Maintenance modelling using Petri Nets

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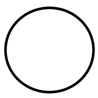
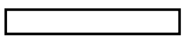
Abstract:

Maintenance modeling is one of the true indicators of the plant availability and reliability of the repairable systems. The effective maintenance modeling effects the efficiency of the plant and also enhances the customer satisfaction. Hence there is need to effectively plan the maintenance strategies and their effective implementation. From few years Petri Net has emerged as a powerful tool for modeling a system. Therefore, this paper aims to use the Petri net for modeling of a repairable systems. This paper focuses on the modeling the repairable systems with preventive maintenance as a main maintenance policy.

1. Introduction

According to [1] the poorly continued systems may frequently lead to recurrent failures and poor utilization of equipment or machinery which results in loss in production and increases the unavailability of the plant. On other hand the effective maintenance planning reduces the predicament of the production and better machinery or equipment utilization. The business leaders must comprehend the importance of maintenance function [2]. Moreover, inappropriate maintenance modeling can cause the frequent failure of system which hinders in achieving the production goals. These days the concept of maintenance planning has changed from fix it when broken to implement effective preventive maintenance planning. Many tools have been suggested by various authors for maintenance modeling. This paper presents maintenance modeling by using graphical modeling tool Petri net.

Petri Nets have emerged as a powerful modeling tool which contains places, transitions and arcs which represented by circles, rectangles and arrow heads respectively [3,4]. The places represent the events and transitions represents conditions to fire the events. The basic symbols are described as follows:

 PLACE	Place represents conditions of an event
 TRANSITION	Transitions represents the event of a system. Firing of an transition leads to change in state of system

→ ARC	Arc represents the relation between place and transition.
● TOKEN	Tokens used to represent the current state of the system. Place holding token represents the working state of system.

2.Petri Net Model of a four-unit system

A simple example of four-unit system is considered below for Petri net modeling.

Consider a four-unit system (A, B, C, and D) for which configuration is shown in Figure 1.

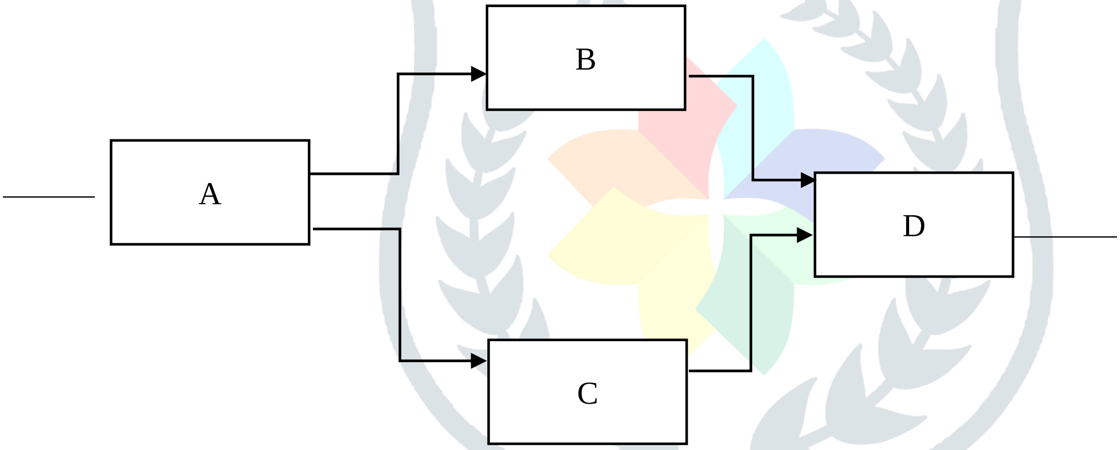


Figure 1. Four-unit repairable system

The system is in working state when unit A works and either of unit B or unit C and D works. The system fails when either unit A fails, or all the units B, C and D fails. The Petri net model is illustrated in Figure 2. In the Petri net model, the tokens associated with ($P_{A\_Working}$, $P_{B\_Working}$, $P_{C\_Working}$, $P_{D\_Working}$) shows that the unit A, B, C, and D are working. ($P_{A\_under\ repair}$,$P_{B\_under\ repair}$, $P_{C\_under\ repair}P_{D\_under\ repair}$) represents that the failed units are under repair.$P_{\_System\_Up}$ is marked with a token indicating the whole system is in working state and no failure has occurred yet. $P_{\_System\_down}$ indicates that the system is in downstate due to some faulty unit the firing of transitions associated with the failure event (i.e.T_1, T_3, T_5, and T_7) eliminates the token from the upstate condition of that unit and enhances a token to the places meant for repair ($P_{A\_under\ repair}$, $P_{B\_under\ repair}$, $P_{C\_under\ repair}P_{D\_under\ repair}$) of the respective units. The timed transitions T_1, T_3, T_5, andT_7 are related with the respective times to failure of the associated units. (t_1, t_2, t_3, t_4) are the immediate transitions. The transition T_1 will fire as soon as delay time has elapsed, the token from place $P_{A\_Working}$ moves to $P_{A\_Wait\_Repair,}$ thus enabling the guard condition at immediate transition t_5. This movement results in the removal of another token from place $P_{\_System\_Up}$ to Place $P_{_System_down}$and brings the system from upstate to downstate. The transition t_1 is enabled with the failure of unit

A (as both the places $P_{A\_Wait\_repair}$ and $P_{repairman}$contain token) and it fires immediately. The token is removed from places $P_{A\_Wait\_repair}$ and $P_{repairman}$ and is moved to place $P_{A\_under\ repair}$. The transitionT_2 gets enabled and after associated delay puts a back system in the upstate. The availability of the system is computed by the probability of the token in the $P_{\_System\_Up}$.

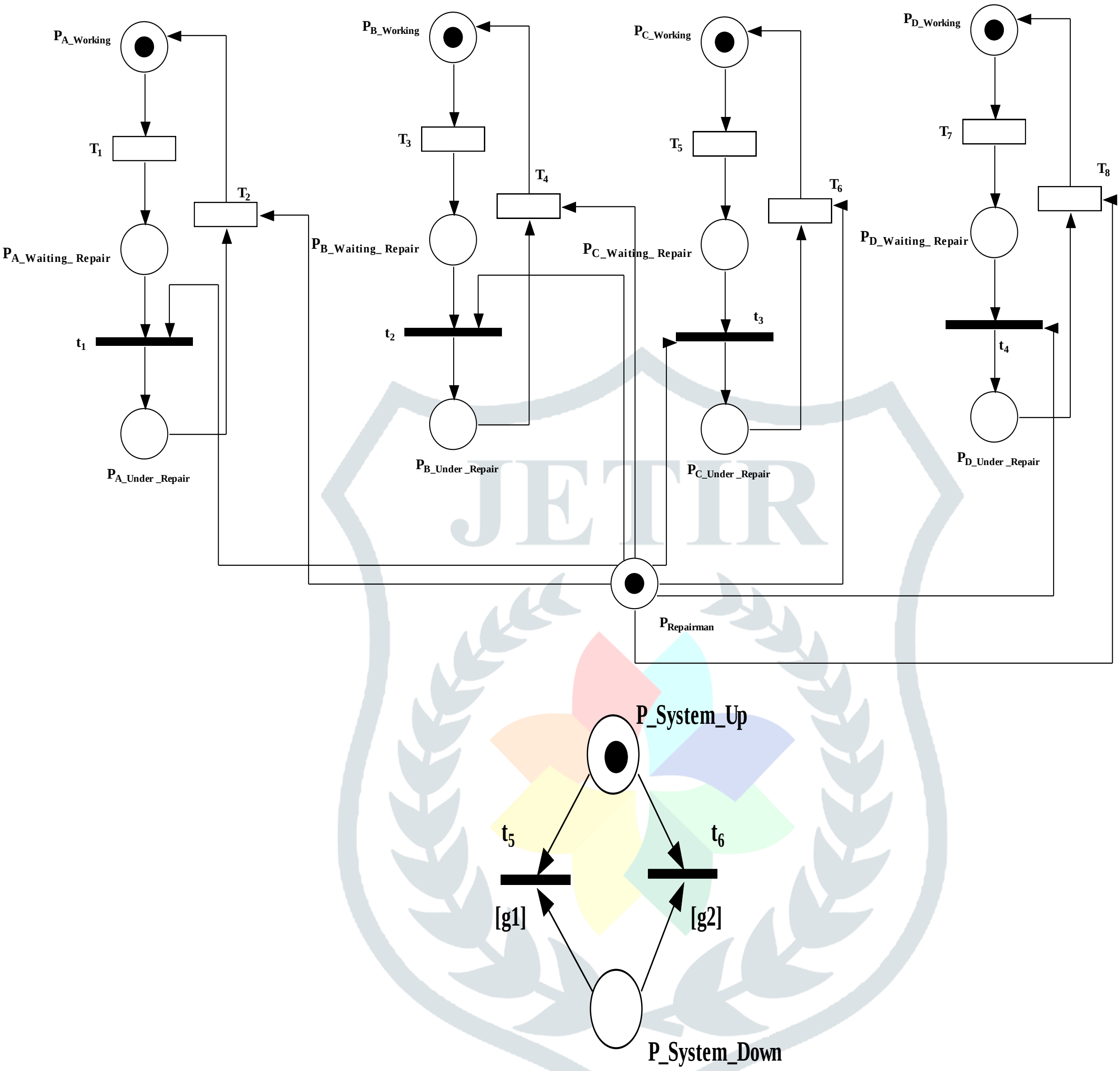


Figure 2. Petri Net Model of a repairable system

3.Preventive Maintenance (PM)

The key objective of carrying out PM is to decrease the recurrent and sudden intermittent failures by performing repairs and other maintenance activities such oiling, greasing etc and inspection of equipment's at rectangular intervals [5-7]. Therefore, PM decreases the probability of equipment failure by proper scheduling of preventive maintenance schedules [8,9].

4. Petri Net based Preventive maintenance modeling

Figure 3 shows the Petri net model for a single component when the component is subjected to Preventive maintenance schedules. The deterministic timed transition T3 and T4 are added in the model along with other regular transitions. The transition T3 has deterministic delay equals to T, which represents the preventive maintenance schedule for the component (as determined by equation given in section) and the transition T4 has deterministic delay equals to m, being the time to perform the preventive maintenance. Transition T1 represents the stochastic delays associated with the failure of the component. In the state shown in Figure 3, the transitions T1 and T3 are enabled due to presence of token at place P_{A_Work} and $P_{repairman}$. The transition T1 fires if the failure occurs before the scheduled maintenance. The transition T3 fires when the component undergoes preventive maintenance (PM) task before its failure. The delay associated with transition T1 is reset every time the component undergoes preventive maintenance, because it is assumed that the component becomes as good as new (AGAN) after going through preventive maintenance

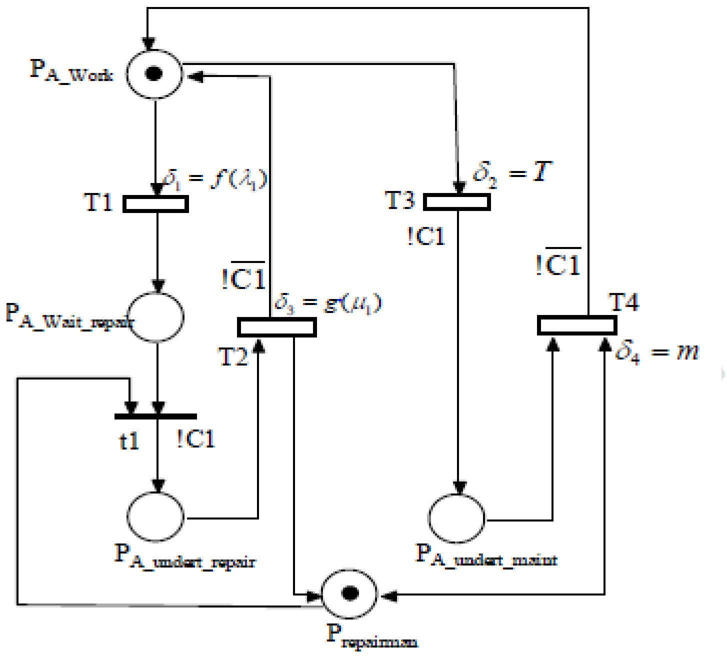


Figure 3. Simple Petri Net Model with Preventive maintenance

Conclusion

This paper presents the petri net modeling for preventive maintenance modeling of repairable system. An example of four-unit system is considered to represent the basic illustration of petri net modeling and simple Petri net model is presented to show the PM modeling. Petri Net modeling has been one of the dynamic graphical tools to study the behavior of the repairable systems. It is an interactive tool for examining the behavior of various components of a system under different conditions of failure and repair distribution patterns. This approach helps the maintenance/plant engineers for better planning for adopting maintenance activities in an effective manner.

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