RELIABILITY CALCULATION FOR GENERATION - INTERCONNECTED POWER SYSTEMS

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"حساب مؤشرات الأعتمادية لنظم القوى المترابطة التوليد"

ملخص البحث:

هذا النظام يقدم طريقه مقترحة لحساب موشرات الاعتمادية لنظم القوى المترابطة. و الطريقة المقترحة تعتمد على تكرار اضافة المسارات المتوالية و تدفق الطاقة و الحالة المحتملة للنظام.

و تأخذ الدراسة في الاعتبار بيانات الاعتماديه لعناصر نظام القوى و قيود التشغيل و كذلك الاشكال المتعددة للنظم و طريقة ترابطها. و لتوضيح الطريقة المقترحة فقد تم تطبيقها على ثلاثة أشكال مختلفة لنظام قوى مترابط

و النظام المقترح يتكون من خطوات عامه هي : تكوين بيانات الاعتماديه للعناصر المختلفة المكونة للنظام ثم حساب موشرات الاعتماديه لكل نظام على حده و كذلك المسارات المحتملة. ثم تكوين بعد ذلك مصفوفة ترابط المسارات المتعددة حسب ترتيبه متى تكرر النظام ناجح أو عاطل.

و تبين من تطبيق الطريقة المقترحه على الثلاثه اشكال المختلفة لنظام القوى المترابطة دقة النتائج في حساب موشرات الاعتماديه. وتقلل من الحسابات المطلوبة حيث أن الطريقة المقترحة تعتمد على الحالات المحتملة للمسار و ليس للعنصر فقط.

ABSTRACT :

This paper introduces a proposed technique to calculate reliability indices of interconnected power systems. The technique is based upon the sequential path supplementation, state space methods and power flow computations. The aspects of component outage reliability data, operating constraints and interconnected power system configurations are taken into considerations. The general steps of the method are : preparation of component reliability data, constructing the reliability data for each subsystem according to the connection of units and ties, enumerating possible operating paths and formulate path connection matrix, and then state transition matrix according to assumed failure criteria.

The application of the proposed algorithm on three different interconnected power systems, shows accurate and valuable results. Also, it reduces the mathematical calculations, because of using path word instead of component word when defining the power system state connection matrix and using network flow to define the condition of each state.

The proposed algorithm is useful in case of planning field, when comparing different plans or alternative designs. It is also valuable for operating engineers when they decide to add ties between substations, and it helps them to compare between the location of ties and associated increase in reliability indices.

KEY WORDS :

Reliability, state space, topology, sequential path supplementation, and network flow.

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1- INTRODUCTION :

Two or more power subsystems are often connected via tie lines to form an inter connected system in order to improve the system reliability and economical benefits.

It was proposed in [1] to use network flow to investigate the load flow calculations with network flow ealculations. The substitution is deemed to be a kind of permissible approximation in reliability evaluatious and the failure criterion is not taken into considerations. although. the capacity limit and the control over the network flow are considered. However. only the probability indiees could be calculated. while no frequency index was touehed upon.

Wang Xifan and Q. Sun [2] proposed an "sifting method" algorithm based upon path combination which reduces the number of network flows that must be calculated. For the intereonnected power system reliability evaluations, the involved sources (subsystems) are multi-state components and the ties are dual state components. All the different state combinations of these components comprise the basic even space under investigation. For the time being the multi-state components are also treated as dual-state components (connection and diseonnection), the sifting of network configuration states starts with sequentially supplementing paths.

There are many methods to find minimum paths. The path euumeratic method presented in [3] is a simple and direct one. However. the sparsity of the eomponent path conjugate matrices is not taken into consideration and therefore it is not very suitable for large seale load flow system calculations. The sparse matrix should be condensed for reliability evaluation in order to reduce the storage space and increase the caleulation efficiency[4-7].

At present. there are two methods for interconnected system reliability calculations. One is the probability array method [8] and the other is the equivalent supporting unit method [9-10].

2- PROPOSED METHOD :

In this paper the interconnected power system reliability indices ean he calculated depending upon the basic reliability data of each component and the network structurei.

The general steps of the proposed method are :

[1] Tabulate the reliability data for each component (Failure rate and average outage rate time per failure).

[2] Calculate the reliability indices of each subsystem according to its component connections and component reliability indices.

[3] Calculate the reliability indices of the lines by using of tie components failure rate and down time per failure.

[4] Use cut/set theory to enumerate main paths and path conneetions matrix.

[5] By the use of component outage and repair rates, calculate path reliability indiees.

[6] Consider the first possible path P_1 and calculate the corresponding component set involved E_1 and path space set. After this step supplement the second path P_2 and calculate the space set, path set, and not supplemented path set.

[7] Repeat the steps 1.....6 of possible supplemented paths P_3, P_4, ..., P_n .

- From steps 5, 6 & 7 determine the possible configuration path states.
- Perform the state-transition matrix [A] to obtain the probabilities and frequeucies of the different possible configuration states.
- Combine failure states set probabilities to get the overall interconnected power system failure and suceess probabilities and frequencies according to the assumed failure criterion and operating constraints.

3- CASE STUDY :

Three configurations of generation-interconnected power systems are illustrated in Fig. (1-a, b, c).

Fig. (1-a) 3-single subsystems without auy interconuecting links, while Fig. (1-b) is supported by a link "L_4" to tie buses B_1 and B_2, also Fig. (1-c) is supported by L_5 to tie B_2 with B_3.

The proposed technique is applied on three casesto calculate reliability indices probability, frequency and mean duration of failure, P_F, f_F and T_F in order to illustrating th variations of these values according to the addition of links L_4 or L_5.

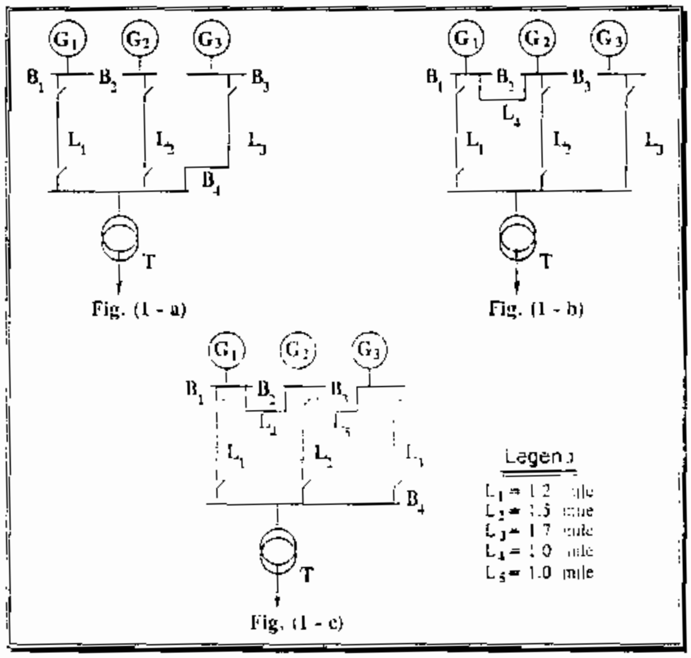

Fig. (1) : Three configurations of interconnected power systems

Considering the power system without any additional interconnecting links, the only paths are P_1, P_2 and P_3 but when the link "L_4" is added, two paths are created P_6 & P- .Also when the link L_5 is added, another two main paths are created P_6 and P_7. The all minimum paths P_1 through P_7 are shown in the following compouent path congate matrix., table (1).

The first step is to calculate path-reliability indices, based on the components failure outage rate and their connections.

Consider, the path "P_1" it consists of substation G_1, 1.2 mile transmission line, two medium voltage circuit breakers, bus circuit breaker and transformer T. By use of the failure outage data shown in tab (2), and the conneetion of these components to form P_1.the path failure rate is given by

Table (1) : Component path congate matrix.

Component \ path	P_1	P_2	P_3	P_4	P_5	P_6	P_7
G1	1	0	0	1	0	0	0
G2	0	1	0	0	1	1	0
G3	0	0	1	0	0	0	1
L1	1	0	0	0	1	0	0
L2	0	1	0	1		0	1
L3	0	0	1	0		1	0
L4				1	1	0	0
L5						1	1
T	1	1	1	1	1	1	1

$$\lambda_{P_i} = \sum_{=i}^{nc_1} \lambda_i$$

Where :

λ_i = is the failure rate of component I in the path P

i = 1,...... nc_l

nc_l = No. of series components forming path P_l.

$= \lambda_s - L_1 \times \lambda_B - 2\lambda_{CB} + \lambda_{bus} + \lambda_t = 0.0005 + 1.20 \times 0.007 - 2 \times 0.002 + 0.002 + 0.004$

$= 0.0945$ f/yr

and the average outage duration per failure is given by

$$r_{P_i} = \frac{1}{\lambda_{P_i}}\left(r_1\lambda_1 + r_2\lambda_2 + r_3\lambda_3 \ldots + r_{nc}\lambda_{nc}\right)$$

$$= \frac{1}{0.0945}(0.0005 \times 0.0001 \times 3 + 1.20 \times 0.007 \times 3 + 2 \times 0.002 \times 3.50 + 0.002 \times 3.50)$$

$= 3.1164$ hr/failure

Table (2) : component outage rate and repair time [6]

No.	Compnnent	Failure rate λ_i f/year	Repair time r_i hr/f
1	Supply (subsystem).	0.0005	3.00
2	46 kv - 11 kv bus.	0.0002	1.20
3	46 kv - 11 kv disconnecting switch.	0.0001	1.50
4	46 kv - 13.8 kv Trans.	0.0040	5.00
5	13.8 kv C.B.	0.0100	3.50
6	13.8 kv (enclosed).	0.0020	1.20
7	13.8 kv feeder breaker.	0.0020	3.50
8	1.8 kv feeder.	0.0150/mile	10.0
9	13.8 kv bus C.B.	0.0020	3.50
10	11 kv feeder.	0.0700/mile	3.00

The reliability indices of all paths are calculated and tabulated in table (3).

Table (3) : Calculated path reliability indices.

Reliability / Path	λ_{pi}	r_{pi}	μ_{pi}
P_1	0.0945	3.1164	0.32088
P_2	0.1155	3.0952	0.33227
P_3	0.1295	3.0849	0.32415
P_4	0.1895	3.0686	0.32588
P_5	0.1685	3.0771	0.32498
P_6	0.2055	3.0680	0.32594
P_7	0.1895	3.0686	0.32588

The second step is to apply sequential patb supplementing method to obtain all possible states of the considered interconnected power system as follow :

[1] Consider the first possible path "P_1" and calculate component set "E_1" and path space set "S_1" witb respect to Fig. (1-a)

$E_1 = \{G_1, L_1\}$

i.e. when path P_1 is supplemented, the component set is E_1. This means that G_1 & L_1 are in operation and the path set is $S_1 = \{P_1\}$ and commutative state

$S_1^* = \{S_{01}, P_1\}$

Where :

$S_{01} = \overline{P_1}$, is the not yet supplemented path set

[2] When the path P_2 is supplemented, the component set and complement elemental set are :

$E_2 = \{G_2, L_2\}$

E_2^* : Commulative component set when P_2 is supplemented.

$= E_1^* \cup E_2$

$= \{G_1, L_1\} \cup \{G_2, L_2\}$

$= \{G_1, G_2, L_1, L_2\}$.

$\overline{E_2}$: Complemented element set when P_2 is supplemented

$= E_2^* - E_2$

$= \{G_1, L_1\}$

each of G_1 & L_1 has two states. Table (3) illustrates the states when P_2 is added.

Table (3) : Interconnected Power Systems states set when P_2 is added.

State	E_2		$\overline{E_2}$		Results
1	G_2	L_2	G_1	L_1	$P_1 \cap P_2$
2	G_2	L_2	$\overline{G_1}$	L_1	P_2
3	G_2	L_2	G_1	$\overline{L_1}$	P_2
4	G_2	L_2	$\overline{G_1}$	$\overline{L_1}$	P_2

From table(3),

$S_2 = \{P_2 , P_1 \cap P_2\}$ and $S_2^* = S_1^* \cup S_2$

$= \{S_{02} , P_1\} \cup \{P_2 , P_1 \cap P_2\}$

$= \{ S_{01} , P_1 , P_2 , P_1 \cap P_2\}$

Where :

S_{02} is the not yet supplemented path set = $\overline{P_1} \cap \overline{P_2}$

[3] When path P_3 is added, E_3 and S_3^* are :-

$E_3 = \{G_3 , L_3\}$

$E_3^* = E_2^* \cup E_3 = \{G_1 , G_2 , G_3 , L_1 , L_2 , L_3\}$

$$\overline{E_3} = E_3^* - E_3 = \{G_1 , G_2 , L_1 , L_2\}$$

$$S_3 = \{ P_3 , P_1 \cap P_3 , P_2 \cap P_3 , P_1 \cap P_2 \cap P_3 \}$$

$$S_3^* = S_2^* \cup S_3$$

$$= \{S_{o2}, P_1, P_2, P_1 \cap P_2 \} \cup \{P_3, P_1 \cap P_3 , P_2 \cap P_3 , P_1 \cap P_2 \cap P_3 \}$$

$$= \{S_{o3}, P_1, P_2, P_1 \cap P_2 , P_3, P_1 \cap P_3 , P_2 \cap P_3 , P_1 \cap P_2 \cap P_3 \}$$

Where :

$$S_{o3} = \overline{P_1} \cap \overline{P_2} \cap \overline{P_3}$$

[4] When path P_4 is added, its elements are E_4 and S_4^* are :-

$$E_4 = \{G_1, L_4, L_2\}$$

$$E_4^* = E_3^* \cup E_4$$

$$= \{G_1 , G_2 , G_3 , L_1 , L_2 , L_3\} \cup \{G_1, L_4, L_2\}$$

$$= \{G_1 , G_2 , G_3 , L_1 , L_2 , L_3 , L_4\}$$

$$\overline{E_4} = E_4^* - E_4 = \{G_2 , G_3 , L_1 , L_3\}$$

$$S_4 = \{ P_4 , P_1 \cap P_4 , P_2 \cap P_4 , P_3 \cap P_4 , P_1 \cap P_2 \cap P_4 , P_1 \cap P_3 \cap P_4 ,$$
$$P_2 \cap P_3 \cap P_4 , P_1 \cap P_2 \cap P_3 \cap P_4 \cap P_5 \}$$

$$S_4^* = S_3^* \cup S_4$$

$$= \{S_{o3}, P_1, P_2, P_1 \cap P_2 , P_1 \cap P_3 , P_2 \cap P_3 , P_1 \cap P_2 \cap P_3 \} \cup \{P_4,$$
$$P_1 \cap P_4 , P_2 \cap P_4 , P_3 \cap P_4 , P_1 \cap P_2 \cap P_4 , P_1 \cap P_3 \cap P_4 ,$$
$$P_2 \cap P_3 \cap P_4 , P_1 \cap P_2 \cap P_3 \cap P_4 \cap P_5 \}$$

$$= \{S_{o4}, P_1, P_2, P_3, P_4, P_1 \cap P_2 , P_1 \cap P_3 , P_2 \cap P_3 , P_1 \cap P_4 , P_2 \cap P_4 ,$$
$$P_3 \cap P_4 , P_1 \cap P_2 \cap P_3 , P_1 \cap P_2 \cap P_4 , P_1 \cap P_3 \cap P_4 , P_2 \cap P_3 \cap P_4$$
$$P_1 \cap P_2 \cap P_3 \cap P_4 \cap P_5 \}$$

Where :

$$S_{o4} = \overline{P_1} \cap \overline{P_2} \cap \overline{P_3} \cap \overline{P_4}$$

[5] When path P_5 is supplemented, E_5 and S_5^* are :-

$E_5 = \{G_2, L_4, L_1\}$

$E_5^* = E_4^* \bigcup E_5 = \{G_1 \ . \ G_2 \ . \ G_3 \ . \ L_1 \ . \ L_2 \ . \ L_3 \ . \ L_4\}$

$\overline{E_5} = E^* - E_5 = \{G_1 \ . \ G_3 \ . \ L_2 \ . \ L_3\}$

$S_5 = \{ P_5, P_1 \cap P_5, P_2 \cap P_5, P_2 \cap P_3 \cap P_5, P_1 \cap P_3 \cap P_5,$
$P_1 \cap P_2 \cap P_4 \cap P_5, P_1 \cap P_2 \cap P_3 \cap P_4 \cap P_5 \}$

$S_5^* = S_4^* \bigcup S_5$

$= \{S_{05}, P_1, P_2, P_3, P_4, P_5, P_1 \cap P_2, P_1 \cap P_3, P_2 \cap P_3, P_1 \cap P_4,$
$P_2 \cap P_4, P_3 \cap P_4, P_1 \cap P_5, P_2 \cap P_5, P_1 \cap P_2 \cap P_3,$
$P_1 \cap P_2 \cap P_4, P_1 \cap P_3 \cap P_4, P_2 \cap P_3 \cap P_4, P_2 \cap P_3 \cap P_5,$
$P_1 \cap P_3 \cap P_5, P_1 \cap P_2 \cap P_4 \cap P_5, P_1 \cap P_2 \cap P_3 \cap P_4 \cap P_5 \}$

The number of components are seven, i.e. the base events are $2^7 = 128$ states. These states are reduced to S_5^* states = 21 state that should be calculated to get probability, frequency and duration for each state of the considered intereonnected power system.

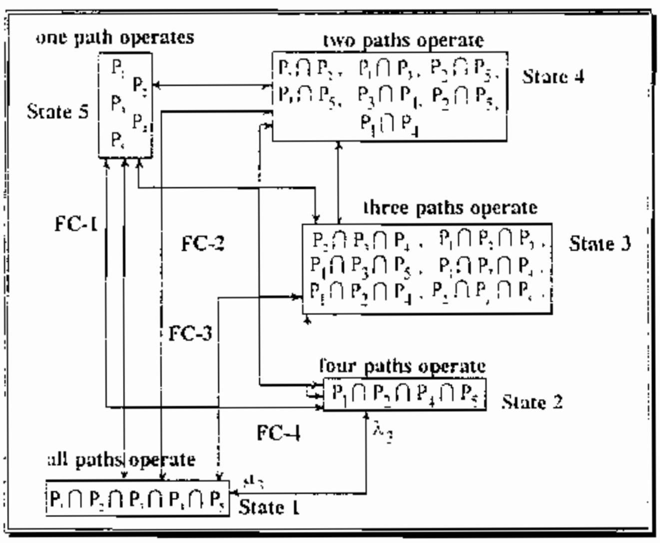

Fig. (2): State-space of paths-sets after merging states.

The transitions rates between states are shown in the transition matrix [A] given below.

The interconnected power system that represented in Fig (1-a) is described by its states and by the possible transitions between them as seen in Fig (2). The main advantage of the state-space approach is that in most cases a Markov model can be applied to describe the process of the system travelling through the states.

The major application of the state-space approach is the reliability calculation of repairable systems, that is, of system where all the components are repairable.

If only the long term values of the state probability P_i (t) are of interest, they can be obtained by solving the set of linear equations. [8].

$$[P]\,[A] = [O]$$

Where :

[P] = row - vector contains state probabilities.

[O] = row - vector contains zeros.

[A] = transition intensity matrix.

The solution for P requires an additional equation which is provided by the fact that the summation of probabilities of all states equals to 1, i.e.

$$\sum_{i=1} P_i = 1$$

From state						P		0
1	5.991	0.1295	1.718	3.446	2.79	P_1		0
2	0.32415	-7.3783	3.28325	3.7709	1.704	P_2		0
3	4.23528	4.23136	-68.3306	23.192	36.672	P_3		0
4	7.81839	6.58058	32.4641	-6.117	16.3486	P_4	=	0
5	6.51264	3.91203	25.2358	24.2966	-59.957	P_5		0

$[\lambda]$ = transition intensity matrix.

From state \ To state	1	2	3	4	5
1	$-\{10\lambda_1 + 11\lambda_2 + 11\lambda_3 + 11\lambda_4 + 14\lambda_5\}$	λ_3	$2\lambda_1 + 3\lambda_2 + \lambda_3 + 2\lambda_4 + 4\lambda_5$	$4\lambda_1 + 4\lambda_2 + 5\lambda_3 + 5\lambda_4 + 6\lambda_5$	$4\lambda_1 + 4\lambda_2 + 4\lambda_3 + 4\lambda_4 + 4\lambda_5$
2	μ_3	$-\{9\lambda_1 + 9\lambda_2 + 11\lambda_4 + 13\lambda_5 + 6\mu_3\}$	$2\lambda_1 + 2\lambda_2 + 3\lambda_4 + 4\lambda_5 + 5\mu_3$	$4\lambda_1 + 4\lambda_2 + 5\lambda_4 + 6\lambda_5 + 3\mu_3$	$3\lambda_1 + 3\lambda_2 + 3\lambda_4 + 3\lambda_5$
3	$3\mu_1 + 3\mu_2 + \mu_3 + 2\mu_4 + 4\mu_5$	$2\mu_1 + 2\mu_2 + 3\mu_4 + 4\mu_5 + 5\lambda_1$	$-\{32\lambda_1 + 32\lambda_2 + 50\lambda_3 + 27\lambda_4 + 20\lambda_5 + 15\mu_1 + 35\mu_2 + 5\mu_3 + 17\mu_4 + 20\mu_5\}$	$8\mu_1 + 8\mu_2 + 3\mu_3 + 9\mu_4 + 8\mu_5 + 16\lambda_1 + 16\lambda_2 + 25\lambda_3 + 15\lambda_4 + 12\lambda_5$	$2\mu_1 + 2\mu_2 + \mu_3 + 3\mu_4 + 4\mu_5 + 16\lambda_1 + 16\lambda_2 + 20\lambda_3 + 12\lambda_4 + 8\lambda_5$
4	$4\mu_1 + 4\mu_2 + 5\mu_3 + 5\mu_4 + 6\mu_5$	$4\mu_1 + 4\mu_2 + 5\mu_4 + 6\mu_5 + 3\lambda_3$	$8\lambda_1 + 8\lambda_2 + 3\lambda_3 + 9\lambda_4 + 8\lambda_5 + 16\mu_1 + 16\mu_2 + 25\mu_3 + 15\mu_4 + 15\mu_5$	$-\{24\lambda_1 + 24\lambda_2 + 18\lambda_3 + 21\lambda_4 + 16\lambda_5 + 28\mu_1 + 28\mu_2 + 35\mu_3 + 37\mu_4 + 30\mu_5\}$	$4\mu_1 + 4\mu_2 + 5\mu_3 + 5\mu_4 + 6\mu_5 + 16\lambda_1 + 16\lambda_2 + 12\lambda_3 + 12\lambda_4 + 8\lambda_5$
5	$4\mu_1 + 4\mu_2 + 4\mu_3 + 4\mu_4 + 4\mu_5$	$3\mu_1 + 3\mu_2 + 3\mu_4 + 3\mu_5$	$2\lambda_1 + 2\lambda_2 + \lambda_3 + 3\lambda_4 + 4\lambda_5 + 16\mu_1 + 16\mu_2 + 20\mu_3 + 12\mu_4 + 8\mu_5$	$4\lambda_1 + 4\lambda_2 + 5\lambda_3 + 5\lambda_4 + 6\lambda_5 + 16\mu_1 + 16\mu_2 + 12\mu_3 + 12\mu_4 + 8\mu_5$	$-\{6\lambda_1 + 6\lambda_2 + 6\lambda_3 + 8\lambda_4 + 10\lambda_5 + 39\mu_1 + 39\mu_2 + 36\mu_3 + 31\mu_4 + 23\mu_5\}$

$$\begin{bmatrix} P_1 \\ P_2 \\ P_3 \\ P_4 \\ P_5 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$\sum_{i=1}^{5} P_i = 1.0$$

$d = 6.8254$ E005	$d_3 = 1.2343$ E005
$d_1 = 1.6482$ E005	$d_4 = 1.2870$ E005
$d_2 = 1.5376$ E005	$d_5 = 1.1182$ E005
$P_1 = 0.2415$	$P_2 = 0.2253$
$P_3 = 0.1808$	$P_4 = 0.1886$
$P_5 = 0.1638$	

After solving the state-space transition equation we have to define the failure criterion and perform the system path states according to such a failure criterion, then calculate reliability indices as follow :

combine all path states in subset W and also states in F subset.

Then P_f = probability of failure

$$P_f = \sum_{i \in F} P_i \qquad \text{(1)}$$

F_F = frequency of failure

$$\sum_{i \in F} P_i \sum_{j \in W} \lambda_{ij} \qquad \text{(2)}$$

i.e. the system failure frequeney is the sum of the system failure state probabilities, each multiplied by the rate of transitions from the respective state to the success domain [8].

T_F = mean duration of stays in combined state F, therefore

$$T_F = \frac{P_F}{F_F} = \frac{\sum_{i \in F} P_i}{\sum_{i \in F} P_i \sum_{j \in W} \lambda_{ij}} \qquad \text{(3)}$$

If we choose the failure criterion as, "the system is considered failed, if only one path is in operation or less. (FC-1)", e.g.

P_5 only is in failure domain

P_1, P_2, P_3, and P_4 are in working domain

$$P_F = \sum_{i \in F} P_i = P_5 = 0.1638$$

$$F_F = \sum_{i \in F} P_i \sum_{j \in W} \lambda_{ij}$$

$= 0.1638 \times 6.51264 - 0.1638 \times 3.91203$

$= 0.1638 \times 25.2358 + 0.1638 \times 2$[illegible]$.2966 = 9.8209$

$$T_F = \frac{P_F}{F_F} = 0.01667$$

If failure criterion is chosen as the system is considered failed if two or less paths are only working (FC-2).

$$P_F = \sum_{i \in F} P_i = P_5 + P_4 = 0.1638 + 0.2253 = 0.3891$$

$F_F = (0.1638) \times (25.235 - 6.512 + 3.912) - 0.3891\,(7.818 + 6.58038) + 32.4641$

$= 0.1638 \times 35.6604 - 0.3891 \times 46.862 = 5.84117 + 18.23 = 24.075$

$$T_F = \frac{P_F}{F_F} = \frac{0.3891}{24.075} = 0.01616$$

If the failure criterion is chosen as the system considered failed when three paths or less are working, therefore (FC-3).

$$P_F = \sum_{i \in F} P_i = P_5 + P_4 + P_3$$

$= 0.1638 + 0.1886 - 0.1808 = 0.5332$

$$F_F = \sum_{i \in F} P_i \sum_{j \in W} \lambda_{ij}$$

$= 0.1638\,(6.51264 - 3.9120) - 0.1886\,(7.81839 + 6.5808) + 0.1808\,(4.23528 + 4.2313)$

$= 1.7075 + 2.71508 + 1.5307 = 5.95328$

$$\Gamma_F = \frac{P_F}{F_F} = \frac{0.5332}{5.95328} = 0.0895$$

If (FC4) the system is considered failed when 4 paths or less are working (FC-4).

$$P_F = \sum_{i \in F} P_i = P_5 + P_4 + P_3 + P_2$$

= 0.163

8 +0.1886 + 0.1808 + 0.2253 = 0.7585

$$F_F = \sum_{i \in F} P_i \sum_{j \in W} \lambda_{ij} = 3.38$$

$$T_F = \frac{P_F}{F_F} = \frac{0.7585}{3.38} = 0.2244$$

Table (4) Fault criterion (FC) versus reliability indices

FC	P_F	F_F	T_F
1	0.1638	0.82090	0.01667
2	0.3891	24.0750	0.0161
3	0.5332	5.95328	0.0895
4	0.7585	3.38000	0.22440

With the same way, repeat the calculations, when link L_5 is added, and the paths P_6 & P_7 are supplemented, the following reliability indiced are calculated in $Fig_{(s)}$ (3-a, b and c).

CONCLUSIONS

This paper introduces an aeeurate algorithm to calculate the reliability indices of interconneeted power systems based on state space method, the sequential path supplementation and power flow computations. The algorithm takes into account outage reliability data, operation constrains and system configuration.

The proposed algorithm reduces the mathematical calculation because of nsing path word instead of component word.

The porposed algorithm employed state space method to calculate reliability indices of an interconnected power system at different failure criteria as seen from figures.

The proposed teehnique is useful for planning engineer to cheek design alternatives according to the desired degree of reliability indices.

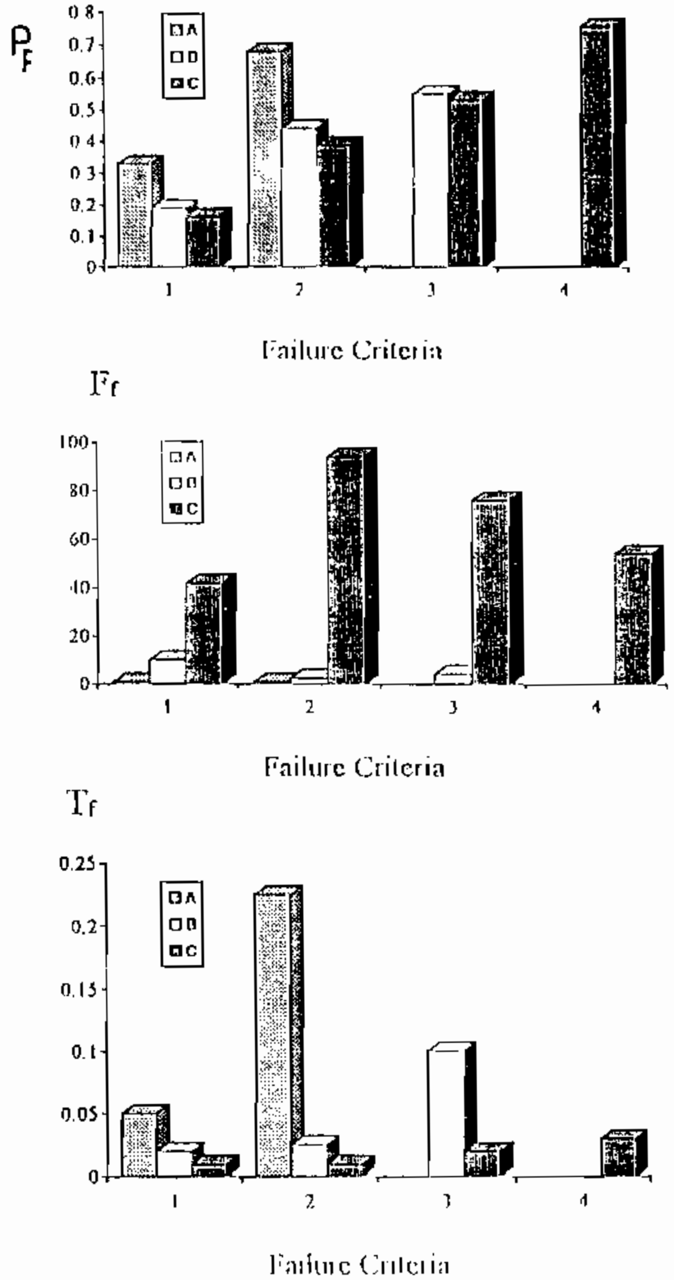

Fig.(3-a, b, and c):Reliability indices for the chosen three interconnected power systems.

REFERENCES :

[1] Pang, C. K. and A. J. Wood : "Multi Area Generation System Reliability Calculation". IEEE Trans. on PAS Vol. 94. PP. 508 - 517, March - April. 1975.

[2] Wang, Xifan and Q. H. Sun : "Network Flow Methods for Multi-Interconnected Power Systems Reliability Indices". The Journal of Jiaotong University. Vol. 18 No. 4, 1984.

[3] Magee. C. K. and A. J. Wood : "Multi-Area Generation Reliability Calculation". IEEE. Trans. on Reliability, Vol. R-30, No. 5, Dec. 1981.

[4] Billinton, R., R. J. Ringle and A. J. Wood : "Power System Reliabili Calculation". Book, 1980.

[5] Wang and J. R. Mc Donald : "Modern Power System Planning". Book, 993

[6] Endrenyi : "Reliability Modeling in Elec. Power Systems" Book, 1979

[7] J G Dalton, D L Garrison, and C M Fallon: "Value-Based Reliability Transimission Planning" IEEE, Aug. 1996.

[8] Cook, V. M., Galloway, Steinberg and A. J. Wood : "Determination of Reserve Requirements of Two Interconnected Systems". IEEE. PAS - 28, 1963

[9] Billinton, R., M. P. Bhavarja and M. P. Thompson : "Power System Interconnection Benefits". CES Trans. or Spring Meeting, March, 1969.

[10] A sankarakrishnan, and R. Billinton: "Effective Techniques For Reliability Worth Assesment In Composite Power System Networks Using Mote Carlo Simulation". IEEE. Aug.,1996.