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Reliability Evaluation of Composite System with Aging Failure

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Abstract- Reliability is concerned with the system capability of survival. In the past forty years, customer expectations have been increasing in response to evolving new technologies. As part of these evolutions, they are demanding from their suppliers: products with higher quality, low initial cost, improved customer support and products that are easy and inexpensive to maintain. For a supplier to survive, succeed and be profitable in today’s market, It must do the following:

a) Constant improvement in the quality of the products.
b) Minimization of the cost.
c) Be flexible and responsive to the customer’s requirement.

This deals with reliability evaluation of combined generation and transmission system known as composite system. It describes a technique and a program to calculate composite system reliability with aging failure and its indices by applying it on a system. Composite system reliability is achieving considerable attention these days as utilities are finding it increasingly necessary to quantitatively evaluate individual busbar and overall system indices. In this research work following reliabilities has been calculated and evaluated for a system:

- Generation system reliability
- Transmission system reliability
- Composite system reliability
- Composite system reliability indices

I. PROBLEM FORMULATION

The RBTS is a 6 bus system composed of two generator buses, 5 load buses, 9 transmission lines and 11 generating units. The total installed capacity is 240 MW and the system peak load is 185 MW.

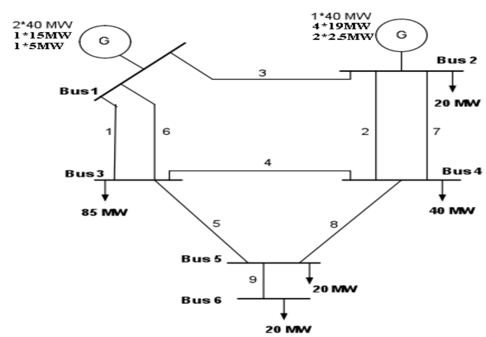

Fig1: Single Line Diagram of RBTS system

RBTS Data

Table 1: Bus Data for RBTS system

Bus	Peak Load,MW		PG	Q VAR Limit,MVAR		Voltage Limits,pu	
	Active	Reactive		Max	Min	Max	Min
1	0	0	1.00	50	-40	1.05	0.97
2	20	0	1.20	40	-75	1.05	0.97
3	85	0	0.00	0	0	1.05	0.97
4	40	0	0.00	0	0	1.05	0.97
5	20	0	0.00	0	0	1.05	0.97
6	20	0	0.00	0	0	1.05	0.97

Generation Data

Table 2: Generator data for RBTS system

Bus No.	Rating(MW)	Failure Per Year	Repair Time(hours)
1	40	6	45
1	40	6	45
1	10	4	45
1	20	5	45
2	5	2	45
2	5	2	45
2	40	3	60
2	20	2.4	55
2	20	2.4	55
2	20	2.4	55
2	20	2.4	55

RBTS-Transmission Data

The relevant reliability data for the nine 110 kV lines in Fig. 1 in terms of the permanent and transient failure rates and the permanent outage repair times are given in [11]. The outage duration of a transient outage is considered to be less than one minute. Outages of substation components which are not switched as a part of a line are not included in the line data.

Table 3: Line Data for RBTS system

From Bus	To bus	R	X	B	Current rating	Failure Per Year	Repair Time
1	3	0.0342	0.18	0.0212	0.49	1.5	10
2	4	0.1140	0.60	0.0352	0.409	5	10
1	2	0.0912	0.48	0.0564	0.409	4	10
3	4	0.0228	0.12	0.0142	0.409	1	10
3	5	0.0228	0.12	0.0142	0.409	1	10
1	3	0.0342	0.18	0.0212	0.49	1.5	10
2	4	0.1140	0.60	0.0352	0.409	5	10
4	5	0.0228	0.12	0.0142	0.409	1	10
5	6	0.0228	0.12	0.0142	0.409	1	10

II. RELIABILITY EVALUATION

An aging failure (end-of-life failure) is a nonrepairable failure. It may suddenly happen when a component enters the wear-out stage on the life basin curve, as shown in Figure 2.3. The aging failure is a conditional failure event that depends on the history; that is, how many years a system component has survived.

Weibull Distribution offers true failure analysis and risk calculations with enormously tiny samples. Results are possible at the initial stage of a problem without the necessity to crash a few more. The Weibull distribution is a 3 factor distribution. The three factors that comprise the Weibull distribution are **β**, **α** and data sets. Weibull analysis is used widely because this distribution allows representation to be done with a negligible amount of failures. The Weibull distribution's strong point is its adaptability. Depending on the parameters' values, the Weibull distribution can approximate an exponential, a normal or a twisted distribution.

Table4: Elements reliability data

Element	Failure rate		Duration		
	Permanent	Active	Permanent	Maintenance	Switching
Busbar	0.001	0.001	2.0	1.0	0.0
Cir.Breaker	0.02	0.02	24	1.0	0.0
Transformer	0.015	0.015	15	1.0	0.0
Disc.Switch	0.002	0.002	4.0	1.0	0.0

Table5: Load Reliability Data

Load at	Failure Frequency[1/yr]	Duration[h]
Bus 2	0.47	**1**
Bus 3	0.216	**1**
Bus 4	0.855	**1**
Bus 5	0.002	**5**
Bus 6	1.002	**9.989**

Weibull Distribution Formula

In probability theory and statistics, the Weibull distribution is a continuous probability distribution and can be calculated from the following formula

$$F(x) = 1 - e^{-\left(\frac{x}{\alpha}\right)^{\beta}} \quad \ldots\ldots(1)$$

The Weibull factor B (beta) is the slope. It implies the rate of failure. The Weibull shape factor β designates whether the failure rate is increasing, constant or decreasing. When β < 1.0 designates that the product has a decreasing failure rate. This scenario is typical of infant mortality and indicates that the product is failing during its burn-in period. When β = 1.0 designates a constant failure rate. Frequently, components that have survived burn-in will subsequently exhibit a constant failure rate. The β > 1.0 designates an increasing failure rate. This is typical of products that are wearing out.

Aging Failure Rate:

The Value of η is calculated from the following formula:

η = 1000000/(FailureRate*EXP(GAMMALN(1+1/Shape Parameter(β))))

Failure Rate Calculation Formula= $\left(\frac{\beta}{\eta}\right)\left(\frac{t}{\eta}\right)^{\beta-1}$

Where β = Shape parameter

η = Scale parameter

Table 6: Aging Failure rate for Aging of Tx's

Time(hr)	β =0.5	β =1.0	β =1.5
t=8760$\times$1	0.087	0.015	0.00236
t=8760$\times$5	0.039	0.015	0.00527
t=8760$\times$10	0.027	0.015	0.00746
t=8760$\times$15	0.022	0.015	0.00913
t=8760$\times$20	0.019	0.015	0.0105
t=8760$\times$25	0.017	0.015	0.0118
t=8760$\times$30	0.016	0.015	0.0124
t=8760$\times$35	0.015	0.015	0.0139
t=8760$\times$40	0.014	0.015	0.0149

Aging Repair Rate:

The Value of θ is calculated from the following formula:

θ = 1000000/(Failure Rate*EXP(GAMMALN(1+1/Shape Parameter(α))))

Repair Rate Calculation Formula= $\left(\frac{\alpha}{\theta}\right)\left(\frac{t}{\theta}\right)^{\beta-1}$

Where α = Shape parameter

θ = Scale parameter

Table 7: Aging Repair rate for Aging of Tx's

Time(hr)	θ =0.5	θ =1.0	θ =1.5
t=8760×1	2.73	15	0.000115
t=8760×5	1.22	15	0.000257
t=8760×10	0.866	15	0.000363
t=8760×15	0.707	15	0.000445
t=8760×20	0.612	15	0.000513
t=8760×25	0.547	15	0.000574
t=8760×30	0.500	15	0.000629
t=8760×35	0.463	15	0.000679
t=8760×40	0.433	15	0.000726

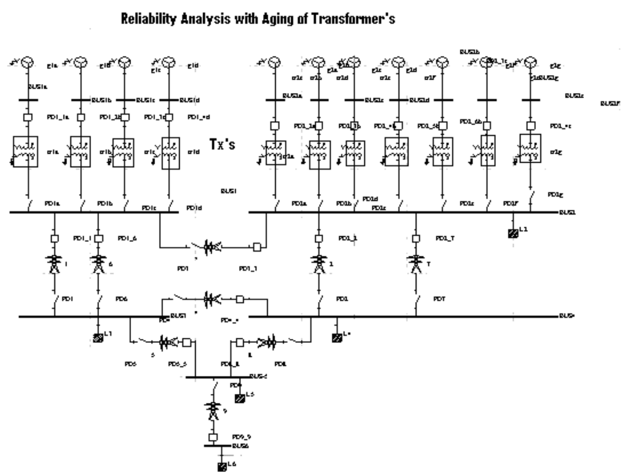

Fig 2: One line diagram of RBTS system in SKM's PTW 6.5 for aging of Tx's

Case 3a: Non repairable aging failure for β =0.5

A nonrepairable aging failure for β **=0.5** refers to a random fatal failure in the normal operating stage of the life basin curve. Obviously, it corresponds to a decreasing failure rate and therefore can be modeled using an exponential distribution.

Table 8: EENS Value for Aging of Tx's for β =0.5

Time (hr)	Reliability Analysis EENS (Kwh/year) Value for Aging of Tx's for β =0.5				
	L2	L3	L4	L5	L6
0	8855688.94	820.60	7000745.07	81967029.91	85576849.91

1	8855688.93	820.56	7000464.56	81966403.38	95575902.39
5	8855688.89	820.39	6999336.69	81963884.14	95572092.43
10	8855688.83	820.16	6997913.76	81960705.56	95567285.30
15	8855688.78	819.92	6996476.30	81957494.17	95562428.51
20	8855688.71	819.66	6995024.31	81954249.97	95557522.07
25	8855688.65	819.38	6993557.79	81950972.97	95552565.98
30	8855688.59	819.12	6992358.74	81948293.37	95548513.37
35	8855688.59	819.12	6992358.74	81948293.37	95548513.37
40	8855688.59	819.12	6992358.74	81948293.37	95548513.37

Case3b: Nonrepairable Chance Failure

A nonrepairable chance failure refers to a random basin curve. Obviously, it corresponds to a constant failure rate and therefore can be modeled using an exponential distribution. fatal failure in the normal operating stage of the life .

Table 9: EENS Value for Aging of Tx's for β =1

Time(hr)	Reliability Analysis EENS(Kwh/year) Value for Aging of Tx's for β =1				
	L2	L3	L4	L5	L6
0	8855688.94	820.60	2065266.86	81867494.39	95477314.39
1	8855688.94	820.60	2065266.86	81867494.39	95477314.39
5	8855688.94	820.60	2065266.86	81867494.39	95477314.39
10	8855688.94	820.60	2065266.86	81867494.39	95477314.39
15	8855688.94	820.60	2065266.86	81867494.39	95477314.39
20	8855688.94	820.60	2065266.86	81867494.39	95477314.39
25	8855688.94	820.60	2065266.86	81867494.39	95477314.39
30	8855688.94	820.60	2065266.86	81867494.39	95477314.39
35	8855688.94	820.60	2065266.86	81867494.39	95477314.39
40	8855688.94	820.60	2065266.86	81867494.39	95477314.39

Case3c: Wear Out Period

A nonrepairable wear out failure refers to a random fatal failure in the normal operating stage of the life basin curve. Obviously, it corresponds to a increasing failure rate and therefore can be modeled using an exponential distribution.

Table 10: EENS Value for Aging of Tx's for β =1.5

Time(hr)	Reliability Analysis EENS(Kwh/year) Value for Aging of Tx's for β =1.5				
	L2	L3	L4	L5	L6
0	8855688.94	820.60	2065266.86	81867494.39	95477314.39
1	8855689.41	822.60	2065267.87	81867494.89	95477314.89
5	8855690.81	828.56	2065270.89	81867496.40	95477316.40
10	8855691.82	832.84	2065273.07	81867497.49	95477317.49
15	8855692.49	835.69	2065274.51	81867498.21	95477318.21
20	8855693.24	838.87	2065276.12	81867499.02	95477319.02
25	8855694.36	843.63	2065278.54	81867500.23	95477320.23
30	8855696.03	850.74	2065282.14	81867502.03	95477322.03
35	8855698.31	860.43	2065287.06	81867504.49	95477324.49
40	8855701.13	872.40	2065293.13	81867507.52	95477327.52

III. RESULTS & DISCUSSION

From the Reliabilty analysis we get the life basin curve by plotting EENS value with time for α=0.5, α=1.0, α=1.5.

IV. CONCLUSION

In this thesis work, method has been presented to calculate reliability of composite system by calculating probability and frequency of failure of system under different conditions.

This area of composite power system reliability evaluation is least developed and also one of the most complicated but in view of environmental, ecological, societal and economic constraints faced by most of power utilities, this area is developing and getting attention in international market.

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