POWER GENERATING UNITS RELIABILITY EVALUATION USING PETRI NETS

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Abstract

A Petri net is an abstract, formal model of information flow. The Petri nets are as additional tool for the study of systems behaviour and considered as one type of graph theory. The theory of Petri nets allows a system to be mathematically modelled. The properties, concepts, and techniques of Petri nets are being developed in a search for natural, simple, and powerful methods to describe and analyse the flow of information and control in systems, particularly systems that may exhibit asynchronous and concurrent activities.

Petri nets as a modelling tool are recommended for use in a specific class of problems related to model discrete-event systems with concurrent or parallel events. Petri nets model systems, and particularly two aspects of systems, event and conditions, and the relationships among them.

Power system reliability evaluation programs are categorized in terms of their application to segments of complete electric power systems. A generating power unit is said to be on outage when it fails unexpectedly and is not available for power production. If one or more generating unit fail, the system might not be able to supply the full amount of electric power required by the customers.

1. Literature Review

C A Petri first introduced Petri net theory in 1962 [1,2]. Carl Adam Petri, A W Holt, Jack Dennis, and many others have subsequently developed it considerably. Petri nets originated in the early work of Dr Petri in Germany in his PhD dissertation, where he developed a new model of information flow in systems. This model was based on the concepts of asynchronous and concurrent operation by the parts of a system and realization that relationships between the parts could be represented by a graph or net.

The concepts of Petri came to the attention of a group of researchers at applied Data Research Inc. in USA, working on the Information Systems Theory Project [1,2].

Jack Dennis introduced the concepts of Petri nets to the Data Research's work with relation to Project MAC at MIT. The Computation Structure Group of MIT has been a most productive source of research and literature in this field, publishing several PhD theses and numerous reports and memoranda on Petri nets.

The Computation Structure Group has organized two conferences.

The First conference in 1970 was the Project MAC Conference on Concurrent Systems and Parallel Computation at Woods Hole. The second conference in 1965 was the Conference on Petri Nets and Related Methods at MIT. From the two conferences, the use of Petri nets has spread widely. A large amount of research since then has been done on both the nature and the application of Petri nets.

2. Structure of Petri nets

Petri net graphs model the static properties of a system in a similar way as a flow chart represents die properties of a computer. The Petri nets contain two types of nodes: circle, which is called places, and bars, which is namely transitions. Directed arrows, from places to transitions and vice versa, connect these two nodes. In an arrow is directed from node i to node j, either from a place to a transition or from transition to a place, then i is an input to j and j is an output to i.

Therefore, Petri net structure is as follows [1,3]:

1. A set of places P = $\{P_1, P_2, \ldots\ldots, Pn)$, n>0
2. A set of transitions T = $(t_1, t_2, \ldots\ldots, t_m)$, m>0

The set of places and the set of transitions are Disjoint, P T = 0, P n T = 0.

3. An input function I
4. An output function 0.

A Petri net structure, C, is a four-tuple, C = (P, T, I, 0).

For more clarification, it should be noted that:

t_1 : time delays associated with the transition between P_1 and P_2 .
t_2 : time delays associated with the transition between P_2 and P_1 .

$t_1 = 1/(ã_1/24)$, where $ã_1$ is the transition rate from 1 to 2.
$t_4 = 1/(ã_4/24)$, where $ã_4$ is the transition rate from 2 to 1.

As a general formula to find the delays associated with the transition between two places can be written as:

$$t_i = 1/(ã_i/24)$$

where $ã_i$ is the transition rate per day. This transition rate is divided by 24, where in this case is converted to a transition rate per hour.

3. Petri net graphs

The definition of Petri net structure is die most theoretical work, which is based on. However, for illustrating the concepts of Petri net theory, a graphical representation of a Petri net structure is much more useful [1,2].

The places and the transitions are connected by directed arrows, with some arrows directed from the places to the transitions and other arrows directed from transitions to places. As an example, when an arrow directed from a place pj to a transition tj defines the place to be an input of the transition. An arrow from die transition to the place indicates an output place. Multiple arrows from the input places to the transition indicate multiple inputs to a transition and multiple arrows represent multiple outputs.

Since Petri nets allow multiple arrows from one node of the graph to another, a Petri net can therefore be represented as multigraph. A Petri net graph is a directed graph since the arrows are directed. In addition, since its node can be partitioned into two sets (places and transitions) such that each arrow is directed from an element of one set (place or transition) to an element of the other set (transition or place), it is also a bipartite directed graph.

A Petri net can accordingly be considered as a generalized signal flow graph.

4. Modelling of Petri Nets

Petri nets as a modeling tool are recommended for use in a specific class of problems related to model discrete-event systems with concurrent or parallel events. Petri nets model systems, and particularly two aspects of systems, event and conditions, and the relationships among them. At y given time, certain conditions will hold. These conditions may cause the occurrence of events; the occurrence of these events may change the state of the system [1, 2].

A simple example might be that the simultaneous holding of both
i. the condition "equipment is needed" and
ii. the condition "equipment is available"
might cause the event "allocate the equipment" to occur. The occurrence of this event results in the ceasing of the two conditions previously mentioned (i and ii) while causing the condition "no equipment is available" to become true. These conditions and events, and their relationships, may be modeled as shown in Fig. 1.

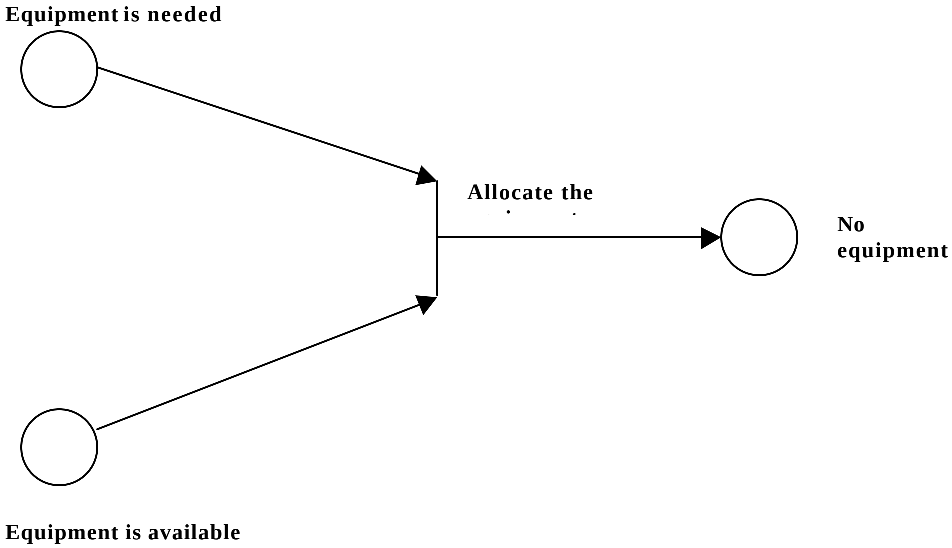

Fig.(1) A Simple Model of Three Conditions & An Event

5. Markov Modelling Using Petri Nets

In the present section, the use of Petri nets as described earlier is discussed with the help of the examples given below. For the first example, consider two generators under one of the following conditions:

(i) both generators are working.
(ii) one of the two generators is working and the other is in a failed condition.
(iii) both of the generators have failed.

A Petri net characterizing the system is given in Fig.2. The three conditions are represented by the three places P1, P2 and P3, respectively.

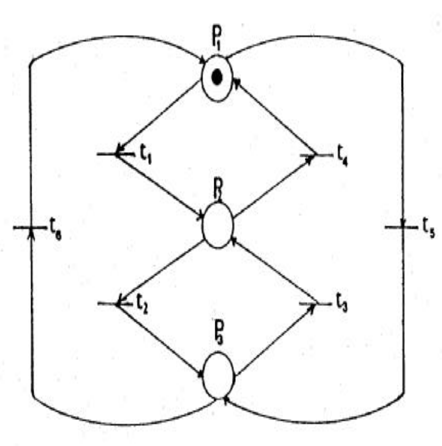

Fig. (2) A Petri Nets Flow-Diagram (Model # 1)

Assuming that an initial marking of the system is:
$M_0 = [1 \ \ 0 \ \ 0]$

where M_0 is the initial marking, and represents the initial conditions of tile system, indicating that the two generators are initially working.

Table 1 illustrates the reachability set of the marking with the corresponding token distribution, the transitions and the state obtained as a consequence of the transition firing.

Table 1 Reachability Set (Model 1)

State	**Token**			**State Connection**			
	P1	**P2**	**P3**	**t**	**s**	**t**	**s**
1	1	0	0	1	2	5	3
2	0	1	0	4	1	2	3
3	0	0	1	3	2	6	1

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The Markov transition graph (Fig 3) can be derived from the state connections illustrated in Table 1. From Fig. 3 the differential equations are formulated. The set of differential equation are given as follows:

$$\frac{dP1(t)}{dt} = -(g_1 + g_5)\ P_1(t) + g_4 P_2(t) + g_6\ P_3(t)$$

$$\frac{dP2(t)}{dt} = g_1\ P_1(t) - (g_2 + g_4)\ P_2(t) + g_3\ P_3(t)$$

$$\frac{dP3(t)}{dt} = g_5\ P_1(t) + g_2 P_2(t) - (g_3 + g_6)\ P_3(t)$$

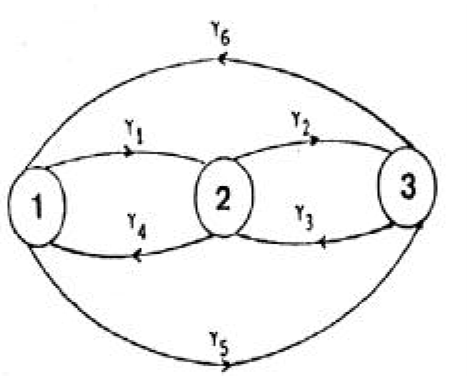

Fig.(3) Markov Transition Rate Diagram (Model # 1)

As a second example, the same generators as before can be considered to be operating under any of the four conditions given below. As in the example, all conditions are mutually exclusive.

(i) the two generators are working.
(ii) the first generator is working, but the second one is in a failed condition.
(iii) the second generator is working, but the first one is a failed condition.
(iv) both generators have failed.

Fig.4 gives the Petri net for this example. The four conditions are now represented by four places, which are P_1, P_2, P_3 and P_4.

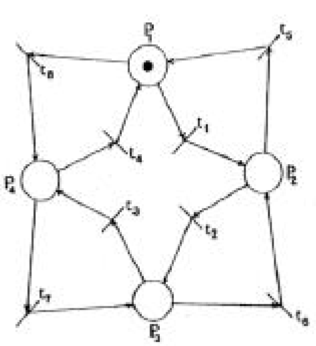

Fig. (4) A Petri Nets Flow Diagram (Model # 2)

An initial marking of the system can be assumed as:

$M_0 = [\,1\ \ 0\ \ 0\ \ 0\,]$

which shows that the two generators are initially working.

Table 2 shows the reachability set of the markings with the corresponding tokens distribution, the transitions and the state obtained as a consequence of the transition firing.

Table 2 Reachability Set (Model 2)

State	Token				State Connection			
	P1	P2	P3	P4	T	s	t	s
1	1	0	0	0	1	2	8	4
2	0	1	0	0	2	3	5	1
3	0	0	1	0	3	4	6	2
4	0	0	0	1	4	1	7	3

The Markov transition graph can be derived from the state connections given in Table 2 and is illustrated in Fig.5.

Fig. (5) Markov Transition Rate Diagram (Model # 2)

Then the set of corresponding differential equations are formulated as follows:

$$\frac{dP1(t)}{dt} = -(g_1 + g_8)\ P_1(t) + g_5 P_2(t) + g_4\ P_4(t)$$

$$\frac{dP2(t)}{dt} = g_1 P_1(t) - (g_2 + g_5)\ P_2(t) + g_3\ P_3(t)$$

$$\frac{dP3(t)}{dt} = g_2 P_2(t) - (g_3 + g_6)\ P_3(t) + g_7\ P_4(t)$$

$$\frac{dP4(t)}{dt} = g_8 P_1(t) + g_6\ P_3(t) - (g_4 + g_7)\ P_4(t)$$

6. Comparison Between F7ow-Graph Method and Petri Nets

The flow-graph [4] and Petri nets are tools for the study of systems behavior and can both be differently considered as types of graph theory.

Petri nets is a method which can be used to study system behavior and allows the Markov state-space diagram and it's corresponding transition rate matrix to be obtained. On the other hand, the flow-graph method is principally applied to calculate the steady state probabilities. If transient behavior is required, then an appropriate numerical method is generally required.

None of these methods are alternatives but are complementary to one another. A comparison between the flow-graph method and Petri nets is illustrated in Table 3.

Table 3 A comparison between Flow Graph and Petri Nets

	Flow Graph	**Petri Nets**
The main objective	Calculates the steady state probabilities	illustrate the flow of information
Firing process	Not used	Used
Transition between node	Has a transition rate	Has transition points
Input and output nodes	Both can be either have more than one input or more than one output	

From the above discussion it is seen that the main value of Petri nets is to supply a model for the flow of information in a system and as such its main value lies in being able to model the transition rate diagram, which is a prerequisite for the majority of the studies discussed in the present paper.

7. Conclusion

The main purpose of the Petri nets was to obtain the steady-state probabilities of multi-state systems. For calculating the steady state behavior, the Petri-nets procedure was developed and compared with a developed procedure by Qamber [4]. Also, a power generating system reliability model, which has been investigated, based on the timed state generating Petri Nets theory. The proposed method can easily be extended and utilised for various systems reliability studies in a more general sense.

The technique used in the present paper has the following advantages:

a- the technique is general that can be applied to any Markov model.
b- the technique can be applied manually.
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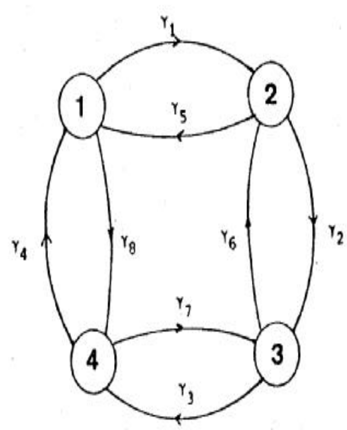

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Isa S. Qamber was born in Al-Muharraq, Bahrain, on July 7, 1959. He received the B.Sc. degree in electrical engineering from King Saud University - Saudi Arabia, in 1982, PGD in 1983, and M.Sc. degree in 1984 both from UMIST, UK, and the Ph.D. degree in reliability engineering from the University of Bradford, UK in 1988. In 1988 he joined the Department of Electrical Engineering, College of Engineering, University of Bahrain, as an assistant professor. Currently, he is an associate professor in the Electrical and Electronics Engineering Department. Dr. Qamber is a member of the CIGRE, the Bahrain Society of Engineers and the IEEE PES Society. His research interests include studying the reliability of power systems and plants, the applications of CAD tools to high power engineering, and control of power systems.