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Title An insight into two methods for performance assessment of multi-state systems

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Context and objective of the paper

The a priori assessment of the so-called production availability [1] of an installation is an essential issue in industries such as oil production [2], power generation [3], manufacturing production, beside the more classical concepts of instantaneous availability and asymptotic availability. Production availability is a probabilistic measure of the production regularity of a system [4], i.e, its ability to maintain a given performance level as a function of time. If x_i is the production level in system state *i* and if *pi(t)* is the probability that the system lies in state *i* at time *t*, the production availability $<x>$ is generally expressed as

$$<x(t)> = \sum_i p_i(t).x_i$$

It is obvious that the previous notion is strongly related to the overall performance of multi-state systems, whose interest appeared through many papers recently published (see [5] for a review). The aim of this paper is to illustrate the concept of production availability on a simple example proposed by Electricité de France [3] and considered as an interesting test-case by the French Group of ESRA Technical Committee "Dependability Modelling". For the present work, this example has been treated by using both stochastic Petri nets and a high level description language known as Alta Rica Data Flow [6].

System description

The system mentioned above has been described in [3] as follows :
"The diagram of Fig.1 represents the system structure. The percentages represent the nominal capacities of the components of the system.

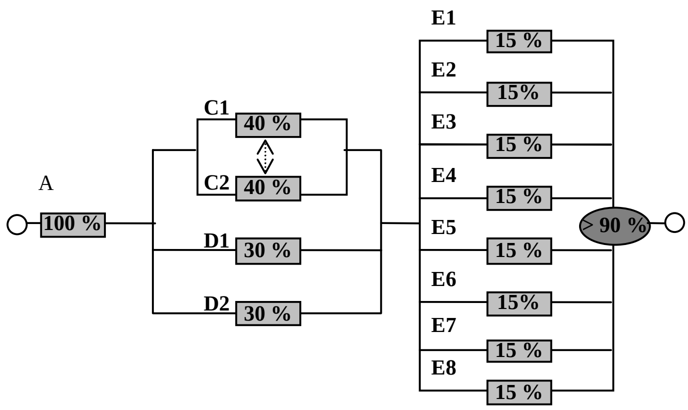

Fig : 1 Capacity diagram

Each component has two possible states, up and down, except for C_2, which has three states: standby (in this state, no failure is possible), up and down. The dotted arrow from C_2 towards C_1 means that C_2 is a standby redundant component, which should function only during down time of C_1.Moreover C_2 is assumed not to be subject of failure on demand.

The first parallel sub-system consists of two 40-percent-capacity components: C_1, C_2 and two 30-percent-capacity components: D_1, D_2. The second parallel sub-system consists of eight identical 15-percent-capacity components (E_1, E_2, . . , E_7, E_8). An *x*-percent-capacity operating component allows *x*-percent of the plant nominal output to be produced and 0 percent when it is failed. For parallel sub-systems we add individual capacities to obtain the sub-system global capacity. But if the resulting capacity is more than 100 percent, the capacity is limited to 100 percent. Moreover, for the second parallel sub-system, if the sum of capacities is below 90 percent, the sub-system is considered to be out of order and therefore its global capacity is 0. For a series assembly of sub-systems, the global capacity is the minimum of individual sub-system capacities.The instantaneous output (at time t) of the system is given by the following expression, which takes into account every assumption stated so far (time t, implicite everywhere, is omitted for clarity):

$$c(t) = min(c(A), min(c(C_1) + c(C_2), 40\%) + c(D_1) + c(D_2), c(E))$$

where $c(E) = min(100\%; \sum E_i)$ *if* $\sum E_i \geq 90\%$ (*i.e.*, if at least 6 of the E_i function) and $c(E) = 0$ otherwise.

The corresponding reliability data are given in table 1. Moreover there is only one repairman for each set of components : {A}, {C_1, C_2, D_1, D_2}, {E_1, ,,, E_8}
Each repairman repairs the components in the order where they broke down (FIFO strategy)”.

Table 1. Reliability data

Components	MTTF (hours)	MTTR (hours)
A	50000	2000
C_1,C_2	10000	5000
D_1,D_2	1000	100
E_1,E_2,….. ,E_8	5000	1000

Expected results

The main objective of this work is, first, to model the behaviour of the system by means of Petri nets and by using Alta-Rica Data Flow language and, second, to predict the stationary probability distribution of the system production availability. Some results concerning extended importance measures [7] will also be given.

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