UNIT- VII

Composite Transmission System Reliability Analysis

System and load point Indices :-

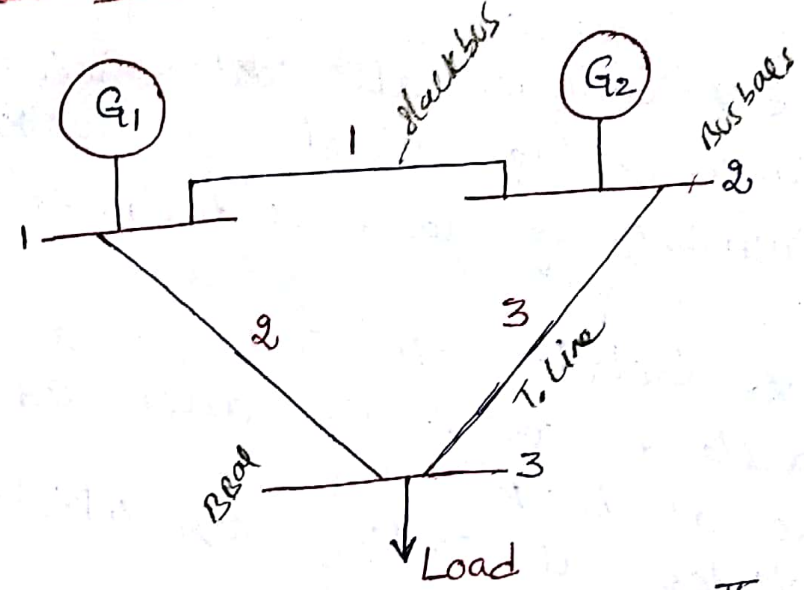

Figure shows a simple configuration. The basic parameters are the probability and frequency of failure at the individual load points, but additional indices can be created from these generic values.

If the indices are calculated for a single load level and expressed on a base of one year, they should be designated as annualized values. (Annualized indices calculated at the system peak load level are usually much higher than the actual ~~load~~ annual indices.) The indices can be calculated using the following equations,

probability of failure $Q_K = \sum_j P_j P_{Kj}$

Frequency of failure $F_K = \sum_j F_j P_{Kj}$

where j is an outage condition in the N/w

P_j is the probability of existence of outage j

F_j is the frequency of occurrence of outage j

P_{Kj} is the probability of the load at bus K exceeding the max load that can be supplied at that bus during the outage j

Expected number of voltage violations $= \sum_{j \in v} F_j$

where $j \in v$ includes all contingencies which cause voltage violation at bus K

Expected number of load curtailments $= \sum_{j \in x, y} F_j$

where $j \in x$ includes all positive of event probability contingencies resulting in line overloads which are ~~alleviated~~ reduced by load curtailment at bus K

$j \in y$ includes all contingencies which result in an isolation of bus K

Expected Load Curtailed $= \sum_{j \in x, y} L_{Kj} F_j$ MW

where L_{Kj} is the load curtailment at bus K to ~~alleviate line overloads~~ reduce arising due to the contingency j (or) the load not supplied at an isolated bus K due to the contingency j)

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Expected Energy Not Supplied

$$= \sum_{j \in x, y} L_{Kj} D_{Kj} F_j \text{ MWh}$$

$$= \sum_{j \in x, y} L_{Kj} P_j \times 8760 \text{ MWh}$$

where D_{Kj} is the duration in hours of the load curtailment arising due to the outage j (or) the duration in hours of the load curtailment at an isolated bus K due to outage j.

Expected Duration of Load Curtailment

$$= \sum_{j \in x_i y} D_{Kj} F_j \text{ hrs}$$

$$\text{reduction} = \sum_{j \in x_i y} P_j \times 8760 \text{ hrs}$$

Max. load Curtailed (limited) $= \text{Max} \{ L_{K_1}, L_{K_2} \ldots\ldots L_{Kj}, \ldots \}$

Max. energy curtailed $= \text{Max} \{ L_{K_1} D_{K_1}, L_{K_2} D_{K_2} \ldots L_{Kj} D_{Kj}, \ldots \}$

Max duration of load curtailment

$$= \text{Max} \{ D_{K_1}, D_{K_2}, \ldots D_{Kj}, \ldots \}$$

Average load curtailed $= \dfrac{\sum_{j \in x_i y} L_{Kj} F_j}{\sum_{j \in x_i y} F_j}$ MW/curtailment

Average Energy Not Supplied

$$= \frac{\sum_{j \in x_i y} L_{Kj} D_{Kj} F_j}{\sum_{j \in x_i y} F_j} \text{ MWh/curtailment}$$

Average duration of Curtailment

$$= \frac{\sum_{j \in x_i y} D_{Kj} F_j}{\sum_{j \in x_i y} F_j} \text{ hours/curtailment}$$

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* Indices due to the isolation of bus K

Expected number of curtailments $= \sum_{j \in y} F_j$

Expected load curtailed $= \sum_{j \in y} L_{Kj} F_j$ MW

Expected Energy Not Supplied

$$= \sum_{j \in y} L_{Kj} D_{Kj} F_j$$

$$= \sum_{j \in y} L_{Kj} P_j \times 8760 \text{ MWh}$$

Expected duration of load curtailment

$$= \sum_{j \in y} D_{Kj} F_j$$

$$= \sum_{j \in y} P_j \times 8760 \text{ hrs}$$

Weather Effects on Transmission Lines :-

(a) The weighted Average-Rate Model :-

1. The rate of failures of a transmission line depends to a large extent on the weather conditions to which the line is exposed.
2. The weather is often modeled as a two-state environment consisting of alternating normal and severe periods. In this representation all the various types of severe weather are pooled into a single condition.

3. The simplest way of accounting for the effects of changing weather is to use modified failure and repair rates for the transmission lines, that are weighted averages of the corresponding normal and severe-weather rates.

4. If the failure and repair rates of a line are λ and μ during normal weather and λ' and μ' during severe weather, and if the mean duration of normal weather is T_N, and that of severe weather is T_w.

Then weighted average failure rate for the line can be defined as

$$\lambda^* = \frac{T_N}{T_N + T_w}\lambda + \frac{T_w}{T_N + T_w}\lambda'$$

The weighted repair rate μ^* is the reciprocal of the weighted mean repair time T_r^*

$$T_r^* = \frac{\lambda T_N T_r + \lambda' T_w T_r'}{\lambda T_N + \lambda' T_w}$$

where $T_r = \frac{1}{\mu}$ and $T_r' = \frac{1}{\mu'}$

$$\mu^* = \frac{\lambda T_N + \lambda' T_w}{\frac{\lambda}{\mu} T_N + \frac{\lambda'}{\mu'} T_w} = \frac{1}{T_r^*}$$

Application :-

1. It can be used for the evaluation of single failures.
2. Multiple failures can be evaluated by this approach only if the lines involved are

exposed to weather conditions that are independent of each other.

(b) The Two-Weather Markov Model :-

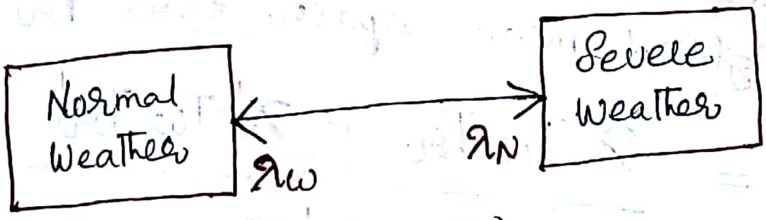
In the state-space approach, the fluctuating weather environment is represented by a two-state Markov Model [Fig(a)].

Assuming exponential distribution for the normal and severe weather durations, the transition rates are

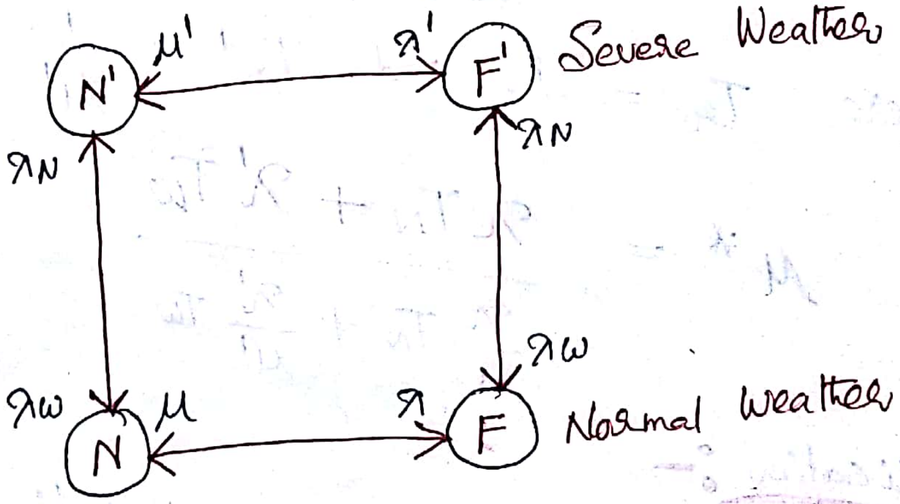
$$\lambda_N = \frac{1}{T_N} \quad , \quad \lambda_W = \frac{1}{T_W}$$

λ_N is equal to the frequency of the severe weather periods.

Assuming that the weather cycles are independent of the component failures and repairs.



Fig(a)



Fig(b)

A single component in a two-weather environment shown in fig (b). The state probabilities are :

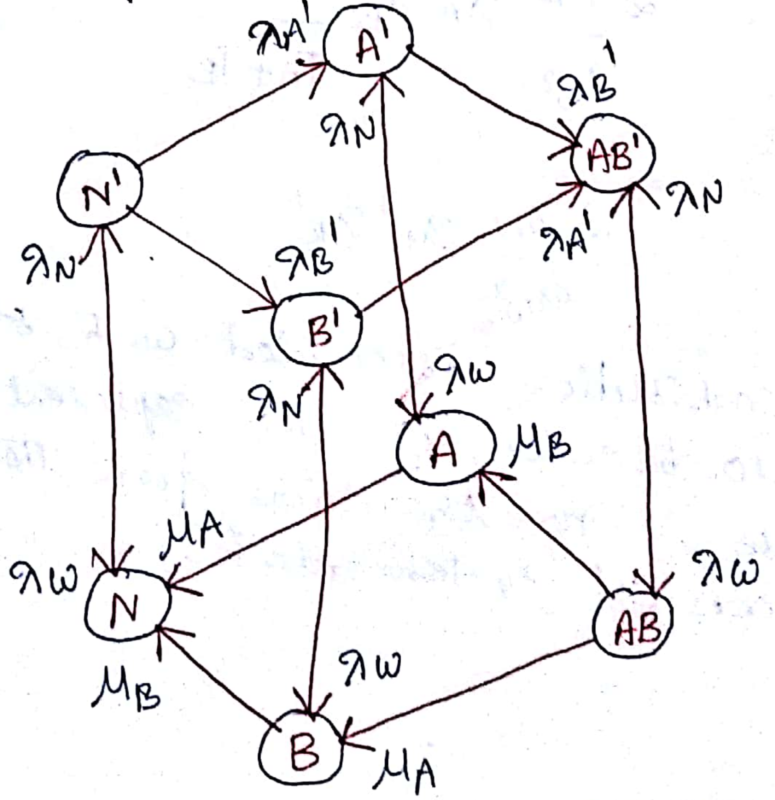
$$P_N = \frac{\lambda_\omega D}{\lambda_N [A+C] + \lambda_\omega [B+D]}$$

$$P_N' = P_N \frac{\lambda_N A}{\lambda_\omega D} \qquad P_F = P_N \frac{B}{D} \qquad P_F' = P_N \frac{\lambda_N C}{\lambda_\omega D}$$

Where
$$A = \mu \lambda_\omega + \mu' [\lambda + \lambda_N + \mu]$$
$$B = \lambda' \lambda_N + \lambda [\lambda' + \lambda_\omega + \mu']$$
$$C = \lambda \lambda_\omega + \lambda' [\lambda + \lambda_N + \mu]$$
$$D = \mu' \lambda_N + \mu [\lambda' + \lambda_\omega + \mu']$$

Using above formulae, the single-failure probabilities and frequencies can be easily determined.

In order to evaluate double failures, a two-component two weather model shown in fig. for independent components A and B.



UNIT-VIII

※ DISTRIBUTION SYSTEM RELIABILITY ANALYSIS

Relative importance of distribution system is relatively cheap and outages have a very localized effect i.e., less effort has been devoted to quantitative assessment of the adequacy of various alternative designs.

1. Basic Reliability Indices.

EVALUATION TECHNIQUES :-

A radial distribution system consists of a set of series components, including lines, cables, disconnects (or isolators), busbars etc.

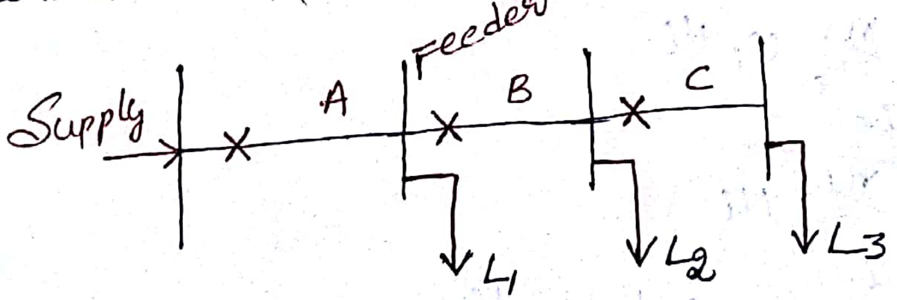
Three basic reliability parameters are average failure rate λ_s, average outage time r_s, average annual outage time U_s.

$$\lambda_s = \sum_{i=1}^{n} \lambda_i$$

$$U_s = \sum_{i=1}^{n} \lambda_i r_i$$

$$r_s = \frac{U_s}{\lambda_s} = \frac{\sum_{i=1}^{n} \lambda_i r_i}{\sum_{i=1}^{n} \lambda_i}$$

Consider the Radial feeder shown in Fig. 1



2. Addition Interruption Indices :-

Failure rate, outage duration, annual outage time is not deterministic values but are the expected or average values of an underlying probability distribution.

The three primary indices are fundamentally important but they donot always give a complete representation of the system behaviour and response.

(a) Customer - Oriented Indices :-

1. SAIFI [System Average Interruption Frequency Index]

$$SAIFI = \frac{\text{Total No. of customers interruptions}}{\text{Total No. of customers served}}$$

$$= \frac{\sum_{i=1}^{n} \lambda_i N_i}{\sum_{i=1}^{n} N_i}$$

where λ_i = Failure Rate

N_i = Number of customers of load point i

2. SAIDI [System Average Interruption Duration Index]

$$SAIDI = \frac{\text{Sum of Customer interruption durations}}{\text{Total Number of Customers}}$$

$$= \frac{\sum_{i=1}^{n} U_i N_i}{\sum_{i=1}^{n} N_i}$$

Where U_i = Annual Outage Time

N_i = Number of customers of load point i

3. CAIFI [Customer Average Interruption Frequency Index]

$$\text{CAIFI} = \frac{\text{Total Number of Customer Interruptions}}{\text{Total Number of Customers affected.}}$$

$$= \frac{\sum_{i=1}^{K} \lambda_i N_i}{\sum_{i=1}^{K} N_{ai}}$$

4. CAIDI [Customer Average Interruption Duration Index]

$$\text{CAIDI} = \frac{\text{Sum of Customer interruption duration}}{\text{Total Number of Customer Interruptions}}$$

$$= \frac{\sum_{i=1}^{K} U_i N_i}{\sum_{i=1}^{K} \lambda_i N_i} = \frac{\text{SAIDI}}{\text{SAIFI}}$$

5. ASAI [Average Service Availability Index]

$$\text{ASAI} = \frac{\text{Customer hours of available service}}{\text{Customer hours demanded.}}$$

$$= \frac{\sum_{i=1}^{K} N_i \times 8760 - \sum_{i=1}^{K} U_i N_i}{\sum_{i=1}^{K} N_i \times 8760.}$$

$$ASUI = 1 - ASAI$$

Average Service Unavailability Index

$$= \frac{\sum_{i=1}^{K} U_i N_i}{\sum_{i=1}^{K} N_i \times 8760}$$

(b) Load and Energy Oriented Indices :-

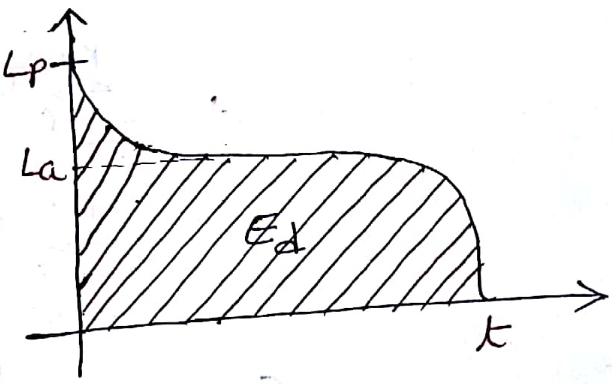
The average load $L_a = L_p K$

where L_p = peak load demand

K = load factor

$$L_a = \frac{\text{Total energy demanded over a period of interest}}{\text{period of interest}}$$

$$= \frac{E_d}{t}$$



where E_d and t are shown on the load duration curve of fig. and t is normally one calendar year.

1. ENSI [Energy Not Supplied Index]

ENSI = Total energy not supplied by the system

$$= \sum_{i=1}^{K} L_{a_i} U_i$$

where $L_{a(i)}$ is the average load connected to load point i

2. AENS [Average Energy Not Supplied Index] (or)

ASCI [Average System Curtailment Index]

$$AENS = \frac{\text{Total energy not supplied}}{\text{Total Number of Customer served}}$$

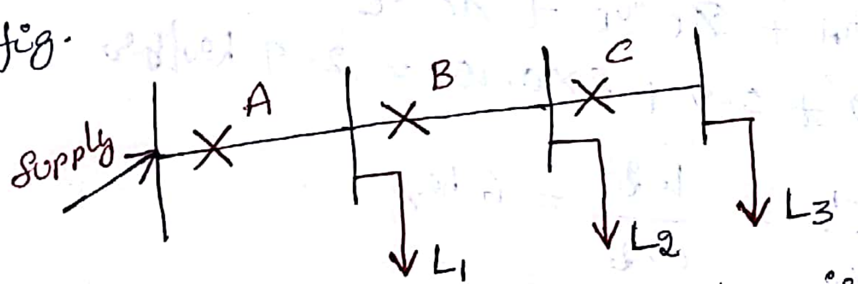
$$= \frac{\sum_{i=1}^{K} L_{ai} U_i}{\sum_{i=1}^{K} N_i}$$

3. ACCI [Average Customer Curtailment Index]

$$ACCI = \frac{\text{Total energy not supplied}}{\text{Total Number of Customers affected.}}$$

Problem :-

1. Consider a 3 load point radial system shown in fig.



Component data for this system is.

Line No.	λ f/yr	r hrs	No. of customers (N_i)	Avg. load demand in (KW) L_{ai}	Load point L_i
			200	1000	L_1
A	0.2	6	150	700	L_2
B	0.1	5	100	400	L_3
C	0.15	8			

1. Evaluate the load point reliability indices.
2. Obtain various customer oriented, load and energy oriented indices of the above system.

Sol 1. Load point reliability indices :-

$$\lambda_S = \sum_{i=1}^{K} \lambda_i$$

$$U_S = \sum_{i=1}^{K} r_i \lambda_i$$

$$r_S = U_S / \lambda_S$$

From fig. $\lambda_{L_1} = \lambda_A = 0.2$

$$\lambda_{L_2} = \lambda_A + \lambda_B = 0.2 + 0.1 = 0.3$$

$$\lambda_{L_3} = \lambda_A + \lambda_B + \lambda_C$$
$$= 0.2 + 0.1 + 0.15 = 0.45$$

$$U_{L_1} = \lambda_A r_A = 0.2 \times 6 = 1.2 \text{ hr/yr}$$

$$U_{L_2} = \lambda_A r_A + \lambda_B r_B = 1.2 + 0.5 = 1.7 \text{ hr/yr}$$

$$U_{L_3} = \lambda_A r_A + \lambda_B r_B + \lambda_C r_C$$
$$= 1.2 + 0.5 + 8 \times 0.15 = 2.9 \text{ hr/yr}$$

$$r_{L_1} = \frac{U_{L_1}}{\lambda_{L_1}} = \frac{1.2}{0.2} = 6 \text{ hrs}$$

$$r_{L_2} = \frac{U_{L_2}}{\lambda_{L_2}} = 5.67 \text{ hrs}$$

$$r_{L_3} = \frac{U_{L_3}}{\lambda_{L_3}} = 6.44 \text{ hrs}$$

2. Customer Oriented Indices :-

1. SAIFI $= \sum_{i=1}^{K} \lambda_i N_i \Big/ \sum_{i=1}^{K} N_i$

$$= \frac{\lambda_{L1} N_{L1} + \lambda_{L2} N_{L2} + \lambda_{L3} N_{L3}}{N_{L1} + N_{L2} + N_{L3}}$$

$$= \frac{0.2 \times 200 + 0.3 \times 150 + 0.45 \times 100}{450}$$

$= 0.289$ int./cust. in yr.

2. SAIDI $= \sum_{i=1}^{K} U_{Li} N_i \Big/ \sum_{i=1}^{K} N_i$

$$= \frac{U_{L1} N_{L1} + U_{L2} N_{L2} + U_{L3} N_{L3}}{N_{L1} + N_{L2} + N_{L3}}$$

$= 1.74$ hrs/cust. in yr.

3. CAIDI $= \sum_{i=1}^{K} U_i N_i \Big/ \sum_{i=1}^{K} \lambda_i N_i$

$$= \frac{SAIDI}{SAIFI} = \frac{1.74}{0.289} = 6.02 \text{ hrs/cust. yr.}$$

4. ASAI $= \dfrac{\sum_{i=1}^{K} N_i \times 8760 - \sum_{i=1}^{K} U_i N_i}{\sum_{i=1}^{K} N_i \times 8760}$

$$= \frac{[N_{L1} + N_{L2} + N_{L3}] \times 8760 - [U_{L1} N_{L1} + U_{L2} N_{L2} + U_{L3} N_{L3}]}{[N_{L1} + N_{L2} + N_{L3}] \times 8760}$$

$$= \frac{[200 + 150 + 100] \times 8760 - [1.2 \times 200 + 1.7 \times 150 + 2.9 \times 100]}{[200 + 150 + 100] \times 8760}$$

ASAI = 0.999801

ASUI = 1 - 0.999801 = 0.000199.

3. Load and Energy Indices :-

1. $ENSI = \sum_{i=1}^{K} La_i U_i$

$= La_1 U_{L1} + La_2 U_{L2} + La_3 U_{L3}$

$= 100 \times 1.2 + 700 \times 1.7 + 400 \times 2.9$

$= 3550$ Kwhr/yr.

2. $AENS = \dfrac{ENSI}{\sum_{i=1}^{K} N_i} = \dfrac{3550}{200 + 150 + 100}$

$= 7.89$ Kwh / cust. in yr.

—x—

UNIT - VII

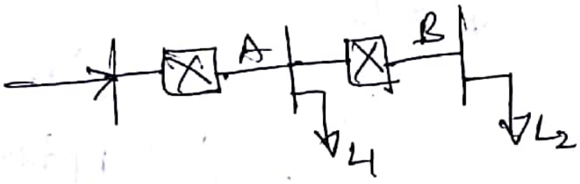
1. Explain the reliability indices in Composite system reliability analysis.
2. Explain the two-weather markov model for weather effects on transmission line problems.
3. Explain the weighted-average-rate-model for the evaluation of weather effects on transmission lines.
4. Explain how the effect of changing weather conditions are modelled.

UNIT - VIII

1. Explain how the distribution system reliability analysis is performed for radial networks.
2. Explain customer, load and energy oriented reliability indices of distribution system.
3. Explain the reliability indices for radial networks in distribution systems.

DSRA (U-VIII)

1.) Consider a 2 load point radial distribution system shown in fig.



Line No.	λ (f/yr)	r (hrs)	No. of customers	Avg demand (kW)	Load points
A	0.12	4	175	750	L_1
B	0.25	7	225	550	L_2

(1) Evaluate the load point reliability indices.

(2) obtain performance indices.

U-VI

1. A generating system consists of 2 units of 30 MW capacity each with a $\lambda = 0.04$ f/yr and $\mu = 0.96$ r/yr. The daily peak loads observed are found to be as follows.

Daily peak load (MW)	% time the peak has occurred
50	30
40	40
30	20
20	10

Estimate LOLP.

UNIT VII

→ Two identical transmission lines operate in a two-weather environment with a mean normal weather of 10 days and mean severe weather duration of 0.1 days. The line failure rate is 0.0002/day in normal weather and 0.05/day in severe weather. The repair rate is 1.0/day. Calculate the probability of double failure using weighted average method.

Sol Using the weighted average rate

$$\lambda^* = \frac{T_N}{T_N + T_W}\lambda + \frac{T_W}{T_N + T_W}\lambda'$$

Given. $T_N = 10$ days $\quad \lambda' = 0.05/day$

$T_W = 0.1$ day $\quad \mu = \mu' = 1/day.$

$\lambda = 0.0002/day$

$$\lambda^* = \frac{10}{10+0.1} \cdot 0.0002 + \frac{0.1}{10+0.1} 0.05$$

$$= 0.0007/day$$

$$\mu^* = \frac{1}{\mu} = 1/day.$$

probability P_2^* of a double failure becomes

$$P_2^* = \left[\frac{\lambda^*}{\lambda^* + \mu^*}\right]^2$$

$$= \left[\frac{0.0007}{0.0007+1}\right]^2$$

$$= 4.9 \times 10^{-7}$$

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