Reliability Prediction Using the Fussel Algorithm

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Abstract - *The objective of this research is prediction with range of success operation system (Reliability). Applying the study on part of the 400 KV Super Grid power system. Estimating the reliability and availability parameters after a field and analytical study of network components and modeling into a single block. The paper treated with two analysis methodology; qualitative analysis techniques which represented by Path Tracing Method (PTM) to provide Minimum Cut Sets (MCSs) and also treated with quantitative analysis techniques that using the Fussel Algorithm (FA) that deal with repairable and non-repairable system. Also to determine degree of contribution the individual components of the system. The indexes of analysis describe system failure characteristics. Prepared for this purpose the Matlab program.*

Key Words: Prediction Reliability, Fussel Algorithm, PTM Method, Reliability Analysis.

1. INTRODUCTION

Reliability assessment of electric power systems has usually been an integral part of planning and operation of electric power systems. The variations in the electric function, industry make a requirement for more genuine techniques to power system availability and reliability estimations [1].

The reliability assessment of super grid generally comprises transmission and generation systems, which are frequently indicated to the bulk or combined power system. The transmission system has to be created to confirm a satisfactory energy move from the generation station to bulk load centers. There is a simulation and analytical approaches are the two modes of techniques handled with reliability analysis to power system [2].

The analytical analysis techniques are treated with mathematical models to give solutions problem of reliability. Exact calculation results are found for a provided set of system topology and input values. Some normally used approaches are Tie-Set, Cut Set, Markov Modelling, Path Tracing, and Fault Tree [2].

Where the Monte Carlo method (a simulation method) which give a solution for difficult problems that impossible solved by analytical approaches [2], this work handling with PTM analytical techniques.

1.1 CUT -SET METHOD

The cut set description technique is a powerful method for estimating the reliability of a system because it can be simply programmed for an efficient solution and fast [4].

The rule of cut set technique deduces total combinations of elements which must be failed or lost in order for a load point, according to consideration to be outrage from all supplies [3].

In other expressions cut set comprises a set components of the system which failure can lead to the failure overall system. The least subset of a cut set is named Minimal Cut Set (MCS), which includes the set of elements that must be unsuccessful in order for the system to not succeed. Every cut in the cut set is in series with next cuts, with the elements inside a cut related using the principle of parallel elements [4].

1.2 PATH TRACING METHOD

In the difficult structure of a system, for example, substation or (switching station) which correspond to elements that interconnection between sub-transmission, transmission and distribution systems. The most appropriate technique for quantifying their ability to achieve this function is to determine a duration and frequency of their failure [4].

In the old analysis, it has been expected that the minimal cut sets can be known from a visual inspection of the system because visual detection can usually be competent with small difficulty for easy systems. The issue of identification develops more complex for larger systems and there is a technique to deduce MCSs which can be applied on a digital computer this technique is named Path Tracing Method (PTM).

The points of this technique are as follows [4]:

1. Determine all least paths.
2. Create a paths matrix that labels all elements in each path.
3. If all constituents of every column of a paths matrix are pure unity the element connected to that column configuration a First Order Cuts(FOCs).
4. Amalgamate two columns of the paths matrix at same the time if whole items of the Amalgamate

columns are pure zero, the elements with those columns configuration a Second Order Cuts (SOCs). Then remove any cut set comprising FOCs to provide a SOCs of MCS.

5. Return to step above every three columns at same the time to provide the Third Order Cuts (TOCs), then remove any cut set including FOCs and SOCs of MCS.
6. Remain return to the highest order of a cut set has been getting.

1.3 FUSSEL ALGORITHM

Mathematical illustration of estimating reliability parameters by using the Fussel algorithm [6] typing in MATLAB program has been corresponding to as numerical steps followed;

$$U_i = \lambda_i * \tau_i \quad (1)$$

$$U_s = \prod_{i=1}^{n} U_i \quad (2)$$

i: a first event in the MCSs.

n: number of the first event in MCSs

τ_i : MDT of the first event.

λ_i: Failure rate of the first event

U_i , U_s: unavailability of the first event and MCSs

$$f_s = U_s \sum_{i=1}^{n} \frac{\lambda_i}{U_i} \quad (3)$$

f_s : PDF of the first failure of MCSs.

$$Q_s = \int_0^t f_s(t)dt \quad (4)$$

Q_s: unreliability of MCSs

$$\Lambda_s = \frac{f_s}{1-Q_s} \quad (5)$$

Λ_s: failure rate of MCSs

$$Q_t = \sum_{s=1}^{N} Q_s \quad (6)$$

N: number of MCSs.

Q_t: unreliability of major event.

$$Q = Q_t * t \quad (7)$$

t: the limit period.

Q: unreliability for the limit period.

$$R = (1 - Q) \quad (8)$$

R : Reliability overall system.

$$U_t = \sum_{s=1}^{N} U_s \quad (9)$$

U_t : unavailability of a major event.

$$\Lambda_t = \sum_{s=1}^{N} \Lambda_s \quad (10)$$

Λ_t : Failure rate of a major event.

$$MTTF_t = \frac{1}{\Lambda_t} \quad (11)$$

$MTTF_t$: Mean time to failure

$$I_{iu} \cong \frac{\sum_{k=1}^{m} U_k}{U_k} \quad (12)$$

$$I_{iq} \cong \frac{\sum_{k=1}^{m_i} Q_k}{Q_k} \quad (13)$$

I_u, I_q: Factors give the degree of importance and contribution of the element in the calculations of the unavailability and unreliability

m: Number of MCS.

2. RESULTS AND DISCUSSION

South region of Iraq consists of; Basrah and Nassiryah zones.

The data (failure rate and mean dead time) as shown in the table-1 its a source to estimate of the reliability indexes. [8]

Table -1: Input data

Zone	Code	Component	Failure rate 1/hr.	Mean dead time hr.
Nassi rya	8	Nassirya PS	1.63 E-4	2637
	49	Nassirya Transformer	1.52E-06	146
Link	19	Nassirya- Kh Al-Zubair	32.39 E-6	2198.1
Basra	10	Khur Al-Zubair	1.3001 E-4	1058.1
	46	Khur Al-Zubair Transformer	2.283 E-6	209
	18	Khur Al-Zubair -Hartha	8.73 E-6	696.35
	9	Hartha PS	1.25 E-4	733.2
	47	Hartha Transformer	2.283 E-6	192

The reliability block diagram assumptions are:

1. The parallel transmission line, transformer, and generator are modeled as a single block.
2. Each first event is statistically impartial.
3. Each element in the network is unidirectional. The block diagram of the south region grid as shown in Fig-1

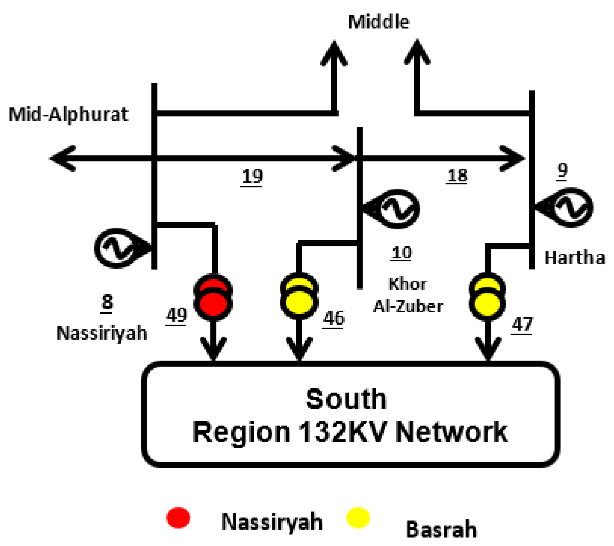

Fig -1: south region grid

Determine power flow paths to result in MCSs in table-2 after use paths matrix for each zone by Matlab program.

Table -2: flow paths & MCSs

Zone	Power flow paths	Minimal cut sets & orders	
Nassirya	1) 8+49	First	[8],[49]
Basrah	1) 10+46 2) 8+19+46 3) 9+47 4) 10+18+47 5) 8+18+19 47	First	[46],[47]
		Third	[8,9,10],[8,10,47],[9,10,19] ,[9,18,46],[10,19,47]

Merge Paths of zones can give paths overall regions

Table -3: Paths matrix of south region

Zone	Component							
	8	9	10	18	19	46	47	49
Nassriya	1	0	0	0	0	0	0	1
Basrah	0	0	1	0	0	1	0	0
	1	0	0	0	1	1	0	0
	0	1	0	0	0	0	1	0
	0	0	1	1	0	0	1	0
	1	0	0	1	1	0	1	0

Arrangement all paths matrixes of zones can give paths matrix overall south region to deduce MCSs of the region.

Table -4: MCS of south region

	Minimal cut sets & orders
Third	[8,9,10],[8,10,47],[8,46,47],[46,47,49]
Fourth	[8,9,18,46],[9,10,19,49],[9,18,46,49],[10,19,47,49]

The reliability indexes of the network can summarize by the table -5.

Table -5: Reliability indexes

Zone	Nassiryah	Basrah	South area
Reliability %	0.0%	84.88%	87.08%
Unreliability t > 0	1.6452E-4.t	1.7252E-5.t	1.4742E-5.t
Unavailability	4.30E-1	6.35E-3	5.45E-03
Failure rate 1/hr	3.70E+2	1.73E-5	1.47E-05
MTFt hr	6.08E+3	5.80E+4	6.78E+04
MDTt hr	3.70E+2	3.70E+2	3.71E+02

The Importance components can summarize in the table-6.
Table-6: Importance components

Component	Quantitative	
	I_u	I_q
8	1.00	1.00
9	9.95E-1	9.88E-1
10	1.00	1.00
18	2.10E-5	6.18E-5
19	3.68E-5	1.31E-4
46	3.75E-5	1.25E-4
47	4.78E-3	1.16E-2
49	3.68E-5	1.31E-4

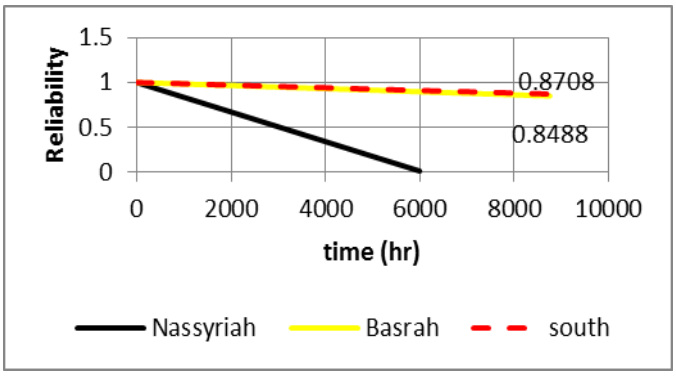

Chart -2: reliability vs time

Analysis results proved that over prediction of the system state, it will survive with present 87.08% for one-year period. In chart-2 Nassiryah zone does not exceed one year and expected will failure after 6080 hours of initial operation ad required 370 hours to repairing the system.

3. CONCLUSIONS

Predicting the performance of the system is important because it gives choices for decision-making in early time, based on possible consequences. The most important conclusion of the research is the role of the load flow in configuring the appropriate paths because if the change gives a new reliability level as well as the degree of contribution each component to the system failure. The carefully with the components that severely affect and make the optimal load flow load ensure that reliability is correctly improved.

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