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Probability Analysis to Prediction Reliability of Power System

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Abstract: The paper deals with probability analysis to estimate of reliability level for therepairable system and expected time to failure and time that required to repairing the system. The study applied on thepart of 400 KV super grid power systemto find a weak point in the network.Using numerical techniques to calculate the reliability indexes in qualitative analysisPath Tracing Method (PTM) which analyze the complex network to give minimum cut sets and quantitative analysis Fussell algorithm thatgives over predict characteristic for the failureprobabilityby using MATLAB program. Then submitting suggestions and solutions to improve the power system in theplanning stage to investments of energy as a cost and reduce a losses energy so obtain network more stable and reliable. Results can show the zones have low-reliability and discuss the factors cause to it and their importance to ensure exploits the energy between regions and stability whole a power system.

Keywords: Failure Probability, Reliability Analysis, PTM Techniques, Fussell Model.

I. INTRODUCTION

The reliability depends on a statistical probability, in general terms, reliability is a measure of how well a system performs their expected function. A power system is very complex, integrating many types of generating resources to provide electricity to a number of customers with varying requirements. Each component has its own characteristics, including its dependability or reliability. One can imagine the difficulty in trying to evaluate the reliability of such complex system as a whole.To simplify the task somewhat, power systems are generally divided into three major components; the generation system, the transmission system and the distribution network. In gross numbers; the distribution component of a power system is responsible for about (85percent) of interruptions. The transmission and generation components are responsible for about (5 percent) and (10 percent) of interruptions, respectively the problem of identification becomes very difficult for larger and very complicated systems.The assessment of reliability is generally interested by average indexes, such as a mean time to repair (MTTR) and a mean time between failures (MTBF). The levels of Reliability are associated with economics since increased reliability is causing increased investments and also allows the consumers to decrease their outage costs.An overall life period of the system or any component can be represented using the hazard rate or failure rate curve that called Bathtub curve as shown in Fig.1. It can be divided into three sections [11]. The first section is an infant mortality, where defects in manufacture are caused failures, use of substandard material, bad assembly poor insulation, etc. The second section is a useful lifetime. Here a failure rate must be constant. The failures are evenly distributed and random. In the third section, the failures are failing of wear out. The failure rate increases in this region so that most of the components will be exceeded the life of service and thus it will be devastating.

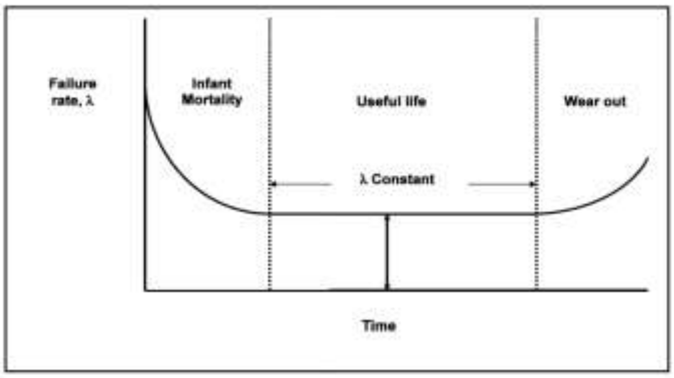

Fig. 1. Bathtub Curve

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The method of calculation of reliability indexes performed in this paper is the Path Tracing Method (PTM) which depends on deduce a Minimum Cut Sets (MCS) After analysis the electrical grid and is implemented by a digital computer program to calculate the reliability indexes.

II. METHODOLOGY

A. Components in Series
If individual components of the system are connected in series, the failure of one component causes a blockout of the system. Reliability of the system may be written as:

$$R_s = \prod_{i=1}^{N} R_i \quad (1)$$

B. Parallel Components
The reliability block diagram of the system consists ofa number of parallel individual components. The failure of all components can causeblockout of the system. Reliability of the system may be written as:

$$R_P = 1 - \prod_{i=1}^{N} (1 - R_i) (2)$$

C. Reliability Block Diagram (RBD)
Use RBD for a complex system that cannot solve by series and parallel rule. The hypotheses to Modeling of the complex network, according to RBD [12-13] as follows:
1) Eachcomponent was unidirectional.
2) Parallel line components were modeled as the individualblock.
3) Statistically independent for all events.
4) Network 132 KV consider centers load.

D. Path Tracing Method (P.T.M)
Its analysis techniques for thecomplex network to deduce quality components which contribute to reliability calculation. The identification issue becomes very difficult for more complex and larger systems and to deduce MCSs this method can be used on the digital computer by following sequential steps. The method steps of PTM as follows:

1) Conclude all minimal a flow of paths.
2) Structure an occurrence matrix that Determines components in every path.
3) If each element for any column of apaths matrix is nonzero a component associated with that column to formafirst order of MCS.
4) Combine each two columns of the paths matrix at a time if each element of the combined two columns is non-zero, components of those two columns form a second order of MCS. Eliminate any cut includethe first order to obtain a second order.
5) Repeat step four with each three columns at the time toobtain the third order of MCS, in this step,eliminating any cut sets, including afirst and second order of MCS.
6) Continue to the maximum fifth order of a cut has been achieved. [4]

E. Fussell Model
Quantitative analysis requiresa minimum cut set which appliesto the mathematical model representation of evaluation reliability indexes in the program of MATLAB by steps of mathematical Equations exemplified as follows:[20,21]

1) Element Analysis
The elements ofthe system repairable havea constant failure rate

$$q_i \le \lambda_i \cdot t \quad (3)$$

$$u_i \le \lambda_i \cdot \tau_i \quad (4)$$

Where
t: period.
i: Element.
τ_i : MDT of the Element.
λ_i: Failure rate of Element.

2) MCSAnalysis
The MCSs represent immediate fail for the parallel element during period $t > 0$ then the Element is repairable so:

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$$U_k = \prod_{i=1}^{n} u_i \quad (5)$$

$$f_k \leq U_k \sum_{i=1}^{n} \frac{\lambda_i}{u_i} \quad (6)$$

$$Q_k \equiv \int_0^t f_k(t)dt (7)$$

$$\Lambda_k = \frac{f_k}{1-Q_k} (8)$$

n: Number of the elementin MCSs.
U_i ,U_k: Unavailability of elementand MCSs.
f_k : PDF of MCSs.
Q_k:Unreliability of MCSs.
$\boldsymbol{\Lambda_k}$: Failure rate of MCSs.

3) Major Analysis
Probability occurs any MCSs lead to failing the system so that:

$$Q_t \leq \sum_{s=1}^{N} Q_k (9)$$

$$U_t \leq \sum_{s=1}^{N} U_k (10)$$

$$\Lambda_t = \sum_{s=1}^{N} \Lambda_k \quad (11)$$

N: No. crucial MCSs.
Q_t: Unreliability overall.
U_t: Unavailability overall.
$\boldsymbol{\Lambda_t}$: Failure rate overall.

The expected time to occur failing

$$MTTF_t \cong \frac{1}{\Lambda_t} \quad (12)$$

The mean time required for repairing:

$$\tau_t \cong \frac{U_t}{(A_t \cdot \Lambda_t)} (13)$$

$MTTF_t$: Mean time to failure overall
$\boldsymbol{\tau_t}$: mean dead time overall.

Unreliability and reliability of the overall system:

$$Q = Q_t * t \quad (14)$$

$$R = (1 - Q) \quad (15)$$

t: the specific period.

4) Element Importance
It is defined as the probability of an element to contributing to system failure. [20, 21]
So that

$$I_{iu} \cong \frac{\sum_{k=1}^{m} U_k}{U_k} \quad (16)$$

$$I_{iq} \cong \frac{\sum_{k=1}^{m_i} Q_k}{Q_k} \quad (17)$$

III. RESULT& DISCUSSION

The study applied on the part of 400 KV super grid Middle Alphurat (M-Alph) that consists of two zonesKADISIYAH and BABIL as shown in Fig. 2. The probabilistic and statistical data is failure rate and mean dead time for each element can summarize in Table I consider input data for Fussell algorithm

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TABLE I Statistical Data

Code	Element	Failure Rate	Mean Dead Time
10	Musayab P.S.	1.136E-4	1017.9
11	Musayab Gas	1.445E-4	4591.1
50	Musayab P.S. - Musayab Gas	8.79E-7	1462.2
51	Musayab P.S. - Babil	1.13E-5	876.2
82	Babil Transformer	1.9438E-6	236.2
83	Musayab Transformer	1.036 E-6	273.5
52	Babil - Kadisiyah	1.63E-5	978.5
12	Diwanyah Gas	1.577E-4	2180.9
55	Dwianyah Gas - Kadisiyah	4.24E-6	763.4
81	Kadisiyha Transformer	1.0135E-6	273.1
53	Babil - Kherat Gas	6.3E-6	876.3
54	Kherat Gas - Kadisiyah	1.45E-5	1019.8
13	Kherat Gas	1.611E-4	1162.3
63	Amara - Kut	3.53E-5	1098.5
64	Nasiriyah - Kut	3.19E-5	1245.8
65	Nassiriyah - Kadisiyah	2.83E-5	679.5
14	Nassiriya P.S.	1.107E-4	1694.2
88	Nassiriyah Transformer	1.31E-6	194.1
60	Rumela Gas - Nassiriyah	2.54E-05	789.3
9	Kut (Zubidiyah)	1.561E-4	1462.2
15	Hartha P.S.	1.023E-3	713.2
16	Khor-Alzuber P.S.	1.225E-4	1122.8
17	Shat-AL-Basrah	1.2979E-4	3078.1
18	Rumela Gas	1.1376E-4	2310.2
56	Shat.Al Basrah - Basrah	7.19E-7	486.2
57	Basrah - Khor Al zuber	4.16E-6	1050.2
58	Hartha - Khor-Alzuber	8.8E-6	789.3
59	KhorAlzuber - Rumela Gas	1.09E-5	689.3
61	Hartha – Qurna	8.79E-6	864.3
62	Qurna - Amara	1.28E-05	713.5
19	Amara	1.202E-4	1649
44	Kut - Kut (Zubidiyah)	1.26E-5	963.2
63	Amara - Kut	3.53E-5	1098
64	Nassiriyah - Kut	3.19E-5	1245
65	Nassiriyah - Kadisiyah	2.83E-5	679.5
9	Kut (Zubidiyah)	1.561E-4	1462

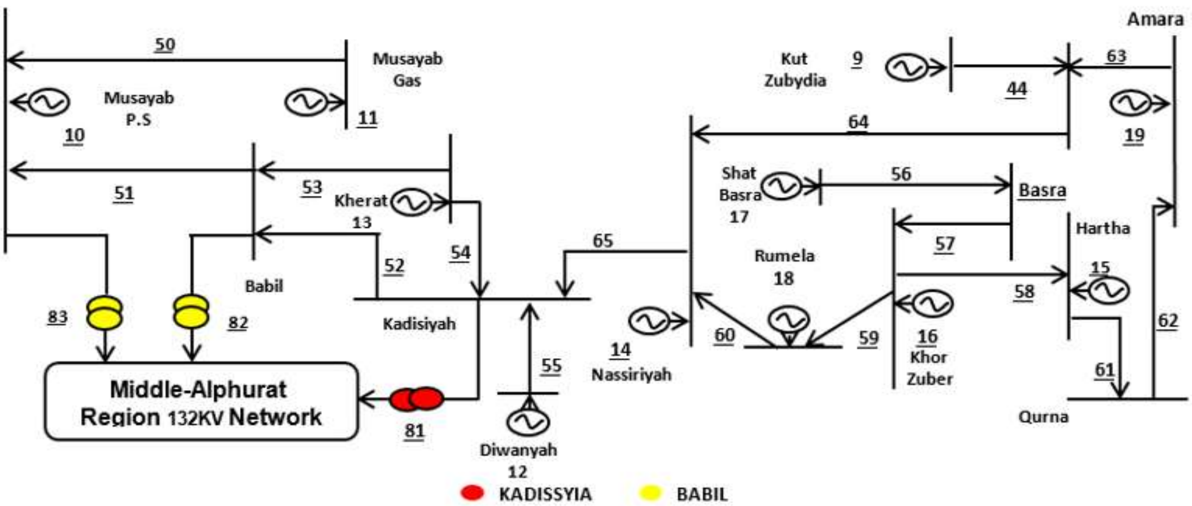

Fig. 2. Single Diagram of Power System Grid

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Deduce the paths of the power from load flow of network in Fig. 2and itssummarizedin Table IIwhich also shown results MCS of each zone after use paths matrixes which presented in Table III.

TABLE II Flow Paths &Mcssof Zones

<table>
<tr><th>Zone</th><th colspan="2">Power flow paths</th><th colspan="2">Minimal cut sets & orders</th></tr>
<tr><td rowspan="4">BABIL</td><td rowspan="4">1) 82+53+13
2) 82+52+54+13
3) 82+52+55+1282+
4) 82+52+65+14
5) 82+52+65+60+18
6)82+52+65+60+59+16
7) 82+52+65+60+59+57+56+17
8) 82+52+65+64+44+9
9)82+52+65+64+63+19
10) 82+52+65+64+63+62+61+15
11) 82+52+65+64+63+62+61+58+16
12) 82+52+65+64+63+62+61+58 +57+56+17
13) 83+10
14)83+51+52+65+60+18</td><td rowspan="4">15) 83+51+53+13
16) 83+51+52+54+13
17) 83+51+52+55+12
18) 83+51+52+65+14
19) 83+50+11
20) 83+51+52+65+60+59+16
21) 83+51+52+65+6+59+57+56+17
22) 83+51+52+65+64+44+9
23) 83+51+52+65+64+63+19
24) 83+51+52+65+64+63+62+61+15
25) 83+51+52+65+64+63+62+61 +58+16
26) 83+51+52+65+64+63+62+61 +58+57+56+17</td><td>2^{nd}</td><td>[82,83]</td></tr>
<tr><td>3^{rd}</td><td>[13,52,83][52,53,83]</td></tr>
<tr><td>4^{th}</td><td>[10,11,51,82][10,11,13,52]
[10,13,50,52][10,11,52,53]
[10,50,52,53][10,50,51,82]
[13,55,65,83][12,13,65,83]</td></tr>
<tr><td>5^{th}</td><td>[10,11,12,13,65]
[10,11,13,55,65]
[10,12,13,50,65]
[10,13,50,55,65]
[12,53,54,65,83]
[53,54,55,65,83]</td></tr>
<tr><td rowspan="3">KADSSIYA</td><td rowspan="3">1) 81+65+14
2) 81+65+60+18
3) 81+65+60+59+16
4) 81+65+60+59+57+56+17
5) 81+65+64+44+9
6) 81+65+64+63+62+61+58 +57+56+17</td><td rowspan="3">7) 81+55+12
8) 81+54+13
9) 81+65+64+63+19
10) 81+65+64+63+62+61+15
11) 81+65+64+63+62+61+58+16</td><td>1^{st}</td><td>[81]</td></tr>
<tr><td>3</td><td>[12,54,65][12,13,65]
[13,55,65][54,55,65]</td></tr>
<tr><td>5</td><td>[12,13,14,60,64]
[12,14,54,60,64]
[13,14,55,60,64]
[14,54,55,60,64]</td></tr>
</table>

The paths flow of power of each zone presented in paths matrix according to PTM. Its shown in Table III.

TABLE III Paths Matrix

Element Code

9	10	11	12	13	14	15	16	17	18	19	44	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	81	82	83
KADYSSIAH																														
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1
0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	1
0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	1	1	0	1	1	0	0	0	0	1	0	0	1
1	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1
0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1
0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	1
0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	1	1	1	1	1	0	0	1
0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	1	1	1	0	0	1	1	1	1	1	0	0	1

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BABIL																														
0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0
0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	1	0	1	0
0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	0	0	0	0	1	0	1	0
1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0
0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0
0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0
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0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	1	1	0	1	0
0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0
0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	1	1	0	0
1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0
0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0
0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1	0	0
0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	1	1	1	1	0	0
0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0
0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0

Show in the Table III set of the paths matrixes of zones can configurethe paths matrix of the M-Alph area to conclude MCS inTable IV.

TABLE IVMcssofM-Alph Area

Minimal cut sets & orders	
3^{rd}	[81,82,83]
4^{th}	[13,52,81,83][12,13,65,83] [13,55,65,83][52,53,81,83]
5^{th}	[10,11,13,52,81][10,11,12,13,65] [10,11,51,81,82][10,11,13,55,65] [10,12,13,50,65][10,11,52,53,81] [10,13,50,55,65][10,13,50,52,81] [10,50,52,53,81][10,50,51,81,82] [12,54,65,82,83][12,53,54,65,83] [53,54,55,65,83][54,55,65,82,83]

The indexes result of the reliability analysis for each zone and the overall M-Alph area cansummarize in Table V.

TABLE VReliability Indexes

Zone	**BABIL**	**KADISIYAH**	**M-Apha**
Unreliability $t > 0$	1.11E-6.t	4.83E-6.t	3.70E-7.t
Reliability %	99.02%	95.76%	99.67%
Unavailability	3.34E-4	1.63E-3	9.65E-5
Failure rate hr^{-1}	1.11E-6	4.83E-6	3.70E-7
MTFt hr	9.02E+5	2.07E+5	2.71E+6
MDTt hr	3.02E+2	3.39E+2	2.61E+2

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The quality and quantity importance for each element can summarize by the TableVI.

TABLE VI Element Importance

Element	Qualitative Importance	Quantitative	
		I_u	I_q
10	5th	9.96E-1	9.94E-1
11	5th	9.94E-1	9.92E-1
12	4th 5th	9.90E-1	9.87E-1
13	4th 5th	1.00	1.00
50	5th	1.93E-3	2.05E-3
52	4th 5th	6.81E-4	1.16E-3
55	4th 5th	9.31E-3	1.14E-2
65	4th 5th	9.99E-1	9.99E-1
81	4th 5th	6.82E-4	1.17E-3
83	3rd 4th 5th	3.67E-3	6.19E-3

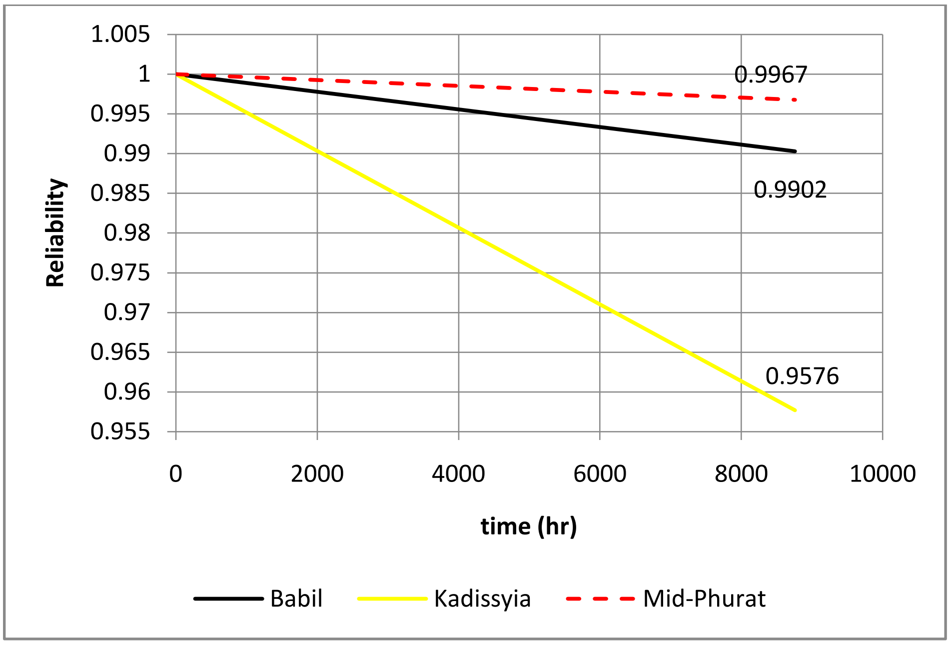

Fig. 3. Reliability VS Time

Expected thatlevel of the reliability for KADISSYIH and BABIL zones will bereduced to (95.76%) &(99.02%) respectively, and overall system (99.67%) for a one-yearperiod.

Expect failure the system after (2.71E+6) hour and requires (261) hour repairing.

IV. CONCLUSION

The resultsexplain theperformance of the power system in future for load flow case that shown in the Fig. 2.

The impact factors on the reliability system summarized by load flow case and degree of contribution of the element and failure characteristics of the elements that are hard to control because of there is unexpected physical failure also to reach for elements have low-failure requires high cost and weight so that the best way to improve the power system reliability with acceptable limit is proposal load flow ensures equal paths to load centers and care of the important elements as shown in the Table VI the element (13) contributes to (100%) in unreliability and unavailability of the system.

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