & 0.9 \\ 0.7 & 0 & 0 & 0.9 & 0.9 \\ 0 & 0.8 & 0 & 0.9 & 0 \\ 0.8 & 0.9 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Step 5: MNV (1) = [3 2 5]
Step 6: Minimal pathset = {D G}
Step 7: Reliability of the minimal pathset = 0.81
Step 8: Reliability of the pathset < Rd. Set k ←- 2 and go to step 5.

The rest of the steps are summarized in Table .1

TABLE .1

Path no i	MNV(i)	Min pathset (i)	Rel of Min pathset (i)	Sys.rel up to and inclusive of minpath(i)
1	3 2 5	DG	0.81	0.81
2	3 2 1 5	DFC	0.504	0.8541
3	3 4 1 5	ABC	0.504	0.9181
4	3 4 2 5	AEG	0.576	0.9394
5	3 2 4 1 5	DEBC	0.4536	0.94214
6	3 4 1 2 5	ABFG	0.5184	0.94486
7	3 4 2 1 5	AEFC	0.3584	0.94517

Step 9. All the minimal pathsets = 7 are considered, but the required system reliability cannot be achieved. The generation of the various NV's and MNV's are as given below.

NV(1) = [3 2] -------→ MNV(1) = [3 2 5]-----→ {D G}
NV(2) = [3 4]
NV(3) = [3 2 1] --------→ MNV(2) = [3 2 1 5]---- {D F C}
NV(4) = [3 2 4]
NV(5) = [3 4 1] -----→ MNV(3) = [3 4 1 5]----→ {A B C}
NV(6) = [3 4 2] ---→ MNV(4) = [3 4 2 5]------→ {A E G}
NV(7) =[3 2 4 1] → MNV(5) = [3 2 4 1 5]→ {D E B C }
NV(8) = [3 4 1 2] ---→ MNV(6) = [3 4 1 2]------→ {A B F G}
NV(9) = [3 4 2 1] ---→ MNV(7) = [3 4 2 1 5]---→ {A C E F}

From Table 1, the following results are evident.

Desired reliability, R_d	Number of minimal pathsets considered	Approximate system reliability
0.85	2	0.8541
0.90	3	0.9181
0.93	4	0.9394
0.94	5	0.94214

Model 2: To demonstrate the applicability of the algorithm, an 8-node, 12-element network shown in Fig.4 is considered. Seven cases are considered. The reliability requirements are greater than 0.5, 0.6, 0.7, 0.75, 0.8 etc. The various results are summarized in the Table 2.

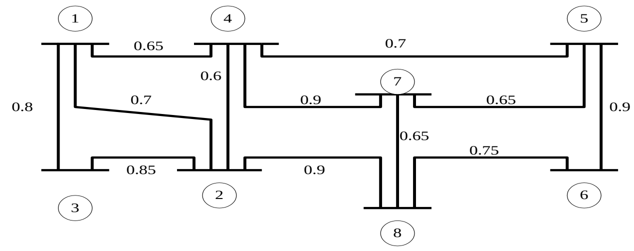

Fig.4. 8 bus power system model

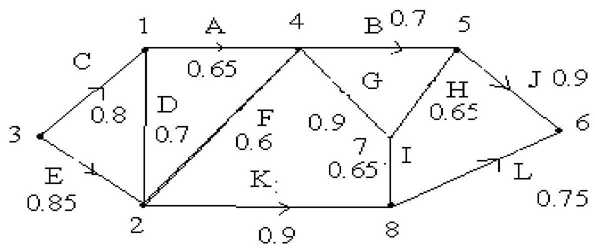

Fig .5 Line diagram of fig.4

Case(i): When the desired reliability is 0.55, (a trivial case), the various pathsets to be considered are as follows.

Path no i	MNV(i)	Min pathset(i)	Rel of Minpathset(i)	Sys.re upto minpath(i)
1	7 5 6 8	EKL	0.573750	0.573750

The number of pathsets to be considered is only 1 and the corresponding system reliability is 0.57375.

Case(ii): When the desired reliability is 0.6, the various pathsets to be considered are:

Path no i	MNV(i)	Min pathset(i)	Rel of Minpathset(i)	Sys.rel upto minpath(i)
1	7 5 6 8	EKL	0.573750	0.573750
2	7 1 2 3 8	CDKL	0.3780	0.630450

The number of pathsets to be considered is only 2 and the corresponding system reliability is 0.63045.

Case(iii): When the desired reliability is 0.7, the various pathsets to be considered are:

Path no i	MNV(i)	Min pathset(i)	Rel of Minpathset(i)	Sys.rel upto minpath(i)
1	7 5 6 8	EKL	0.573750	0.573750
2	7 1 2 3 8	CDKL	0.3780	0.630450
3	7 1 5 6 8	CABJ	0.32760	0.746871

The number of pathsets to be considered is only 3 and the corresponding system reliability is 0.748599

Case(iv): When the desired reliability is 0.75, the various pathsets to be considered are:

Path no i	MNV(i)	Min pathset(i)	Rel of Minpathset(i)	Sys.rel up to minpath(i)
1	7 5 6 8	EKL	0.573750	0.573750
2	7 1 2 3 8	CDKL	0.3780	0.630450
3	7 1 5 6 8	CABJ	0.32760	0.746871
4	7 5 2 3 8	EFBJ	0.32130	0.796994

IJETAE EXPLORING RESEARCH AND INNOVATIONS

International Journal of Emerging Technology and Advanced Engineering

Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Special Issue 1, December 2017)

The number of pathsets to be considered is only 4 and the corresponding system reliability is 0.796994.

Case(v): When the desired reliability is 0.8, the various pathsets to be considered are:

Path no i	MNV(i)	Min pathset(i)	Rel of Minpathset(i)	Sys.rel up to minpath(i)
1	7 5 6 8	EKL	0.573750	0.573750
2	7 1 2 3 8	CDKL	0.3780	0.630450
3	7 1 5 6 8	CABJ	0.32760	0.746871
4	7 5 2 3 8	EFBJ	0.32130	0.796994
5	7 1 2 4 3 8	CDFBJ	0.21168	0.800605

The number of pathsets to be considered is only 5 and the corresponding system reliability is 0.800605.

Case(vi): When the desired reliability is 0.85, the various pathsets to be considered are:

Path no i	MNV(i)	Min pathset(i)	Rel of Minpathset(i)	Sys.rel up to minpath(i)
1	7 5 6 8	EKL	0.573750	0.573750
2	7 1 2 3 8	CDKL	0.3780	0.630450
3	7 1 5 6 8	CABJ	0.32760	0.746871
4	7 5 2 3 8	EFBJ	0.32130	0.796994
5	7 1 2 4 3 8	CDFBJ	0.21168	0.800605
6	7 1 2 4 6 8	CAFKL	0.2106	0.804112
7	7 1 2 5 6 8	CAGHJ	0.293265	0.831803
8	7 1 5 2 3 8	CAGIL	0.22815	0.836960
9	7 5 1 2 3 8	EDABJ	0.243652	0.843295
10	7 5 2 4 3 8	EFGHJ	0.268515	0.855861

The number of pathsets to be considered is only 10 and the corresponding system reliability is 0.855861.

Case(vii): When the desired reliability is 0.9, the various pathsets to be considered are:

Path no i	MNV(i)	Min pathset(i)	Rel of Minpathset(i)	Sys.rel up to minpath(i)
1	7 5 6 8	EKL	0.573750	0.57375
2	7 1 2 3 8	CDKL	0.3780	0.63045
3	7 1 5 6 8	CABJ	0.32760	0.74687
4	7 5 2 3 8	EFBJ	0.32130	0.79699
5	7 1 2 4 3 8	CDFBJ	0.21168	0.80060
6	7 1 2 4 6 8	CAFKL	0.2106	0.80411
7	7 1 2 5 6 8	CAGHJ	0.273780	0.83180
8	7 1 5 2 3 8	CAGIL	0.22815	0.83696
9	7 5 1 2 3 8	EDABJ	0.243652	0.84329
10	7 5 2 4 3 8	EFGHJ	0.268515	0.85586
11	7 5 2 4 6 8	EFGIL	0.223762	0.85795
12	7 5 6 4 3 8	EKIHJ	0.290891	0.87182
13	7 1 2 3 4 6 8	CDFGHJ	0.176804	0.87272
14	7 1 5 2 4 3 8	CDFGIL	0.14742	0.87287
15	7 1 5 2 4 6 8	CDKIHJ	0.191646	0.87407
16	7 1 5 6 4 3 8	CABHIL	0.115342	0.87420
17	7 5 1 2 4 3 8	EDAGHJ	0.203624	0.87507
18	7 5 1 2 4 6 8	EDAGIL	0.169686	0.87534
19	7 5 2 3 4 6 8	EFBHIL	0.113124	0.8753
20	7 5 6 4 2 3 8	EKIGBJ	0.281940	0.87923
21	7 1 2 5 6 4 3 8	CDFBHIL	0.089434	0.87923
22	7 1 5 2 3 4 6 8	CDKIGBJ	0.185749	0.87958
23	7 1 5 6 4 2 3 8	CAFKIHJ	0.106774	0.87961
24	7 5 1 2 3 4 6 8	EDABHIL	0.085785	0.87962

All the 24 minimal pathsets are considered, but desired reliability cannot be achieved.

TABLE 2

S.NO	Rel. specification Rs≥	No. of pathsets considered	Achieved reliability
1	0.5	1	0.573750
2	0.6	2	0.630450
3	0.7	3	0.746871
4	0.75	4	0.796994
5	0.8	5	0.800605
6	0.85	10	0.855861
7	0.9	24	0.879623*

*Even though all the 24 minimal pathsets are considered, the desired reliability of 0.9 cannot be achieved. The maximum reliability obtainable is only 0.879623.

IV. CONCLUSION

An algorithm is presented for the generation of the minimal path sets in a monotonically increasing order of cardinality. It is a better algorithm for the generation of minimal path sets, cardinality wise by considering more number of path sets for a system. If the desired reliability is achieved, at any stage, the algorithm terminates without obtaining all the minimal path sets of higher cardinality, with a considerable saving in the computational effort. To validate the algorithm it is observed that the for five bus power system model is 0.94 by considering 7 minimal path sets and eight bus power system model is 0.879623 by considering 24 minimal path sets. The time taken for finding the reliability is less even though all the path sets are considered.

REFERENCES

[1] P.A. Jensen and M. Bellmore, "An algorithm to determine the reliability of a complex system", IEEE Trans. Reliab. R-18, No.4, pp.169-174 (Nov 1969).

[2] E. V. Krishna Murthy and G. Komissar, "Computer aided reliability analysis of Complicated networks", IEEE Trans. Reliab. R-21, No. 2, pp. 86-89 (May 1972).

[3] P.M. Lin, B.J. Leon and T.C. Haung, "A new algorithm for symbolic system reliability analysis", IEEE Trans. Reliab. R-25, No.1, pp. 2-15 (Apr 1976).

[4] P.M. Lin, B.J. Leon and T.C. Haung, "A new algorithm for symbolic system reliability analysis", IEEE Trans. Reliab. R-25, No.1, pp. 2-15 (Apr 1976).

[5] J.E. Biegel, "Determination of tiesets and cutsets for a system without feedback", IEEE Trans. Reliab. R-26, No.1, pp. 39-42 (Apr 1977).

[6] M.O. Lock, "Inverting and minimalizing pathsets and cutsets", IEEE Trans. Reliab. R-27, No.2, pp. 107-109 (June 1978).

[7] K.K. Aggarwal and Suresh Rai, "Symbolic reliability evaluation using logical signal relations", IEEE Trans. Reliab. R-27, No. 3, pp. 202-205 (Aug 1978).

[8] J.A. Abraham, "An improved algorithm for network reliability", IEEE Trans. Reliab. R-28, No.1, pp. 58-61 (Apr, 1979).

[9] R.B. Misra and K.B. Misra, "Enumeration of all simple paths in a communication network", icroelectron. Reliab. R-20, pp. 419-426(1980).

[10] G.L. Hwang, T.A. Tillman and M.H. Lee, "System reliability Evaluation techniques for complex/large systems- A review",IEEE Trans. Reliab. R-30, No.3, pp. 416-423(Dec 1981).

[11] G.S. Hura ,"Enumeration of success paths in a graph ", Microelectron. Reliab. Vol. 22, No.5, pp. 1033-1034 (1982).

[12] V.K. Bansal, K.B. Misra and M.P. Jain, "Minimal pathset and minimal cutsets using search technique ", Microelectron. Reliab.Vol. 22, No.6, pp. 1067-1075, (1982).

[13] G. B. Jasmon and O.S. Kai, "A new technique in minimal path and cutest evaluation",EEE Trans. Reliab. R-34, No.2, pp. 136-141 (June 1985).

[14] G.B. Jasmon,"Cutset analysis of networks using basic minimal paths and network decomposition", IEEE Trans. Reliab. R-34,No. 4, pp. 303-307 (Oct 1985).

[15] V. K. Jain and Krishna Gopal , "An algorithm for determining the most reliable path of a network ", Microelectron. Reliab. Vol. 26, No.5, pp. 883-884 (1986).

[16] W.J. Rueger , "A memory effective fast algorithm for computing the reliability of complex systems/networks", Microelectron.Reliab.,Vol. 27, No.2, pp. 273-277 (1987).

[17] M.A.Samad, "An efficient algorithm for simultaneously deducing minimal paths as well as cuts of a communication network". Microelectron. Reliab., Vol. 27, No. 3, pp. 437-441,
(1987).

[18] M.A. Samad, "An efficient method for terminal and multiterminal pathset enumeration",Microelectron. Reliab., Vol. 27, No. 3, pp. 443-446, (1987).

[19] Ahmad, S.H. "**S**imple enumeration of minimal cutsets of acyclic directed graph ",IEEE Trans. Reliab. R-37, No.5, pp. 484-487 (Dec.1988).

[20] S. Hasanuddin Ahmad , "Simple enumeration of minimal tiesets of undirected graph ",Microelectron. Reliab. Vol.29, No.4, pp. 509-510 1989).

[21] S. Hasanuddin Ahmad, " Enumeration of minimal cutsets of an undirected graph",Microelectron. Reliab., Vol. 30, No. 1, pp. 23-26, (1990).