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MARKED STATE GRAPH OF MACHINE PRODUCTION SYSTEM WITH STOCK OF CROP PRODUCTION UNITS

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Sivak I.M. ***Marked state graph of machine production system with a stock of crop production units.***

Abstract. *The author proposed analytical approaches to the description of the models of the marked graph of the operation states of the machine production system with a stock of plant production units. The obtained dependencies of the system states make it possible to establish, given the given characteristics of the investigated machines and equipment for the production of crop production, rational modes of providing resources for processing and repairing the equipment in case of technical failures.*

Key words: *graph, condition, system, crop production, combine.*

Сівак І.М. ***Розмічений граф станів роботи машинної виробничої системи з запасом одиниць продукції рослинництва.***

Анотація. *Автором запропоновані аналітичні підходи щодо опису моделей розміченого графу станів роботи машинної виробничої системи з запасом одиниць продукції рослинництва. Отримані залежності станів систем дають змогу встановити при заданих характеристиках досліджуваних машин та обладнання виробництва продукції рослинництва раціональні режими подачі ресурсів на обробку та ремонт обладнання у разі технічних відмов.*

Ключові слова: *граф, стан, система, рослинництво, комбайн.*

Introduction

In the modern agro-industrial complex [1], almost all agricultural machines and equipment that are involved in the technology of production of plant products [2], taking into account the strong influence of natural and production factors [3], work with stocks [4]. Accordingly, models and making rational decisions should be based on these conditions [5].

Analysis of recent researches

For the efficient operation of the grain harvester, it is necessary to ensure optimal loading of all its systems, primarily the threshing-separating system, as it ensures the throughput of the bread mass, this contributes to productive work and reduction of grain injury [6]. The direction of development of modern grain harvesters depends on the needs of farmers, this includes:

- a wide range of types of basic models and modifications [7];
- cost is important; ensuring high-quality maintenance and repair [8];
- increased operational reliability [9];
- providing automatic control of technical and technological parameters [10].

One of the essential reserves for increasing the productivity and reliability of combine harvesters is the harmonization of their design for coordinated operation of the engine with the main systems of the combine harvester [11]. The consumption of fuel and lubricants, the reliability and quality of technological operations, the availability of maintenance and repair will depend on the observance of certain ratios [12].

The engines of modern grain harvesters have electronic control systems that allow to ensure the necessary work on harvesting grain crops, in accordance with the seasonal load on the harvester, the yield of agricultural crops, etc. [13]. The analysis of many models of combine harvesters from different manufacturers showed a certain similarity and homogeneity of combine harvesters in terms of parameters, regardless of their design and layout schemes [14]. There are deviations in certain parameters, but they are insignificant, in general no more than 8...10% [15]. Further improvement of combine harvesters involves simultaneously increasing quality indicators, as well as improving the efficiency of the combine harvester's work process [16]. This can be ensured with optimal performance parameters of work processes, but mainly the work of the grain harvester is carried out with variable component indicators, for example: different yield and moisture content of the bread mass; different configurations, 10 relief and field area, this leads to the adjustment of the performance indicators of their work [17]. It is possible to achieve compliance with the indicators of the efficient operation of the grain harvester by adapting it to the conditions of harvesting, that is, the conditions of the agricultural economy, as a result of monitoring and operational management of the work process, which will significantly increase the efficiency of technical means [18].

The aim and objectives of research

The aim of the research is to describe the analytical search for models of the marked state graph of the machine production system with a stock of crop production units.

Research results

The solution of the system with a stock of m units of products is presented in Fig. 1.

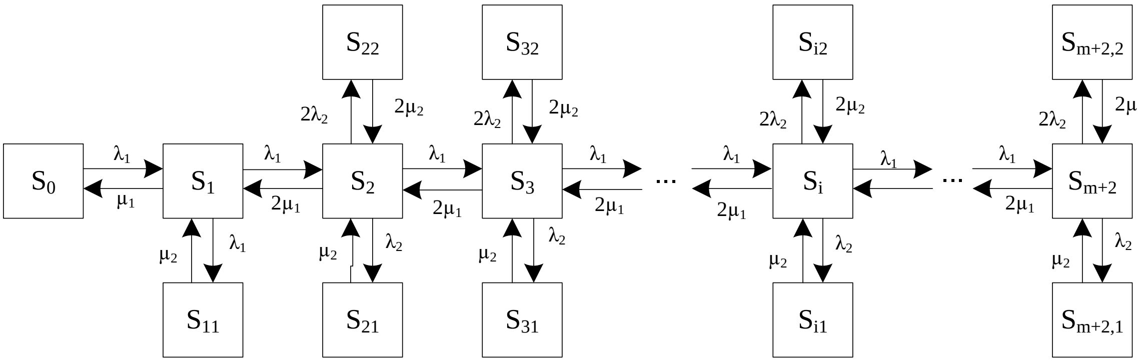

Fig. 1. Marked state graph of the two-machine production system with a stock of *m* units of production

$$P_0 = \left[1 + \frac{\lambda_1}{\mu_1} + \frac{\lambda_2}{\mu_2}\frac{\lambda_1}{\mu_1} + \left\{ \frac{1}{2} + \frac{\lambda_2}{\mu_2} \right\} \sum_{i=2}^{m+2} \left(\frac{1}{2} \right)^{i-2} \left(\frac{\lambda_1}{\mu_1} \right)^{i} \right]^{-1};$$

$$P_i=\left(\frac{1}{2}\right)^{i-1}\left(\frac{\lambda_1}{\mu_1}\right)^i P_0,$$

$$P_{i1}=P_{i2}=\frac{\lambda_2}{\mu_2}P_i.$$

Let's consider the model of the functioning of the system of three production systems with a stock of two units of products (Fig. 2).

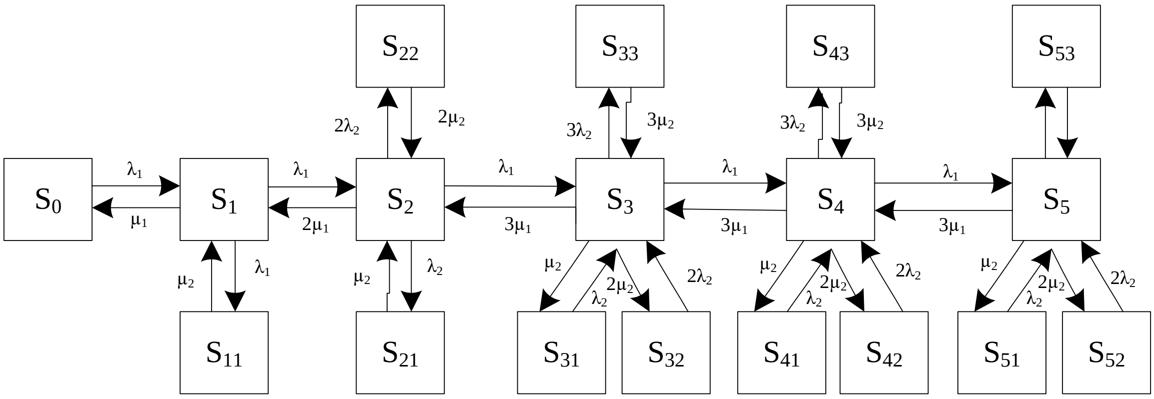

Fig. 2. A marked graph of the operating states of three production systems with a stock of two units of production

The marked graph of the operating states of three production systems with a stock of two units of products (Fig. 2) has its own characteristics:

- S0 – free state of the system, processing of work items is not carried out;
- S1 – one production system processes the object of work, two are idle;
- S11 – state of technical failure of the working production system, which occurred in state S1;
- S2 – two production systems process work items, one is idle;
- S21 – state of technical failure of one of the working production systems, which occurred in state S2;
- S22 – state of technical failure of two working production systems, which occurred in state S2;
- S3,4,5 – all three production systems process work items;
- S31,41,51 – state of technical failure of one of the production systems, which occurred in state S3,4,5;
- S32,42,52 – state of technical failure of two production systems, which occurred in state S3,4,5;
- S33,43,53 – state of technical failure of all three production systems, which occurred in state S3,4,5.

The parameters of the model (Fig. 2) remain unchanged.

The mathematical model of system functioning (Fig. 3) is represented by a system of equations:

$$\frac{dP_0}{dt}=-\lambda P_0+\mu_1 P_1;$$

$$\frac{dP_1}{dt}=-(\lambda_1+\lambda_2+\mu_1)P_1+\lambda_1 P_0+\mu_2 P_{11}+2\mu_1 P_2;$$

$$\frac{dP_{11}}{dt}=\mu_2 P_{11}+\lambda_2 P_1;$$

$$\frac{dP_2}{dt} = -(\lambda_1 + 3\lambda_2 + 2\mu_1)P_1 + \lambda_1 P_1 + \mu_2 P_{21} + 2\mu_2 P_{22} + 3\mu_1 P_3;$$

$$\frac{dP_3}{dt} = -(\lambda_1 + 6\lambda_2 + 3\mu_1) \times P_3 + \lambda_1 P_2 + \mu_2 P_{31} + 2\mu_2 P_{33} + 3\mu_2 P_{33} + 3\mu_1 P_4;$$

$$\frac{dP_{31}}{dt} = -\mu_2 P_{31} + \lambda_2 P_3;$$

$$\frac{dP_{32}}{dt} = -2\mu P_{32} + 2\lambda_2 P_3;$$

$$\frac{dP_{33}}{dt} = -3\mu_2 P_{33} + 3\lambda_2 P_3;$$

$$\frac{dP_4}{dt} = -(\lambda_1 + 6\lambda_2 + 3\mu_1) \times P_4 + \lambda_1 P_3 + \mu_2 P_{41} + 2\mu_2 P_{42} + 3\mu_2 P_{43} + 3\mu_1 P_5;$$

$$\frac{dP_{41}}{dt} = -\mu_2 P_{41} + \lambda_2 P_4;$$

$$\frac{dP_{41}}{dt} = -2\mu_2 P_{42} + 2\lambda_2 P_4;$$

$$\frac{dP_{43}}{dt} = -3\mu_2 P_{43} + 3\lambda_2 P_4;$$

$$\frac{dP_5}{dt} = -(6\lambda_2 + 3\mu_1)P_5 + \lambda_1 P_4 + \mu_2 P_{51} + 2\mu_2 P_{52} + 3\mu_2 P_{53};$$

$$\frac{dP_{51}}{dt} = -\mu_2 P_{51} + \lambda_2 P_5;$$

$$\frac{dP_{52}}{dt} = -2\mu_2 P_{52} + 2\lambda_2 P_5;$$

$$\frac{dP_{53}}{dt} = -3\mu_2 P_{53} + 3\lambda_2 P_5.$$

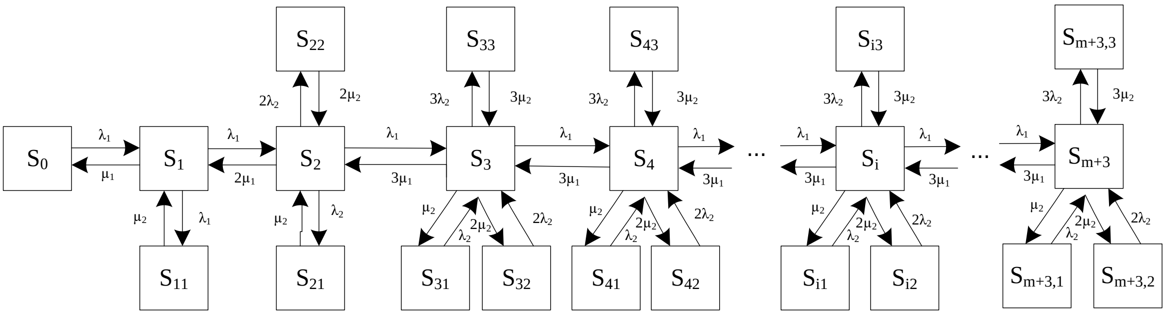

Fig. 3. Marked graph of the operating states of three production systems with a stock of *m* units of production

The solution of the equivalent linear system of equations will be as follows:

$$P_0 = \left[1 + \frac{\lambda_1}{\mu_1}\left(1 + \frac{\lambda_2}{\mu_2}\right) + \frac{\lambda_1^2}{\mu_1^2}\left(\frac{1}{2} + \frac{\lambda_2}{\mu_2}\right) + \right]^{-1} +$$
$$+\left[\frac{1}{2}\left(\frac{1}{3} + \frac{\lambda_2}{\mu_2}\right)\left(\frac{\lambda_1^3}{\mu_1^3} + \frac{1}{3}\frac{\lambda_1^4}{\mu_1^4} + \frac{1}{9}\frac{\lambda_1^5}{9\mu_1^5}\right)\right];$$

$$P_1 = \frac{\lambda_1}{\mu_1} P_0;$$

$$P_{11} = \frac{\lambda_2}{\mu_2} \frac{\lambda_1}{\mu_1} P_0;$$

$$P_2 = \frac{1}{2} \frac{\lambda_1^2}{\mu_1^2} P_0;$$

$$P_{21} = P_{22} = \frac{1}{2} \frac{\lambda_2}{\mu_2} \frac{\lambda_1^2}{\mu_1^2} P;$$

$$P_3 = \frac{1}{6} \frac{\lambda_1^3}{\mu_1^3} P_0;$$

$$P_{31} = P_{32} = P_{33} = \frac{1}{6} \frac{\lambda_2}{\mu_2} \frac{\lambda_1^3}{\mu_1^3} P_0;$$

$$P_4 = \frac{1}{18} \frac{\lambda_1^4}{\mu_1^4} P_0;$$

$$P_{41} = P_{42} = P_{43} = \frac{1}{18} \frac{\lambda_2}{\mu_2} \frac{\lambda_1^4}{\mu_1^4} P;$$

$$P_5 = \frac{1}{54} \frac{\lambda_1^5}{\mu_1^5} P_0;$$

$$P_{51} = P_{52} = P_{53} = \frac{1}{54} \frac{\lambda_2}{\mu_2} \frac{\lambda_1^5}{\mu_1^5} P_0;$$

Summarizing the obtained results, we will obtain a solution for a system with a stock of m units of production (Fig. 3).

$$P_0 = \left[1 + \frac{\lambda_1}{\mu_1}\left(1 + \frac{\lambda_2}{\mu_2}\right) + \left(\frac{\lambda_1}{\mu_1}\right)^2 \left(\frac{1}{2} + \frac{\lambda_2}{\mu_2}\right)\right]^{-1} +$$

$$+ \left[\frac{1}{2}\left(\frac{1}{3} + \frac{\lambda_2}{\mu_2}\right) \sum_{i=3}^{m+3} \left(\frac{1}{3}\right)^{i-3} \left(\frac{\lambda_1}{\mu_1}\right)^i\right]^{-1};$$

$$P_1 = \frac{\lambda_1}{\mu_1} P;$$

$$P_{11} = \frac{\lambda_2}{\mu_2} \frac{\lambda_1}{\mu_1} P_0;$$

$$P_2 = \frac{1}{2} \frac{\lambda_1^2}{\mu_1^2} P_0;$$

$$P_{21} = P_{22} = \frac{1}{2} \frac{\lambda_2}{\mu_2} \frac{\lambda_1^2}{\mu_1^2} P_0;$$

$$P_i = \frac{1}{2}\left(\frac{1}{3}\right)^{i-2} \left(\frac{\lambda_1}{\mu_1}\right)^i P_0;$$

$$P_{i1} = P_{i2} = P_{i3} = \frac{\lambda_2}{\mu_2} P_i;$$

$i = 3, 4, ..., m + 3.$

Conclusions

1. In practical terms, the developed models allow, given the given characteristics of the studied machines and plant production equipment, to obtain rational modes of supplying resources for processing and repairing equipment in case of technical failures. This will lead to an increase in equipment productivity without significant financial costs.

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