1. Mirosław ZAGÓRDA[1], 2. Paweł KIEŁBASA[1], 3. Paweł PYSZ[1], 4. Maroš KORENKO[2], 5. Miroslav ŽITŇÁK[3]

Faculty of Production and Power Engineering, University of Agriculture in Krakow, Department of Machine Operation, Ergonomics and Production Processes [1]Slovak University of Agriculture in Nitra, Faculty of Engineering, Institute of Design and Engineering Technologies, Nitra, Slovakia[2] Slovak University of Agriculture in Nitra, Faculty of Engineering, Institute of Agricultural Engineering, Transport and Bioenergetics, Nitra, Slovakia[3]

ORCID: 1. 0000-0002-4514-1048, 2. 0000-0003-0249-8626, 3. 0000-0001-7083-1078, 4. 0000-0001-6191-1850 5. 0000-0001-6611-8077

doi:10.15199/48.2024.06.34

Load analysis of the electrical system of an agricultural tractor with EZ-Pilot parallel driving system and CFX-750 panel from TRIMBLE

***Abstract**. The research involved measuring the electrical consumption of the peripherals of a John Deere 6210R agricultural tractor. A set consisting of a Trimble CFX-750 navigation panel together with the EZ-Pilot automatic driving system and a DCM-300 modem for receiving the RTK (RTN) correction transmitted over the GPRS network was used as tractor-mounted peripherals and realizing the function of automatic guidance along parallel lines. It was noted that depending on the driving mode implemented, the current consumption ranged from 11 A to 16 A. However, it becomes necessary to carry out measurements on voltage drops and current consumption for a standard power source and electrical installation. In many cases, it may be necessary to upgrade the installation to the new power consumption conditions by changing the alternator or planning to reduce power consumption by replacing light sources*

Streszczenie.** Badania obejmowały pomiar zużycia energii elektrycznej przez urządzenia peryferyjne ciągnika rolniczego John Deere 6210R. Zestaw składający się z panelu nawigacyjnego Trimble CFX-750 wraz z systemem automatycznej jazdy EZ-Pilot oraz modemu DCM-300 do odbioru poprawki RTK (RTN) transmitowanej siecią GPRS wykorzystano jako urządzenia peryferyjne montowane na ciągniku i realizujące tę funkcję automatycznego prowadzenia po liniach równoległych. Zauważono, że w zależności od realizowanego trybu jazdy pobór prądu wahał się od 11 A do 16 A. Koniecznym jednak staje się wykonanie pomiarów spadków napięć i poboru prądu dla standardowego źródła zasilania i instalacji elektrycznej. W wielu przypadkach może zaistnieć konieczność dostosowania instalacji do nowych warunków poboru mocy poprzez wymianę alternatora lub zaplanowanie zmniejszenia poboru mocy poprzez wymianę źródeł światła. **(Analiza obciążenia instalacji elektrycznej ciągnika rolniczego z systemem jazdy równoległej EZ-Pilot i panelem CFX-750 firmy TRIMBLE).

Keywords: precision agriculture, telematics, tractor electrical installation
Słowa kluczowe: rolnictwo precyzyjne, telematyka, instalacja elektryczna ciągnika

Introduction

The electrical system of vehicles including agricultural tractors is sized for the demand that results from the installed electrical equipment. The use of additional loads can cause failure or discharge of the battery. Proper operation of electrical and electronic devices that are on the vehicle's equipment requires a constant value of supply voltage. This is difficult to meet because the fluctuation of the supply voltage can be in the range of 7 to 15 volts for a 12-volt installation. Therefore, the power supply systems of the equipment, to improve their reliability, are adapted to small variations in the supply voltage. Motor vehicles and agricultural tractors with 12- and 24-volt installations are particularly vulnerable to voltage drops [1]. The voltage value used to power the consumers on a given vehicle is determined by the rated power of the starter (from 0.3 to 11 kW), which depends on the size and type of internal combustion engine [2]. Another component of the system is the battery, which is designed to provide enough energy to start the engine, especially at low temperatures, and to store enough energy while the engine and alternator are running for the next start-up [2, 3]. Instantaneous voltage drops during engine start-up can reach up to 30% [3] and interfere with the operation of other consumers connected to the system. Modern agriculture and production technologies, combined with the improvement of agricultural machinery, have resulted in the use of mechatronics, electronics, information technology and telecommunications systems that can be found in any machine adapted to precision farming technology [4 - 9]. The automation of many processes, including the process of driving a tractor unit in the field, has not only increased operator comfort [7], but also the load on the installation. This is due not only to the use of additional electronic devices that can be plugged into power outlets in the cab (Figure 1), as long as they do not draw more than 25 A, but also to the use of 360o lighting (Figure 2), which allows safe operation also at night thanks to 20 halogen or LED headlights [10].

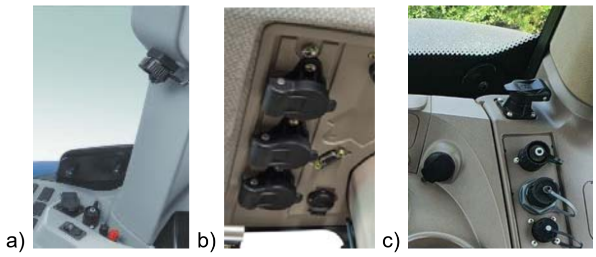


Figure 1. Power outlets in the tractor cab: a) New Holland t7 series, b) Fendt, c) John Deere [10- 12]

Figure 2. 360° lighting of a John Deere tractor [10]

Mechatronic control systems use GNSS receivers and additional modems to receive the RTK correction in addition to information collected from sensors [4]. The range of variation of the supply voltage of such systems can be in the range of 7.0 to 32.0 V DC [13, 14]. Automatic navigation systems, which place a heavy load on the installation during their operation, require routing of separate wiring and direct connection to the battery (Figure 7) [13 - 16]. A promising direction of development in this aspect may be the use of QCL [17-18], which, due to their very high energy efficiency, significantly reduce the power consumption of systems responsible for determining the topography of the area. Telematics systems are very important, the stable operation of which has its implications for the optimization of the technological process. One should be aware that possible disturbances, interruptions in the operation of the system cause significant implications in the technological process. This is due to modern technologies in which the working signal of one machine (working parameters) becomes a control signal for subsequent machines, so disruption of this process is very unfavorable and complicates the technology of not only the current activity, but also the procedures of subsequent technologies. Another important element of the system is a service module that allows real-time identification of abnormal states of machine components and informing service of such an event, which allows in many cases to avoid more serious failures and machine downtime.

Purpose and scope of the study

The purpose of the study was to analyze the load on the electrical system of an agricultural tractor due to the installation of the EZ-Pilot parallel driving system and Trimble's CFX-750 navigation panel. The scope of the study included taking measurements while recording the geographic coordinates of all measurement points in such a way as to generate maps of the variation of the analyzed quantities in an example crop field.

Material and methods

Load tests on the electrical system of the John Deere 6210R tractor (Figure3) were carried out for 3 driving modes.

Figure 3. John Deere 6210R

Measurements were carried out on an area of 26 hectares with automatic driving along parallel straight lines (Figure 4), curves resulting from the boundary line (Figure 4) and when making turns between parallel lines (Figs. 4 and 5).

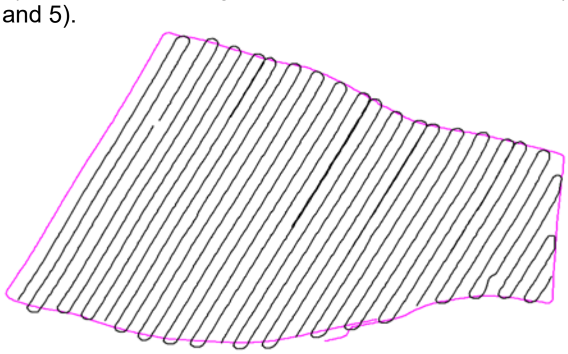


Figure 4. 26-hectare study site

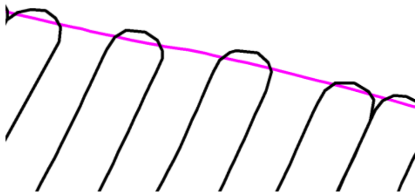


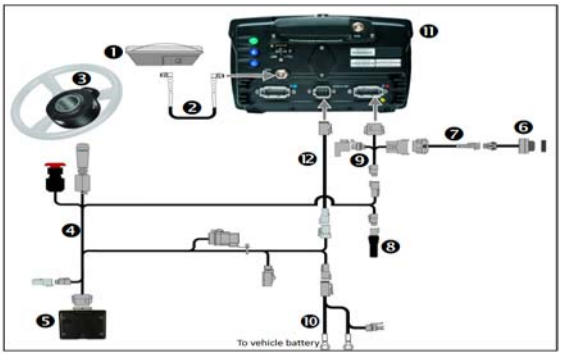
Figure 5. Sites of recurrence

Measurements were taken at 3 locations along the straight line. Measurements during turnarounds were taken at 2 locations along the curve. Measurements on the curved line along the field boundary were taken with a time interval of 20 s.

a)

b) c)

Figure 6. Trimble navigation set: a) CFX-750 navigation panel, b) EZ-Pilot system, c) DCM-300 modem.



Item	Description
1	Antenna
2	Antenna cable
3	SAM-200 steering motor
4	IMD-600 to SAM-200 to CAN power cable
5	IMD-600 unit
6	Sonalert device
7	Display to Sonalert cable
8	CAN terminator
9	Display to Field-IQ cable
10	Basic power cable
11	CFX-750 display
12	Display power cable

Figure 7: Diagram of the automatic navigation installation [11, 12]

A set consisting of a Trimble CFX-750 navigation panel with the EZ-Pilot automatic driving system and a DCM-300 modem for receiving the RTK (RTN) correction transmitted via the GPRS network was used as additional equipment mounted on the tractor and performing the function of automatic guidance along parallel lines, curves and turns (Figure 6). During the drive, the electrical parameters of the plant load generated by the above-mentioned set were measured. The values and durations of load spikes and voltage drops in the installation were determined.

Figure 7 shows a diagram of the automatic navigation system used in the study.

Results

During the measurements, the John Deere 6210R tractor (Figure 3) covered a route of 17190 m (Figure 4). On straight lines with a total length of 14000 m, measurements were made at 111 points (Figure 8). Driving along a curved line at a length of 2110 m allowed 48 results to be recorded (Figure 9). Measurements during turnarounds, where the crossing length was 1080 m, yielded a total of 70 results (Figure 10).

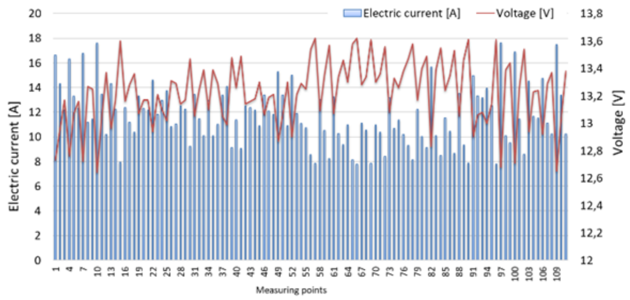


Figure 8. Current consumption (A) and voltage drops (V) during the A-B straight line level

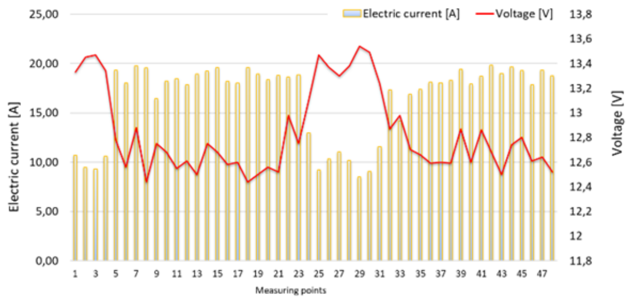


Figure 9. Current consumption (A) and voltage drops (V) during travel along the A-B curve line

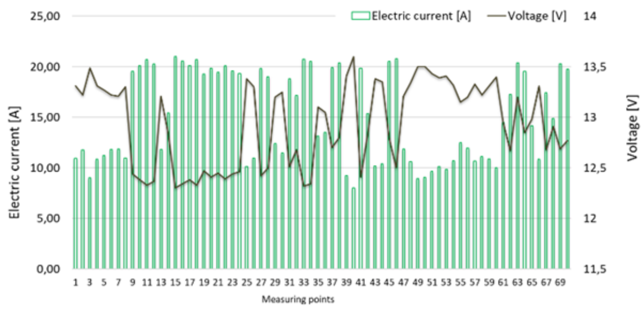


Figure 10. Current consumption (A) and voltage drops (V) when performing reversals

During the execution of the tests, the average values of the supply voltage varied in the range of 12.9 - 13.2 V with a coefficient of variation of 3% (Figures 8-10). This shows that voltage drops during the operation of the navigation system did not affect the proper operation of the set.

Figure 11 shows the average value of current consumption by the Trimble CFX-750 navigation system of driving an agricultural tractor depending on the operation being carried out, i.e.: driving straight ahead, driving on a curve and driving on a headland.

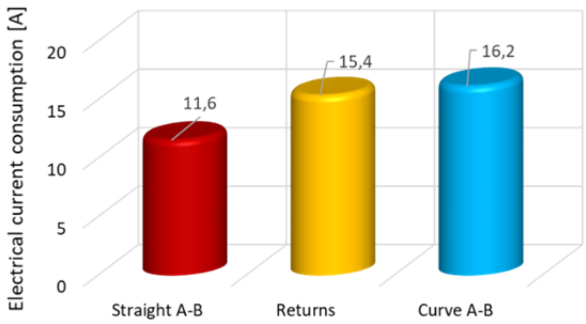


Figure 11: Current consumption of the automatic navigation system

The highest values were observed in the case of driving along a curved line along the field boundary receiving an average value of 16.2 A (Figure 11) with a standard deviation of 3.8 A. A lower value of 4.9% was observed in the case of curved line travel (Figure 5) performing turnarounds. The load resulting from the operation of the navigation system and parallel driving when making turns averaged 15.4 A (Figure 11) with a standard deviation of 4.5 A. The average load on the system during straight-line driving was 11.6 A, which was 28% lower than the values for the A-B curve and the turnarounds by 25% (Figure 11). The standard deviation of the results obtained during straight-line runs was 2.4 A.

Noteworthy is the fact that the highest current consumption was recorded when driving on the A-B curve, the total time of which was only 14% in the global structure of driving time (Figure 12). The second-highest result in terms of value occurred during the performance of turning, and accounted for 9% of the total operating time (Figure 12). Accordingly, the average load of the installation with currents of more than 15 A accounted for 23% of the time of performing journeys over a field of 26 hectares.

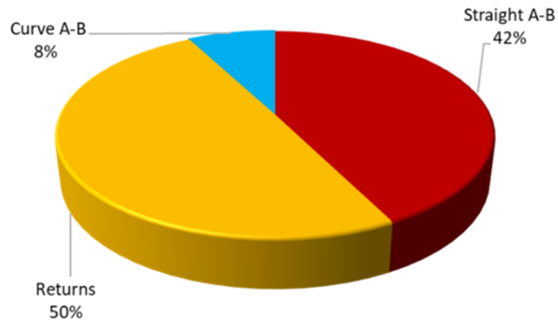


Figure 12. Structure of the operating time of the automatic navigation system over an area of 26 hectares

The system operated for the longest time in the A-B straight-line guidance mode (Figure 12), when the average supply voltage values were 13.2 V.

It should be noted that the coefficient of variation of current consumption by the tractor navigation system did not exceed the value of 30%, which was recorded in the case of making turns. In other cases, it did not exceed 22%.

A spatial depiction of the changes in current in the tractor's electrical system is shown in Figure 13. The largest values appear along the field boundary and the place where turns were made.

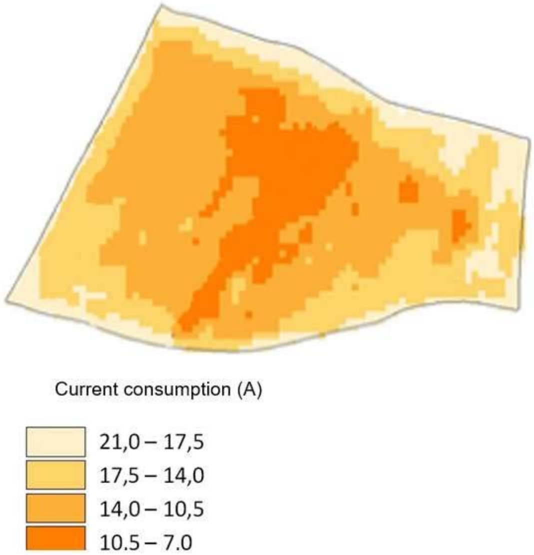


Figure 13. Spatial distribution of current increase in the installation of an automatic navigation system over an area of 26 hectares

Conclusion

Increasing the number of power consumers supplied by the alternator and battery in agricultural tractors is not a problem, because in most cases power outlets are prepared in the cabs. However, it becomes necessary to carry out measurements on voltage drops and current consumption for the standard power source and electrical system. In many cases, it may be necessary to upgrade the installation to the new power consumption conditions by changing the alternator or planning to reduce power consumption by replacing light sources in the vehicle's lighting.

Acknowledgement

Funded by a subsidy of the Ministry of Education and Science for the Agricultural University of Hugo Kołłątaj in Krakow for 2024

***Authors**:*
Mirosław Zagórda PhD Eng, University of Agriculture in Krakow, Faculty of Production and Power Engineering, Balicka Av.116B, 30-149 Krakow, e-mail: Miroslaw.Zagorda@urk.edu.pl, Paweł Kiełbasa Associate Professor, University of Agriculture in Krakow, Faculty of Production and Power Engineering, Balicka Av. 116B, 30-149 Krakow, E-mail: pawel.kielbasa@urk.edu.pl, Paweł Pysz MSc Eng, University of Agriculture in Krakow, Faculty of Production and Power Engineering, Balicka Av. 116B, 30-149 Krakow, e-mail: pawel.pysz@urk.edu.pl, doc. Ing. Maroš Korenko, PhD. Slovak University of Agriculture in Nitra Department of Quality and Engineering Technologies, e-mail: korenko@mech.uniag.sk. Miroslav Žitňák, Profesor, Slovak University of Agriculture in Nitra, Faculty of Engineering, Institute of Agricultural Engineering, Transport and Bioenergetics Nitra, Slovakia e-mail: miroslav.zitnak@uniag.sk

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