FAST ALGORITHM FOR NETWORK DECOMPOSITION AND ITS APPLICATION TO RELIABILITY OF LARGE POWER SYSTEMS

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ABSTRACT

A new concept of handling the decomposition technique to implement the large power system reliability problem on a small computer is introduced. The decomposition of a system means tearing the system into subsystems. In the present work, the system is decomposed to three subsystems. Increasing the number of subsystems is found to minimize the examined system states and thus minimizes time of calculation. Numerical examples to illustrate the above method are included.

Keywords: Power system, Reliability, Decomposition.

Notation

$mode_k$	An (ex1) array, it corresponds to the k^{th} system state which has 2^e states. The generation of these states is well documented in [2].
e_1, e_2, e_3	The numbers of links for subnetworks S_1, S_2 and S_3 respectively.
n_1, n_2, n_3	The numbers of nodes for subnetworks S_1, S_2 and S_3 respectively.
p_{n1}	Number of partitioning nodes between S_1 and S_2.
p_{n2}	Number of partitioning nodes between S_2 and S_3.
A_1, A_2, A_3	The link-node incidence matrices, [2], for subnetworks S_1, S_2 and S_3 respectively.
p_i	The probability of the i^{th} link to success.
R_s	System reliability.
$STATE_1$	An 2^{e1} x p_{n1} matrix.
$STATE_2$	An 2^{e2} x $(p_{n1}*p_{n2})$ matrix.
$STATE_3$	An 2^{e3} x p_{n2} matrix.
ASTATE	An 2^{e2} x p_{n2} auxiliary matrix.
$PROB_1$	An 2^{e1} array.
$PROB_2$	An 2^{e2} array.
$PROB_3$	An 2^{e3} array.

1. INTRODUCTION

In many practical situations, a reliability model has a non-series-parallel configuration. In [1], power systems are classified into three configurations according to the following sub-categories:

i- Small system : which has less than 10 links and there is no need to efficient algorithms to analyze the reliability.

ii- Moderate system : which has 10-20 links and to analyze the reliability of such systems, algorithms which can efficiently be implemented on a computer are needed.

iii- Large system : which has more than 20 links and to analyze the reliability of such systems, approximated algorithms which can efficiently be implemented on a computer are used to minimize the memory locations.

Modern computers can extend the above categories to relatively large systems. On the other side, power systems increase in size in order to supply the new customers. For example, the ARPA network [3] with 13 paths and 28 cutsets in 1971 has developed to 281 paths and 1300 cutsets in 1976, and it is even larger now.

The basic method and algorithm for evaluating the terminal-pair reliability of a system by using the network decomposition approach are well documented in the literature [2] and [4]. In [2], two different techniques to evaluate the terminal-pair reliability were presented. The first is suitable to analyze small power systems, and the other is to evaluate the reliability for moderate systems using the decomposition technique. In [4], the idea of decomposition is applied to networks in order to reduce appreciably the computational requirements in deducing the basic minimal paths. It was mentioned [4], that only one partition is optimum in a network.

In this paper, the system decomposition is done by tearing it into three subsystems. A comparison will be done to show the reduction of the system states and the saving of the execution time. The computer program is written in PASCAL and run on a standard IBM, 386-PC, 50-MHz.

2. ASSUMPTIONS

We will assume that the system under consideration satisfies the following assumptions:

1. All nodes are 100% reliable. This means that, only link failure will be considered.
2. Any link can carry all the load demand of the load point. This means that, the system is good if at least one path of the system is good.

3. THE BASIC ALGORITHM

Notation

n, e	number of nodes and links respectively.
A	link-node incidence matrix.
p_i	the probability to success of i^{th} link.
ns, nt	number of sources and terminals respectively.
s[-]	sources.
t[-]	terminals.

The idea of decomposition or partitioning of a network will be shown to be advantageous in simplifying network problems. The decomposition splits the network into subnetworks which can be separately analyzed. The analysis are combined to arrive at the same end result for the network considered as a whole.

The reliability problems solved using the decomposition technique depend upon the following two stages:

stage 1: evaluation of the subnetwork variables needed to evaluate the whole network reliability.

stage 2: the method needed to combine the variables of subnetworks to arrive at the same end result of network reliability.

In this section, we will try to generalize the stage #1. The following steps are used to analyze the subnetwork:

1. Renumber all links and nodes in the subnetwork, then define the following values: n,e,A,ns,nt,s[-],t[],p_i.
2. For k= 0 to 2^e-1, construct the $mode_k$ array and evaluate each state probability. Store the result in PROB[k]
3. For i= 1 to ns do steps 4-8. (outer loop)
4. Let jj (auxiliary counter) be equal to 1.
5. For j= 1 to nt do steps 6-8. (inner loop)
6. Define all paths between i^{th} source and j^{th} terminal.
7. For k= o to 2^e-1 do, if $mode_k$ is equal to or is a set of one path evaluated in step 6, then let STATE[k,jj]=1, else let STATE[k,jj]=0.
8. Let jj=jj+1.

4. RELIABILITY EVALUATION OF LARGE NETWORKS

The decomposition splits the network into three subnetworks S_1,S_2, and S_3. This partition must be through nodes separating the source node in S_1 subnetwork and the sink node in S_3 subnetwork. The partitioning nodes separating S_1 and S_2 are considered as sinks in S_1 and sources in S_2. Also, the partitioning nodes separating S_2 and S_3 are considered as sinks with respect to S_2 and sinks with respect to S_3, the original source of the network is the source of subnetwork S_1 and original sink is the source of subnetwork S_3.

The method needed to combine the variables of subnetworks, obtained in section 3, to arrive at the same end result of network reliability is as follows:

1. Split the original network to three subnetworks according to the above rule of decomposition, then define all values e_i, n_i, s[-], t[-] and A_i for the i^{th} subnetwork. Also, define the numbers of partitioning nodes p_{n1}, and p_{n2}.
2. According to the algorithm steps given in section 3, evaluate the two arrays for each subnetwork, $STATE_i$ and $PROB_i$. The dimensions of these arrays are as given in notation.
3. Initialize the system reliability (R_s) to equal 0.
4. For i = 0 to 2^{e1}-1 do steps 5-11.
5. Initialize a ($2^{e2}xp_{n2}$) matrix named ASTATE to equal 0.
6. For j = 1 to p_{n1} do steps 7-9.
7. If $STATE_1$[i,j]=1, do steps 8-9.
8. For ii = 0 to 2^{e2}-1 do step 9.
9. For kk = 1 to p_{n2}, let ASTATE [ii,kk] =ASTATE [ii,kk]+$STATE_2$[ii,kk+p_{n2}(j-1)].
10. Let the matrix TERM be equal to ASTATE*$[STATE_3]^T$, then convert each element exceeding 0 in the matrix TERM to the product

$PROB_1[i]* PROB_2[i']* PROB_3[j']$ value, where i' and j' are the row and column numbers for that element, respectively.

11. Let $R_s = R_s$ + the summation of all resulting terms in the matrix TERM.

5. ILLUSTRATIVE EXAMPLES

Table (1) gives running times obtained for the examples shown in Figures (1) and (2). Example 1 is an ARPANET 74 after simple reductions [6] and example 2 is an IEEE 14 bus system after simple reductions[9].

Table 1. Running Times of Programs

Examples	Figure 1	Figure 2
Network Reliability	0.97511590	0.97321044
FRATTA/MONTANARI (73)[5][1]	112 .s	-
ABRAHAM (79)[6][2]	6 s.	-
DEBANY (86)[7][3]	1.46 s.	-
HARIRI/RAGHAVENDRA (87)[8][4]	0.8 s.	-
ABDELAZIZ/ABDELWAHED/EL-GENEIDY (93)[2][5]	0.16 s.	9.33 s.
Our algorithm [5]	0.05 s.	0.71 s.

1: IBM 360-67; 2: DEC PDP-10; 3: HONEWELL DPS 8-70; 4: VAX-11-750; 5: IBM 386-50 Mhz.

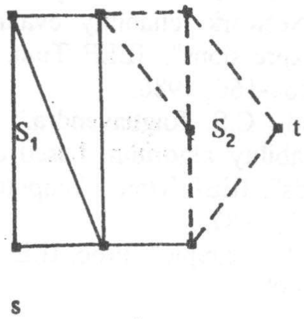

Figure 1–a

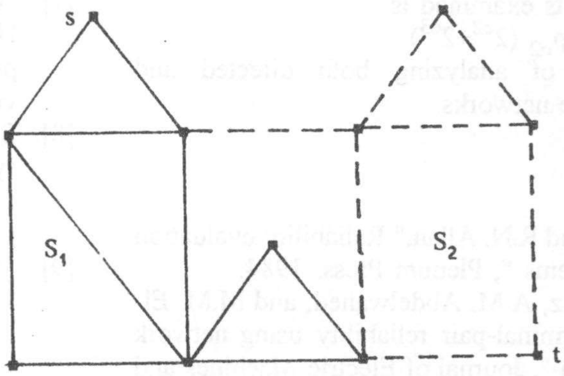

Figure 2–a

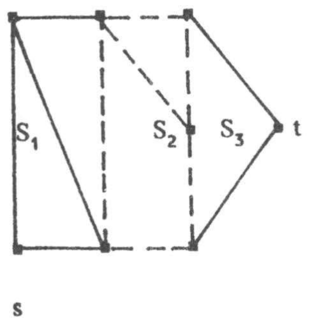

Figure 1–b

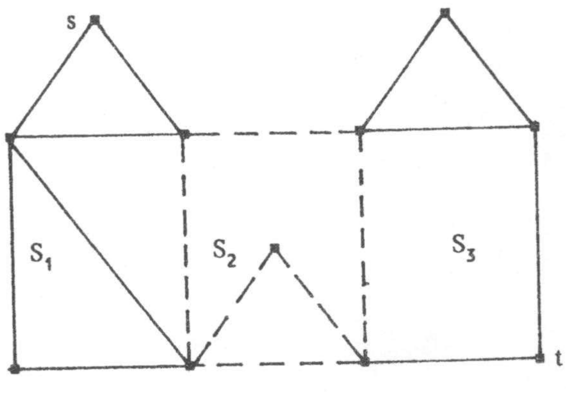

Figure 2–b

FIGURE 1: A 12-Links/8-Nodes Network

FIGURE 2: A 17-Links/11-Nodes Network

6. CONCLUSIONS

In this paper, the idea of the power system decomposition is discussed and is used to evaluate the reliability of large networks. The technique described in this paper exhibits the following advantages:

1. The time to execute the algorithm depends on the number of events that the algorithm examines. In [2], the number of events examined is a small fraction of the number of elementary events. The new decomposition technique reduces the time to execute the algorithm by reducing the number of events that the algorithm examines, where the number of events examined is $p_{n1}\,(2^{e1}+2^{e2}) + p_{n2}\,(2^{e2}+2^{e3})$.
2. It is capable of analyzing both directed and undirected large networks.

REFERENCES

[1] R. Billinton and R.N. Allan," Reliability evaluation of power systems ", Plenum Press, 1984.

[2] A.R. Abdelaziz, A.M. Abdelwahed, and M.M. El-Geneidy," Terminal-pair reliability using network decomposition ", Journal of Electric Machines and Power Systems, vol. 21, No.6, pp. 755-766, 1993.

[3] S. Soh, and S. Rai, "Experimental results on preprocessing of path/cut terms in sum of disjoint products technique", IEEE Tran. Reliability, vol. 42, pp. 24-33,1993.

[4] G.B. Jasmon, "Cutset analysis of networks using basic minimal paths and network decomposition", IEEE Tran. Reliability, vol. 34, pp. 303-307,1985.

[5] L. Fratta, and U.G. Montanari, " A Boolean algebra method for computing the terminal reliability in a communication network", IEEE Trans. Circuit Theory, vol. 20, pp. 203-211, 1973.

[6] J.A. Abraham, "An improved algorithm for network reliability", IEEE Tran. Reliability, vol. 28, pp. 58-61, 1979.

[7] W.H. Debany, P.K. varshney, and C.R.P. Hartmann," Network reliability evaluation using probability expressions", IEEE Tran. Reliability, vol. 35, pp. 161-166, 1986.

[8] S. Hariri, and C.S. Raghavendra," SYREL: A symbolic reliability algorithm based on path and cutset methods", IEEE Tran. Computers, vol. 36, pp. 1224-1232, 1987.

[9] "AEP 14 bus test sample", Proc. IEE, vol. 115, p. 1467, Oct. 1968.