Problems

1 Reconsider Problem 1 of Chapter 9. Evaluate the frequency of encountering and duration of residing in each of the three states.

2 Reconsider Problem 3 of Chapter 9. Evaluate the frequency of encountering and duration of residing in each possible throughput state for the single and two pump cases.

3 Evaluate the frequency and duration of each possible throughput state for the single pump case of Problem 3 of Chapter 9, if an identical pump is carried as a spare which has an installation rate of 10 repl/hr. Assume there are no restrictions on installation or repair.

4 A repairable system contains three different units, and all must operate for system success. If one unit fails, no further failures can occur until the failed unit is repaired and the system placed back into service. Develop an expression for the probability of the system being in the operable state and calculate the frequency of encountering the failed state. What is the average duration of a failed state? Use the expressions to calculate the probability, frequency and duration of failure if all units are identical and have a failure rate of 1 f/yr and a repair rate of 100 repairs/yr.

5 A system contains two components. Both components are required for system success. If one component fails, the other cannot fail while the failed component is being repaired. If the component failure and repair rates are λ_1, λ_2, μ_1 and μ_2 respectively, determine the probability of failure, the frequency of failure and the average downtime of the system. Evaluate these indices if $\lambda_1 = \lambda_2 = 0.1$ f/yr and $\mu_1 = \mu_2 = 365$ repairs/yr.

6 Evaluate the same indices for the system described in Problem 5 if both components are identical and a similar component is carried as a spare having an average installation time of 1 hr.

7 Use the frequency balance approach to evaluate the frequency of encountering and duration of residing in each of the states shown in Figure 10.12 where rates are expressed in occurrences/yr.

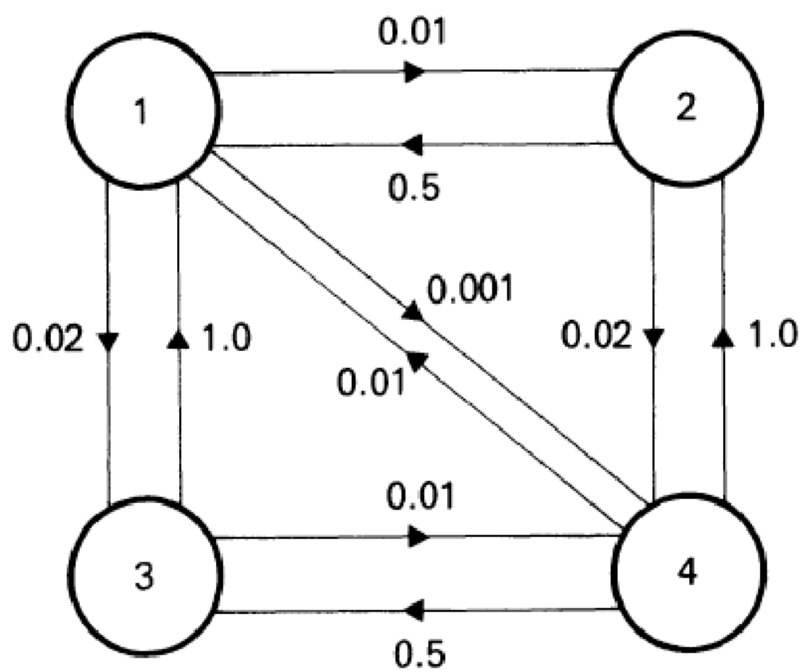

Fig. 10.12

8 A repairable system contains three components. Components 2 and 3 are in parallel and both are required for subsystem success. Component 1 is in series with the parallel combination of 2 and 3. If the system fails, no further failures can occur until the system is placed back in service. Develop expressions for the probability of the system being in the failed state and the frequency of encountering the failed state. Use your expressions to calculate the probability and frequency if $\lambda_1 = 0.5$ f/yr, $\lambda_2 = 1.0$ f/yr, $\lambda_3 = 1.5$ f/yr and $\mu_1 = \mu_2 = \mu_3 = 25$ r/yr. What is the reliability of this system for a 1000-hr mission?

9 The state space diagram shown in Figure 10.13 represents a system containing two components, A and B. The operational constraints are as follows

(a) The system is completely successful if both A and B are operating.
(b) The system enters a derated state if A fails.
(c) The system is completely failed if B fails.

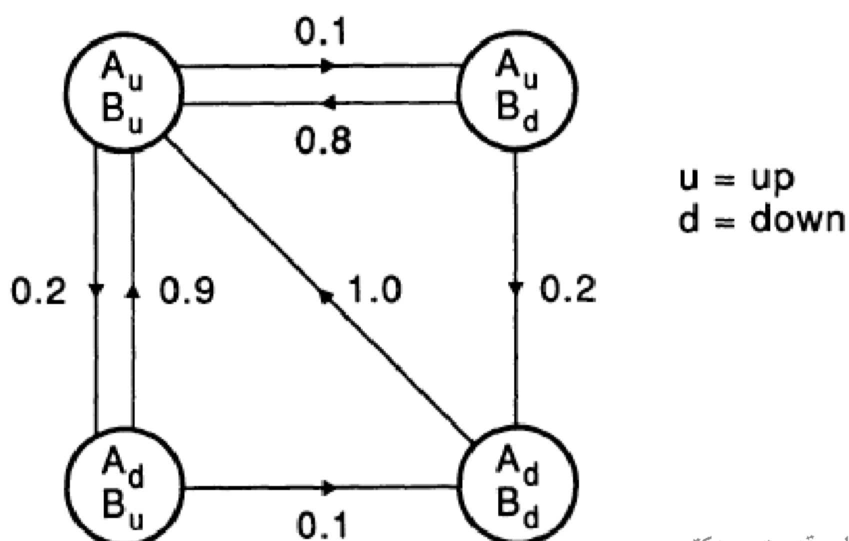

Fig. 10.13

Briefly describe distinctive features of the failure/repair process illustrated in the state space diagram in which the transition rates are expressed as failures/yr. Calculate the limiting values for probability of residing, frequency of encountering and average duration of:

(i) each of the four states;
(ii) the derated state;
(iii) the completely failed state.

10 A system consists of three identical components, two of which must function for system success. All components are repairable but, owing to manpower resources, only one failed component can be repaired at a time. Using a Markov approach, deduce expressions for system unavailability, frequency of system failure and MTTF. Evaluate the unavailability, frequency and MTTF if the component failure rate is 1 f/yr and the component repair time is 24 hr.

11 A particular component operates under the following conditions and assumptions:

(a) One identical component acts as a spare for the operating component and this can be installed with an installation rate γ.
(b) The component has a failure rate λ whilst operating but cannot fail whilst acting as a spare.

(c) When the operating component fails and a spare is available, the spare is installed before repair of the failed component is started.
(d) A failed component is repaired at a rate μ, following which it is used as the spare.
(e) There is no restriction on the number of repairs that can be done simultaneously.

Derive expressions for probability of residing in the down state, frequency of encountering the down state, and the average down time.

12 A repairable system consists of two repairable components for which one spare servicing both components is available. The system characteristics are as follows:

(a) The system is successful only when both components are operating.
(b) When the system enters its failure state, it is de-energised and no subsequent component failures can occur until the system returns to its operating state.
(c) When the system fails and a spare is available, this spare is installed before repair is commenced on the failed component.
(d) Owing to manpower restrictions, only one failed component can undergo repair at a time.
(e) State residence times are exponentially distributed.
(f) Component failure rate is 1 f/yr, average repair time is 50 hr and average installation time is 2 hr.

Construct the state space diagram and hence evaluate the limiting state values for system unavailability, frequency of failure, and average down time.