Scheduling of preventive maintenance of an power equipment of the agricultural enterprises

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Abstract. Presented paper deals with the topic of preventive maintenance of an power equipment of typical agricultural enterprises. A decision support method was designed, incorporating the analysis of annual schedules of load diagrams of the typical agricultural enterprises and the planning of preventive maintenance of the power equipment with month priority during which maximal consumption of electric energy take place. The correction of typical load diagrams on the basis of the fact sheet about electric loading of the consumer is possible. The designed method optimizes maintenance costs without supplementary investment and running costs. An algorithm of the designed method is offered and a case study of its implementation is described in the paper. Keywords: planning, servicing, working graph, load diagram.

1. Introduction

The requirements for maintenance of power equipment of agricultural technological processes are conditioned by the requirements of business - ensuring the reliable functioning of the technological process while minimizing costs. There are also requirements to minimize the risks to the health and safety of service personnel and farm animals and poultry. As a rule, the maintenance power equipment of small and very often medium-sized agricultural enterprises is performed not by the respective technical specialists of these enterprises, but by the specialists of specialized enterprises (SE), it is stipulated by normative documents, for example, the Rules for the technical operation of electrical installations of consumers of Ukraine.

There are different strategies of maintenance. For example, a strategy of maintenance is based on strategy of Preventive Maintenance (PM). As is known [1], PM is carried out within the recommended time limits set by the equipment producer. However, this is not always justified in the specific conditions of use of electrical equipment. For agricultural conditions, there are often branch recommendations regarding the frequency of maintenance of electrical installations, depending on the
2. Material and methods
The purpose of this article is improvement of the planning method of PM of the power equipment for small and medium agricultural enterprises by SE specialists.

As a result of the review of the literature and practice of planning PM, the development of recommendations for improving the planning method of PM of the power equipment of agricultural enterprises was based on the following conditions:

- as a basis the frequency of PM is used, which is specified in the instructions of the manufacturers of equipment and recommended by the normative-technical documentation taking into account the operating conditions;
- planning must be implemented in an accessible interface, such as Microsoft Excel;
- input data must be available for use by SE specialists in the maintenance of the power equipment for small and medium agricultural enterprises.

Using the developed recommendations, the planning of PM of the power equipment of technological processes of typical agricultural enterprises will be simulated and analyzed.

3. Results and discussion
The planning of PM of the power equipment is the scheduling the main works of PM, it is maintenance (M) and current repair (CR). The annual schedule of PM is based on calculations of the
labour input of the PM works and recommendations about their frequency. The power equipment list may change as new customers appear. Priority terms of the realization of PM works for SE specialists we suggest to determine on the basis of load diagram of the consumer of electric energy, in particular, with this purpose it is possible to use typical load diagrams.

Typical load diagram of electricity consumer is average hourly schedule of electrical load for a number of consumers, similar by classification of the economic activity type (CEAT), by mode of operation and a set of electric receivers. «Album of typical load diagrams» for different types of activity of electricity consumers, including agricultural enterprises, is recommended for use by the Ministry of fuel and power of Ukraine.

For example, in an album there is typical load diagrams by CEAT-2012 such as 01.41 (Breeding of cattle of dairy breeds), 01.42 (Breeding of other cattle and buffaloes), etc. Load diagrams are made for each month of year. At the same time the correction of typical load diagrams on the basis of the fact sheet about electric loading of the consumer is possible. Example of typical load diagram for January is shown in Figure 1.

![Figure 1. An example of typical load diagram in January for the electricity consumer of a class 01.41 (Breeding of cattle of dairy breeds)](image)

Using the software for work with typical load diagrams (User Graph), which recommended by the Ministry of fuel and power of Ukraine, we form base of typical load diagrams of the agricultural enterprises which power equipment is a subject of PM.

On the basis of these diagrams in spreadsheets Microsoft Excel we create annual load diagrams and form a respective database.

Table 1 shows an example of the formed data for the create of typical annual load diagram for the electricity consumer of class 01.41 ($N_i$ – order number of the month of the year, $W_i$ – active energy consumed by the electric equipment of the consumer in the i-th month, kWh).

| $N_i$ | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| $W_i$| 1801| 1865| 1661| 1807| 1661| 1642| 2118| 1866| 2016| 2089| 2169| 2109|
We suggest planning the PM works with power equipment of consumers, starting from precedes month according to the month, where there was a maximum load.

Examples of typical annual load diagrams for classes of the consumers according to CEAT-2012: 01.41 (Breeding of cattle of dairy breeds), 01.42 (Breeding of other cattle and buffaloes), 01.43 (Breeding horses and other equine animals), 10.31 (Processing and preserving of potatoes) are shown in Figures 2-5. According to diagrams, it is advisable to start planning the PM works with power equipment of consumers of classes: 01.41 from June, 01.42 from September, 01.43 from October, 10.31 from February – from precedes months according to the months, where there was a maximum load \((N_i/W_{\text{max}})\).

**Figure 2.** The typical annual load diagram for class of the consumer CEAT-2012: 01.41

**Figure 3.** The typical annual load diagram for class of the consumer CEAT-2012: 01.42
Figure 4. The typical annual load diagram for class of the consumer CEAT-2012: 01.43

Figure 5. The typical annual load diagram for class of the consumer CEAT-2012: 10.31

Priority months for start planning the PM works with power equipment of consumers (NiPM) can be defined by using the following formula:

\[ N_{iPM} = N_{iW_{\text{max}}} - 1 \]

(1)

Restriction must be applied \( i = i_{\text{min}} \) for the purpose of prevention of errors with the same values of \( N_{iW_{\text{max}}} \) for several months in a row. Therefore, planning should begin in the first preceding month according to the months, where there was a maximum load.

The end of the general schedule summarizes the labour inputs of the PM works by months, which provides an opportunity to check the uniformity of the distribution of work according to condition:

\[ K_i < K_{i_{\text{max}}} \]

(2)
where $K_i$ - is the coefficient of inequality, it can be defined by using the following formula:

$$K_i = \frac{Q_{\text{max}} - Q_{\text{min}}}{Q_y}$$  \hspace{1cm} (3)

where $Q_{\text{max}}$, $Q_{\text{min}}$ – respectively maximum and minimum the labour inputs for the month of the annual schedule of PM works, man-hour;  
$Q_y$ – actual annual the labor input of PM works of SE, man-hour.

Maximum possible the coefficient of inequality $K_{\text{imax}}$ is determined for SE according to available staff and the scope of other work that may be performed, which is not covered in this paper.

For the practical implementation of the proposed method of planning of PM works, a general algorithm was developed, the block diagram of which is shown in Figure 6, where $W_i$ – the electricity consumption in $i$-th month; $P_{\text{dis}}$, $t_k$ – active power consumed during the relevant period of the day of $i$-th month; $j_i$ – number of days in $i$-th month.

«Album of typical load diagrams» designed with the use of Microsoft Excel spreadsheets. It is also advisable to use them to account for power equipment and for basic calculations during the formation of annual schedule of PM works. In doing so, the use of Microsoft Excel spreadsheets makes it impossible to take into account restriction $i = i_{\text{min}}$ for expression (1) in the general algorithm (Figure 6) in the case of multiple values, because the choice of $N_iW_{\text{max}}$ in Microsoft Excel spreadsheets by function HLOOKUP begins on the first such month.

Microsoft Excel spreadsheets, like all Microsoft Office programs, support the Visual Basic for Application (VBA) programming language. This allows you to automate some processes of the interaction between program and user. The VBA language is quite convenient for first acquaintance and programming in the Windows environment. Therefore, we have developed a program for automation of the formation of annual schedules of the PM works to test the practical implementation of the proposed method of planning of the PM works with power equipment of consumers.

The program is a VBA code that is contained in a Microsoft Excel workbook file that contains data for the following calculations and the planning of the PM works. When you enter the last parameter of the output data, the program automatically completes the annual schedule of PM works with values of labor input of M and CR. Distribution starting from precedes month according to the month, where there was a maximum load for this consumer as a result of the analysis of typical annual load diagram.

Provided that for the different consumers contracted for PM with SE, the priority month is the same month, the consumer with higher electricity consumption may have the priority of choosing a planning program.

Table 2 shows an example of the result of the formation of schedule of PM works for the conditional example under consideration.

Table 2. The result of the formation of schedule of PM works

| Conditional Client | Months          |
|-------------------|-----------------|
|                   | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  |
|                   | M   | CR  | M   | CR  | M   | CR  | M   | CR  | M   | CR  | M   | CR  |
| 01.41             |     |     |     |     | 18  |     |     |     | 10  |     | 18  |     |
| 01.42             | 8   |     | 8   |     |     |     |     |     |     |     |     | 8   |
| 01.43             | 12  | 12  |     | 6   | 14  |     |     |     |     |     |     | 12  |
| 10.31             |     | 18  |     | 18  |     | 18  |     | 18  |     |     | 18  |     |
| $Q_y$             | 12  | 18  | 18  | 12  | 18  | 26  | 20  | 18  | 18  | 12  | 18  | 26  |
Figure 6. Flowchart of the algorithm of calculations for the planning of the PM works taking into account annual load diagrams.
4. Conclusion
The offered method of scheduling PM allows during before an intense use of the electric power (because of, first of all, more intensive use of power equipment or use of more powerful power equipment) to lead preventive works (M and CR). Thus reliability of the power equipment will increase, the quantity of failures will decrease, from here, the quantity of works on restoration of operational capability of the equipment will decrease. Thus, SE will increase efficiency without supplementary investment and running costs.

As far as we know, the method of planning work of the PM on the basis of determining the priority month of the beginning of planning using typical load schedules for agricultural consumers was not proposed by other authors.

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