Using telematics data to support effective solutions for tracking and monitoring the power system condition of unmanned vessels

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Abstract. The paper studies the prospects of using telematics data to support effective solutions for tracking and monitoring the condition of the power supply system (PSS) components of unmanned vessels (UV) through the determination of positioning and, accordingly, operating time of PSS components. The paper attempts to describe one of the modules of the proposed integrated telematics system for UV monitoring, diagnostics and control. For practical implementation of telematics for unmanned merchant vessels, an algorithm has been developed to diagnose the technical condition of PSS components based on the operating time and condition of the units and components of the UV PSS. The results obtained by the algorithm show the technical condition of the observed technical equipment, time of its operation, and justify the need for repair or its complete replacement. The block diagram presents the algorithm that employs a minimal set of data to determine the use of technical equipment for further planning of its preventive maintenance. The paper provides the graphical interpretation of data on the time of PSS components operation and an example of displaying the interface of the remote operator of the UV. It is proposed to use telematics for tracking and monitoring the UV PSS operation in order to improve the quality of equipment maintenance, provide rational use of resources, extend its service life, and plan the repair time. In the future, it is proposed to create an integrated intelligent system based on telematics data, which allows the UV control and monitoring of the technical condition of its equipment.

1. Introduction
Over the past several decades, automation has reduced the number of crew on ships. Technological progress on the one hand and the human factor on the other contributed to this process. In fact, this prompted companies to invest in automation that is based on transformative AI and machine learning technologies, which resulted in autonomous navigation as an effective solution to improve the productivity, efficiency and safety of navigation by eliminating the human factor. Statistical studies suggest that unmanned vessels can increase the efficiency of the vehicle and logistics industry by almost 90%, potentially increasing the annual revenue to € 0.45 trillion [1].

In addition to the indisputable advantages of unmanned vessels, they require remote monitoring and diagnostics of the condition of the technical equipment, including the power system, which are of special relevance from both technical and economic point of view, because along with a high cost of the autonomous vessel itself, the total cost of its equipment and machinery is of decisive importance. Total cost is a more complex concept than, for example, the cost of the main engine or the cost of
servicing the components and individual units. It is formed on the basis of material costs needed for continuous monitoring of the technical condition of PSS components. One of the advanced methods of obtaining reliable data on the PSS condition is the use of telematics data and the corresponding software.

2. Materials and methods

At present, telematics is becoming increasingly popular and is widely discussed in scientific works related to technology, engineering, and monitoring the condition of moving vehicles. Vehicle telematics is mainly associated with traffic management systems, although in fact it is only a small part of this broad concept.

Thus, studying the prospects of using telematics for monitoring and diagnosing the technical condition of the UV PSS acquire special relevance, and theoretical and practical significance, which determines the choice of the topic of this study.

The issues of using telematics in various technical fields to solve different problems are multifaceted, since mechatronic systems integrate mechanical, electromechanical, electronic and computer components into a single centralized automated control system. The creation of such systems requires knowledge in the field of many industries: mechanics, electrical engineering, electric drive, electronic engineering, computers and microprocessors, programming, control system theory. Therefore, this issue is of interest for scientists from various fields of science and technology: Naderpour M.; Lu J.; Siami M.; Seidel C.; Entner H.; Held P.; Khmelnitsky A.D., Krutova T.A.

Practical aspects of using telematics to control the intensity of vehicle use are considered in the works by Oskarbski J.; Mikulski J.; Mikulski J.; Salekha H.M., Nuzhdina R.V., Kurochkina S.V.

However, despite the enormous prospects and potential of telematics, studies show that only about 20–30% of companies engaged in the vehicle industry use telematics in their daily activities. The issues of introducing telematics into the maritime vehicle industry have not yet been widely discussed in the scientific literature. The specifics of monitoring and tracking the operational efficiency of each unit of transport, operational profitability, compliance with regulatory requirements for equipment maintenance, and its safety are mostly considered from a theoretical point of view, while in practice there are still many problematic aspects. Currently, a reduced version of telematics is actively employed, which is mainly reduced to monitoring the location of an object and controlling a limited list of parameters, practically excluding determination of the technical condition of the related components and systems, and the functionality of automatic control. The paper attempts to describe one of the modules of the proposed integrated telematics system for monitoring, diagnostics and control of unmanned vessels.

3. Results

The purpose of the paper was to consider the prospects and develop methodological approaches to the use of telematics data to support effective solutions for tracking and monitoring the condition of the UV PSS.

A vehicle telematics system is an information system that provides automated collection, processing, transfer and provision of data on the location and condition of vehicles, their units and mechanisms for the purpose of effective and safe use [2].

To diagnose and monitor the technical condition of the UV PSS, it seems expedient to apply a special algorithm based on data on the location of the vessel (since the navigation zone can impose significant restrictions on operating parameters) and the values of direct and indirect parameters of the operation of significant (mainly in terms of safety) PSS components that are received from the telematics system. Accurate estimation of the equipment utilization time is a very important prerequisite for performing other management tasks and making decisions related to strategic business planning and early replacement (or backup) of equipment that has exhausted its resource. As for UV, there is a problem of lack of personnel on board to carry out operational measures in the emergency
situation associated with sudden failures of technical equipment or systems (especially during long crossings).

During the normal operation of the technical equipment, in order to carry out preventive measures for the control, monitoring and technical assessment of PSS components, at least two types of data are extracted from the telematics database: geographical location of the UV; operation time of the technical equipment.

These values are analyzed using a special algorithm, the block diagram of the algorithm is shown in Fig. 1. Let us consider the steps of this algorithm in more detail.

1. Export of data from the telematics system in the form of a standard electronic table for each component of the PSS. This report helps focus on the required data and ignore other data that are not relevant.

2. Determination of the number of pieces of equipment that are monitored as part of the PSS (NE) and the number of telematics data records sent to the report on the operation of each piece of equipment (ND). Then the values of the equipment counters (i) and the order of the time points (j) are set where the records are ordered from the latest to the oldest. Thus, the time point \( T_{ij} \) of the first records will be larger than the later ones in the list (that is, \( T_{ij} > T_{ij+1} \)).

3. Check if the equipment \( i \) is fixed by entering the time data \( j \) as located in the port (location = port). This is done by examining the value of the geozone parameter and searching for the word "port" as an indicator that the UV location in GPS coordinates is within the previously set geomarks of the port. If the UV is located in the port, the tracking variable \( IN_{ij} \) is assumed to be "true"; otherwise, it is "false". When the only one UV is monitored, go to step 8. If several UV are monitored, go to step 4 to analyze the PSS condition of the next vessel located in the port, otherwise go to step 5.

4. If the UV was in the port for a certain time point \( j \), it is checked whether it was in the port for the previous time interval \( j - 1 \). If this condition is true (\( IN_{ij} = IN_{ij-1} = "true" \)), it is necessary to update the time variable in the port (\( TI_i \)) by calculating the time difference between data records \( j \) and \( j + 1 \) (\( T_{ij} \) and \( T_{ij+1} \), respectively), as shown in the equation below. If this condition is false (\( IN_{ij} \neq IN_{ij-1} \)), go to step 6.

\[
TI_i = TI_i + (T_{ij} - T_{ij+1})
\]

5. If the UV equipment was outside the port at a certain time point \( j \), it is necessary to check whether it was not in the port for the previous time interval \( j - 1 \). If this condition is true (\( IN_{ij} = IN_{ij-1} = "true" \)), the time variable of the UV absence in the port should be updated (\( TO_i \)) by calculating the time difference between data records \( j \) and \( j + 1 \) (\( T_{ij} \) and \( T_{ij+1} \), respectively), as shown in the equation below. If this condition is false (\( IN_{ij} \neq IN_{ij-1} \)), go to step 6.

\[
TO_i = TO_i + (T_{ij} - T_{ij+1})
\]
Figure 1. Algorithm for evaluating the telematics-based PSS

6. If the \(i\)-th PSS equipment, according to telematics data, had different location values (in and outside the port) in data records \(j\) and \(j + 1\), both time variables \(TI_i\) and \(TO_i\) should be updated using the above equations, which assume that the time difference is equally divided between the statuses in and outside the port.

\[
TI_i = T_i + \frac{(T_{i,j} - T_{i,j+1})}{2} \\
TO_i = TO_i + \frac{(T_{i,j} - T_{i,j+1})}{2}
\]

7. Repeat steps 3–6 for the next data entry \((j = j + 1)\) until the last ND data entry is analyzed.

8. Repeat steps 3–7 for each monitored component of the PSS \((i = i + 1)\) until the complete history report of the locations of the last component of NE equipment is analyzed. At this step, it is necessary to calculate the utilization factor \(U_i\) for each equipment as the ratio of the time when the UV is outside the port \((TO_i)\) to the total time analyzed \((TO_i + TI_i)\):

\[
U_i = \frac{TO_i}{TO_i + TI_i}
\]
This approach to monitoring and diagnostics of the SP equipment allows reduction of operating costs, including fuel consumption, wear parts, preventive maintenance and repair. The use of telematics data reduces the cost of unplanned maintenance and repair since it allows identification of the problems before they occur, take preventive measures and perform comprehensive diagnostics to prevent breakdowns of certain units [3–6].

Figure 3 shows the analysis of telematics data on the state of the PSS equipment on the example of a small vessel, which can be used to monitor compliance with the requirements for maintenance of its key units and components, and to ensure maximum operation time.

| Equipment/unit       | Status  | Running hour |
|----------------------|---------|--------------|
| Engine oil filter    | Overtime| 865.9/5000   |
| Cooling system       | Overtime| 865.9/5000   |
| Fan                  | Repair  | 863.9/10000  |
| Compressor           | Repair  | 865.9/10000  |
| Pump                 | Good    | 865.9/20000  |
| Transmission filter  | Repair  | 865.9/10000  |
| DPF                  | Good    | 865.9/42000  |
| Slip coupling        | Repair  | 865.9/10000  |
| Thrust bearing       | Overtime| 865.9/39000  |
| Drive pulley         | Repair  | 865.9/10000  |
| Skating              | Good    | 865.9/15000  |
| Ejector              | Good    | 865.9/20000  |
| Coolant              | Good    | 865.9/20000  |

**Figure 3.** Graphic presentation of telematics data for monitoring the technical condition of the PSS equipment (on the example of a small vessel)
The telematics system for monitoring and diagnosing the technical condition of the PSS includes devices for monitoring the operation of systems and units, which allow sending, receiving and storing telemetry data. They are connected via the vessel's on-board diagnostics such as the On-Board Diagnostics Parameter Identification or via the Controller Area Network port with a SIM card, and the built-in modem provides wireless communication.

The system collects GPS data, as well as an array of other data, and transmits them via GPRS (General Packet Radio Service), 4G mobile data and cellular network or satellite connection to a centralized server. The server interprets the data and displays them to end users via secure websites and applications. The collected telematics data can include data on the pressure drop in the compressor, the bearing temperature and the rotational speed of the gas turbine pump, the temperature of the exhaust gases in the cylinders, the water pressure in the low-temperature cooling circuit, etc.

4. Conclusion

Thus, the results of the study yield the following conclusions. The use of telematics for monitoring and control of the UV PSS operation opens up wide opportunities for improving the quality of equipment maintenance, rational use of resources, extending its service life, and planning repair time. Promising area of research is the creation of an integrated intelligent system based on telematics data, which allows operating the UV and monitoring the technical condition of its equipment.

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