ZBIGNIEW KASZTELEWICZ*, JERZY SZYMAŃSKI**

DIGITAL CONTROL METHOD OF CATERPILLAR ELECTRIC DRIVES IN SURFACE MINE MACHINES

STEROWANIE CYFROWE ELEKTRYCZNYMI NAPĘDAMI JAZDY GĄSIENICOWYCH MASZYN PODSTAWOWYCH W KOPALNIACH WĘGLA BRUNATNEGO

In the paper modern drive solutions of caterpillar excavators and spreaders for surface brown coal mine as well as control methods of systems are presented. Nowadays DC motors are replaced by AC motors. AC motor drives are controlled by advanced frequency converters in which scalar or vector control strategies are implemented. DC link between frequency converters is used for energy saving when the part of induction motors work as generators. The solution of the multi-motor caterpillar drive systems are discussed on the basis of a brown coal excavator with non-turnable caterpillars and spreader with one section of turnable and other section non-turnable caterpillars.

Keywords: brown coal mine, caterpillar, electric drive, bucket-wheel excavator, multi-motor drive, spreader, voltage frequency converter

W artykule przedstawiono metody sterowania przemiennikami częstotliwości zapewniające zsynchronizowaną pracę silników napędowych gąsienic jezdnych koparek i zwałowarek. Energooszczędność i dużą manewrowość maszyn górniczych uzyskano poprzez wykorzystanie energii hamowania silnikami klatkowymi i poprzez zastosowanie nowej metody sterowania napędami. Zastosowane metody cyfrowego sterowania zapewniły samo wyrównywanie się momentów silników w różnych stanach obciążeń gąsienic. W napędach zastosowano niskonapięciowe silniki asynchroniczne, sterowane skalarnymi niskonapięciowymi przemiennikami częstotliwości.

Słowa kluczowe: koparka, zwałowarka, maszyna gąsienicowa, napęd elektryczny, napęd jazdy, napęd wielosilnikowy, przemiennik częstotliwości, węgiel brunatny

---

* AGH UNIVERSITY OF SCIENCE AND TECHNOLOGY, DEPARTMENT OF OPENCAST MINING, AL. MICKIEWICZA 30, 30-059 KRAKOW, POLAND
** RADOM UNIVERSITY OF TECHNOLOGY, FACULTY OF TRANSPORT AND ELECTROTECHNICAL, DEPARTMENT OF ELECTRICAL DRIVE AND INDUSTRY ELECTRONIC, UL. MALCZEWSKIEGO 29, 26-600 RADOM, POLAND
1. Introduction

Classical drives’ solutions of caterpillars’ machines in brown coal industry were based on the DC motors. Classical drive solutions don’t assure proper, precise and energy saving control of electrical motors in static and dynamic states.

Among the basic caterpillars machines utilized in brown coal industry excavators and spreaders are numbered. These machines can possess only non-turnable caterpillars set or set of turnable caterpillars along with non-turnable caterpillars set.

Digitally control of asynchronous motors has no reasonable alterative nowadays when the control of speed and torque of the motor is demanded. In the new drives’ industrial project digitally controlled squirrel cage motors have practically displaced classical drives’ solutions (Czopek, 2001; Krzemiński, 2001; Kasztelewicz et al., 2007).

The mechanical characteristic of drive’s set of caterpillar mining machine is depicted in the Fig. 1. This is a four quadrant characteristic, where the demand for motoring moment as well as generator moment is equally high.

Fig. 1. The area of location of mechanical characteristics of squirrel cage motor. The motor is digitally controlled and works in the caterpillar’s drive of excavator or spreader.

The position of the operation point in different quarters of coordinate system: (1) – forward movement on the flat land or on the ramp upwards, (2) – backward movement on the flat land or on the ramp downwards, (3) – backward movement on the ramp upwards, (4) – backward movement on the ramp down, (1, 4) – left or right turn when the machine moves forwards, (2, 3) – left or right turn when the machine moves backwards.
The drive of caterpillar machine works in the four quadrants of coordination system: quadrants 1 and 2 – motor work (driving of the machine) for two driving directions, quadrant 3 and 4 – generator work (braking of the machine) for two driving directions. When the machine is doing the turn the quadrant 1 and 4 or 2 and 3 are used. The motoring mode is realized in the drives of turnable caterpillars which turn on the way of longer radius. The generating mode, in turn, is realized in the drives of caterpillars which turn on the way of shorter radius.

In order to stop the mining machines there is usually no need of high braking torque of braking motors even when the braking is realized on the slope.

High braking torque is produced in the motors which break the non-turnable caterpillars in the time of the turn of the machine. The value of high braking torque is comparable with the motoring torque.

The usage of squirrel cage motor’s digital control enable smooth regulation of the speed and torque of the motor in the motor state as well as in the generator state.

Proposed by authors digital control method of multi-motor drives of excavators and spreaders enable a proper work of the motors in the different states of load of caterpillars. This kind of drive’s solution is energy efficient, have lower exploitation costs in comparison with still used classical drives (Drury, 2001; Kasztelewicz, 2006).

In order to control multi-motor drives different control methods are used which, in turn, are enabling the synchronization of drive sets (Jeftenic et al., 2006). In the proposed control method multi-motor drive of caterpillar’s machine synchronize the rotational speeds of individual motors to average reference values.

As an example of excavators’ and spreaders’ drives the authors decided to discuss the build of the drive set and control method of excavator type SRs1200 with set of four non-turnable caterpillars and the spreader type A2RsB5000M with set of four non-turnable caterpillars and set of two turnable caterpillars.

In the excavator SRs1200 the caterpillars are mounted to stiff chassis’s construction. Each caterpillar is driven by means of separate squirrel cage motor fed from frequency converter. Data: motors – 4x 90kW/737 rpm/min/3x500V, frequency converters – 4x 110kW/150%τn 60s.

In spreader A2RsB5000M squirrel cage motors fed by means of frequency converter where used in the drive of individual caterpillar. Data: motors – 6x 75kW/985 rpm/min/3x500V, frequency converters 110kW/150% Tn 60s.

Because of the reason that excavator SRs1200 and spreader A2RsB5000M work in the same brown coal mine i.e. “Konin” brown coal mine, the power of individual power converters were equalized for both machines in order to improve the start-up and service operations.

In the word literature review made by authors the usage of frequency coverers in order to control the squirrel cage motors is indicated. Nevertheless, the control method is not described in such applications (Jeftenic et al., 2006; ABB, 2005; Szymański, 2000).
This paper is based on the algorithms of controls of frequency converters in the mining machines caterpillar drives made by authors. Presented control methods were made for caterpillar’s drives of new and renovated mining machines. However, the methods can be used in other caterpillar machines.

2. The control method of non-turnable caterpillar drive set

During the researches on the control method of excavator type-SRs1200 with non-turnable caterpillars the analysis of the drive’s geometrical path of the caterpillar during the turn was made. Besides the mathematical analysis the model of the excavator was made (Projekt celowy, 2001). These data were used to construct the control algorithm of individual motors. The constructed model of excavator’s (SRs1200) caterpillar drive set is presented in the Fig. 2.

![Fig. 2. Caterpillar drive set of excavator SRs 1200:](image)
a) model of drive set in 1:30 scale with 4 squirrel cage motors and 4 frequency converters, 
b) placement of caterpillars in excavator SRs 1200

In the algorithm of drive control each motor is controlled individually. The frequency converters are controlled by means of PLC controlled.

By means of new control method the energy efficient drive with much lower exploitation cost was constructed. The drive assures high manoeuvre. Besides, exploitation probes which were made during the hard mining working conditions, have fully confirmed legitimacy of developed control method of multi-motor drives. Linear speed of each caterpillar’s during the turn of machine was counted on converter output voltage frequency. These voltage frequencies determines rotational speed of motor’s shafts.
The frequency converters control the rotational speed of the motor by means of 1^{st} harmonic of their output voltage (Krzemiński, 2001). In order to determine the frequency of the 1^{st} harmonic of frequency converter’s output voltage the analysis of excavator’s individual caterpillar during the movement on the turn was conducted. Characteristic feature of caterpillars drive is the fact that in the initial phase of start-up the load of the drive’s motors is usually low because of the tighten of freely hanging caterpillars.

The fact of “tighten of caterpillars” makes possible the utilization of commonly used in the industry scalar frequency converters (Krzemiński, 2001; Jeftenić et al., 2006; Kasztelewicz, 2006). Scalar frequency converters enable the production of the starting torque which is equal to 150%\( T_n \), in the time when the nominal current is forced in the motor.

The velocities of individual excavator’s caterpillar are equal only in the time of forward movement. When the machine makes a turn reference average speed of individual caterpillars will be different – Fig. 3. The speeds are depended on the length of the caterpillars turn’s radii (\( R_1\)–\( R_4 \)). The speed of the chassis’s construction which turn with \( R \) radius will be different from the caterpillar’s speed.

The motor which fed the caterpillars has velocities corrected in the way that their load is equal. Furthermore, the speeds of the motors are situated in the range of permitted velocities. During the turn the motors which fed external caterpillars (turn on the \( R_3 \) and \( R_4 \) radii) produce driving torque. Internal motors (turn on the \( R_1 \) and \( R_2 \) radii) are producing braking torque.

The control method of excavator’s SRs1200 driving motors, when the machine drives forward, is depicted in the Fig. 4 and Fig. 5. When the machine moves forward voltage’s set frequencies of the motors which fed individual caterpillars \( F_{R_1} \)–\( F_{R_4} \) are proportional to linear velocities of the caterpillars of the machine, are the same and equal to the velocity of the movement of machine’s chassis (excavator, spreader). The speed of the chassis is set by means of \( F_S \) signal.

![Fig. 3. Geometrical arrangement of the excavator’s (SRs1200) chassis with non-turnable caterpillars and indication of forced turn radii of individual caterpillars \( R_1\)–\( R_4 \) when reference excavator chassis’s turn radius \( R \) is set](image)
The synchronization method depicted in the Fig. 4 has built in individual caterpillar speed’s automatic decrease system in case of overload. If the overload of the motor which drive the caterpillar occurs (load above 0.9Tn) than the automatic reduction of the speed of the motor takes place. The reduction of the speed has a value Δω = i*ωk (ωk – the value determined experimentally e.g. ωk=2 Π 0.1Hz ). The number of iteration steps i [i ∈ < 0,1,..9 >] is increased automatically in order to decrease the load of the motor to reference value 0,9Tn. The motor’s load decrease mechanism is utilized because of different mechanical characteristics of the individual motors, the friction of the gear, the friction of the caterpillars or not exact calculation of reference rotational speeds of the motors n F_{R1}^{-}F_{R4}.

When the machine goes downwards the control method is similar except the fact that all motors work as generators and produce braking torque- Fig. 5. Frequency converters have to work together with the system which takes the excess of the energy away (braking resistor which convert the excess of the energy into the heat or recuperation unit which gives the energy back to supplying mains.

In case when the machine makes a turn the frequency F5 is calculated for individual motor which fed the caterpillars. The calculation is based on the dependencies which take into account the radii of the turn. The control of driving (external) caterpillars is realized by means of the principle depicted in the Fig. 4. The control of braking (internal) caterpillars is realized in turn by means of the principle depicted in the Fig. 5.
For the forwards drive the frequency fulfills equation (1).

\[ F_S = F_{R1} = F_{R2} = F_{R3} = F_{R4} \]  

(1)

where:

- \( F_{R1}-F_{R4} \) — power supply frequency of caterpillars’ driving motors
- \( F_S \) — the frequency of motor’s voltage supply in order to determine the movement’s velocity of chassis’s middle movement.

The calculation frequency for determination of linear speed of the chassis’s middle of the machine with stiff construction is expressed by means of equation (2).

\[ F_S [Hz] = F_{MAX} \cdot \frac{V_z [\%]}{100[\%]} \]  

(2)

where:

- \( F_S \) — power supply frequency of the motor in order to determine the velocity of the chassis’s middle when the machine drives ahead
- \( V_z [\%] \) — reference speed of the machine (excavator) in range of (25-100)% \( V_{MAX} \)  
  \( (V_{MAX} = 6 \text{ m/min}) \)

Fig. 5. The principle of control of caterpillars’ electrical motors of excavator SRs1200 for the forward movement on the ramp downwards or for internal caterpillars during the turn.

Frequency converters process the mechanical braking energy into electrical energy which in turn as a heat is dissipated on the \( R_b \) resistors.

\( (4 \text{ or } 2 \text{ electrical engines work as a generator with torque between } 0 \leq T_{q_b} \leq 0.9T_{q_{b_{max}}}) \)
The control algorithm of caterpillars’ drive is based on the assumption that, the maximal velocity $V_{\text{MAX}} = 6 \text{ m/min}$ is achieved when rotational speed of the motors is equal $1000 \text{ rpm/min}$. Because of the reason that caterpillars’ drive set are equip with squirrel cage motors with nominal speed equal to $737 \text{ rpm/min}$, the maximal output frequency of the frequency converters (for $100\% V_s$) should be equal to $F_{\text{MAX}} = \frac{1000}{737} * 50 \text{ Hz} = 67.8 \text{ Hz}$, and minimal frequency (for $25\% V_s$) $F_{\text{MIN}} = 0.25 * F_{\text{MAX}} = 17.0 \text{ Hz}$.

The basic parameters of frequency converters, upon which the control of the machine is realized, which in turn assure the realization of reference movement path are as follows:

- movement direction: forwards – backwards,
- turn radius $R$ of the machine for calculation of reference output frequencies $F_{R1}$-$F_{R4}$ for each of four drives
- the start-up time $T_R$ and braking time of the machine $T_B$.

In order to determine the algorithm of the arc’s drive route of the vehicle additional assumption were made:

- the reference radius of the turn is related to geometrical centre of vehicle’s chassis
- the reference linear speed is related to the centre of the chassis. The linear velocity of individual caterpillar can’t not be smaller than $25\% V_{\text{MAX}} (1.5 \text{ m/min})$ and higher than $100\% V_{\text{MAX}} (6 \text{ m/min})$,
- calculated linear speeds of caterpillars are related to their geometrical centres.

The geometrical arrangement of excavator’s chassis, arrangement of caterpillars, definition of radii is depicted in the Fig. 3.

The algorithm of reference frequency’s calculation for individual frequency converters $F_{R1}$-$F_{R4}$ is realized in case when the reference value of turn’s depth $S_Z$ is different from zero. The turn’s deep $S_Z (-100\% + +100\%)$ is equal to 0% when the machine moves forward. $S_Z = 100\%$ when $S_Z$ is maximal when the turn’s depth, i.e. the turn’s radii is minimal ($R_{\text{MIN}} = 60 \text{ m}$). The sign + means turn right, sign – means turn left.

If the reference value of the turn’s depth is greater than zero than the velocities of individual caterpillars are proportional to rotational speeds of induction motors the calculation’s algorithm is as follows:

- the turn’s reference radius $R$ for the centre of excavator’s chassis is calculated (3),

\[
R [\text{m}] = 100 \cdot \frac{R_{\text{MIN}}}{S_Z} \tag{3}
\]

- next, the turn radii of the centres of individual caterpillar for right and left turn are calculated (4)
- taking into account that the angular speeds of chassis’s centre and caterpillar’s centre should be equal, the frequencies for individual frequency converter are calculated (5).
Left turn

\[
R_1 = \sqrt{(R - A/2)^2 + (C/2)^2}
\]

\[
R_2 = \sqrt{(R - B/2)^2 + (C/2)^2}
\]

\[
R_3 = \sqrt{(R + A/2)^2 + (C/2)^2}
\]

\[
R_4 = \sqrt{(R + B/2)^2 + (C/2)^2}
\]

Right turn

\[
R_3 = \sqrt{(R - A/2)^2 + (C/2)^2}
\]

\[
R_4 = \sqrt{(R - B/2)^2 + (C/2)^2}
\]

\[
R_1 = \sqrt{(R + A/2)^2 + (C/2)^2}
\]

\[
R_2 = \sqrt{(R + B/2)^2 + (C/2)^2}
\]

\[
F_1 = F_S \cdot \frac{R_1}{R}, \quad F_2 = F_S \cdot \frac{R_2}{R}, \quad F_3 = F_S \cdot \frac{R_3}{R}, \quad F_4 = F_S \cdot \frac{R_4}{R}
\]

(4)

In case when one of the calculated frequencies is greater than \(F_{\text{MAX}} = 67.8\) Hz, or less than \(F_{\text{MIN}} = 17\) Hz than correctional calculations are made which lead to proportional decrease of all frequencies \(F_1\)-\(F_4\).

Because of the reason that reference start-up time \(T_R\) and braking time \(T_H\) of excavator concerns the period when the speed changes from 0 to \(V_{\text{MAX}}\), and in frequency converters these times are defined as the time when the output frequency changes from 0 Hz to 50 Hz. The updated values of start-up time \(T_{RV}\) and braking time \(T_{HV}\) should be calculated (6):

\[
T_{RV} = T_R \cdot \frac{F_{\text{MAX}}}{50}, \quad T_{HV} = T_H \cdot \frac{F_{\text{MAX}}}{50}
\]

(6)

When the machine moves forward calculated values of \(T_R\) and \(T_H\) are sent to all frequency converters. If the movement on the radius is concerned proper corrections of times \(T_R\) and \(T_H\) should be made what in turn results from different values of frequencies \(F_1\)-\(F_4\). The corrections should be made in the way which makes possible that the end of the start-up or braking of the machine is made in the same time for all caterpillars.

In multi-motor drives of mining caterpillar machines scalar frequency converters are used. In industrial drives speed as well as torque can be controlled.

The control of speed can be defined as:

– \(SC\) (speed control) here \(T\) (torque) = variety for \(\omega\) (motor’s speed) = constant.

The control of torque can be defined as:

– \(TC\) (torque control) where \(\omega\) (motor’s speed) = variety for \(T\) (torque) = constant.
The control of speed and control of torque can be expressed by means of equation (1).

\[ SC \Rightarrow Tq_M = f(\omega_M), \quad TC \Rightarrow \omega_M = f(Tq_M), \]

here \( Tq_{\text{min}} \leq Tq_M \leq Tq_{\text{max}} \) and \( \omega_{\text{min}} \leq \omega_M \leq \omega_{\text{max}} \) (7)

where: \( SC \) — means Speed Control; \( TC \) — means Torque Control; \( \omega_M \) — speed of motor shaft, \( Tq_M \) — torque on shaft of motor.

The speed control — \( SC \) realized in the frequency converter makes possible automatically motor’s speed reduction when the maximal value of load \( T_{\text{max}} \) is exceeded. The speed control — \( SC \) works similarly as the method depicted in the Fig. 4 and Fig. 5. When the speed control is realized as internal function of frequency converter than the control algorithm in PLC controller is significantly simplified.

3. The control method of spreaders’ and excavators’ with turnable caterpillars’ drive set

If the excavator or spreader has a part of drive equipped with turnable caterpillars and other part of the drive equipped with non-turnable caterpillars – it should be taken into account when the speed of individual caterpillar is determined. In the time of turn the radii of the turn are calculated different for turnable caterpillars’ and different for non-turnable caterpillars’ set. The view of the mechanical construction of type \( A_2RsB5000M \) spreader is depicted in the Fig. 6.

![Fig. 6. Spreader \( A_2RsB5000M \);
a – construction’s view, b – caterpillar’s geometry: 2 caterpillars on turnable cart and 4 non-turnable caterpillars](image-url)
The radii of all vehicle’s caterpillars can be calculated on the basis of Fig. 6b and Fig. 7. The radii \( r_1 \) and \( r_2 \) which determine the centre of carts is expressed by means of (8).

\[
r_1 = \frac{C}{\sin \alpha} , \quad r_2 = \frac{C}{\tan \alpha}
\]  

(8)

![Images of machines' models](https://via.placeholder.com/150)

Fig. 7. The machines chassis’s model with one turnable caterpillars drive set and one non-turnable drive set: a) – forward movement; b) – turn left; c) – turn right

After the calculation of cart’s centre movement radii \( r_1 \) and \( r_2 \) the radii on which the caterpillars will move can be calculated. To the values \( r_1 \) and \( r_2 \) the distance between centre of the cart and the middle of the caterpillar should be added or subtracted (dependend on the internal or external location of the caterpillar). After the calculations the radii \( R_1 \) – \( R_6 \) are achieved (9).

\[
R_1 = \frac{C}{\sin \alpha} - \frac{1}{2} A , \quad R_2 = \frac{C}{\sin \alpha} + \frac{1}{2} A , \\
R_3 = \frac{C}{\tan \alpha} - \frac{1}{2} B - D , \quad R_4 = \frac{C}{\tan \alpha} - \frac{1}{2} B , \\
R_5 = \frac{C}{\tan \alpha} + \frac{1}{2} B , \quad R_6 = \frac{C}{\tan \alpha} + \frac{1}{2} B + D
\]  

(9)

On the basis of the described control methods of control several industrial project of excavators and spreaders were realized. Described machines are working from several years in “Belchatow” brown coal mine (spreader with 2 caterpillar non-turnable drive, excavator with 8 non-turnable caterpillar and 4 turnable caterpillar drive set) and “Konin” brown coal mine (excavator with 4 non-turnable caterpillars, spreader with set of 4 non-turnable caterpillar drives and 2 trunable caterpillar drives).
4. The configuration of excavator’s (SRs1200) drive set

The excavator’s or spreader’s drive is functionally complex multi-motor system. Significant mass of the machine, resilience of the construction, high load changes of individual caterpillars force high static as well as dynamic demands on the drive.

In the case when the motors are stiff fixed to the construction and the machine makes the turn the motors which run internal caterpillars work as generators, producing braking torque. The external which drive external caterpillars work as motors, producing motoring torque. The motors of internal caterpillars turn the machine construction on shorter radius in comparison with the external caterpillar’s motors.

In order to assure long generator work of the motors in time when machine makes a turn a common DC-link circuit for all frequency converters is used – Fig. 8.

![Diagram of internal and external caterpillar in the time of the turn](image)

The motors are fed by means of frequency converters.

The usage of common DC circuit between the multi-motor drive’s frequency converters makes possible the transmission of the energy from the frequency converters which maintain the generator mode of the motors (braking of the motors) to the frequency converters which maintain the motoring mode of the motors. The usage of common DC circuit have another advantage i.e. incensement of reliability when the converter work with high deformations of instantaneous supply voltage and high values of high-frequency currents (Szymański, 2007).
When the machine moves on the ramp down on the straight segments all motors work as generators. In such case the usage of recuperation or dissipation units is necessary. Commonly the braking resistors are utilized which in turn need much of space on the vehicle.

Sometimes, in order to achieve high energy efficiency and high effectiveness of excavator’s or spreader’s braking the braking energy recuperation units are used. The recuperation units cooperate with frequency converters and supplying mains and save the space on the vehicle.

Instantaneous load of individual caterpillar in the time of movement is dependent on the type of the ground, the angle of turn and the placement of individual plates of caterpillars. The influence of the caterpillar’s plates placement appears in significant load’s instantaneous torque changes – Fig. 9.

![Fig. 9. Torque’s waveforms of two external and two internal drive’s motors of excavator’s (SRs1200) caterpillar in the moment of when excavator makes a turn on the dry ground. Braking motors (3, 4) transfer electrical energy to driving motors (1, 2) by means of frequency converters](image)

In order to achieve the movement on the given route the proper speed of individual caterpillar should be assured. Industrial, scalar frequency converters which work in speed open loop can keep the reference motor’s shaft rotational speed with sufficient accuracy even when instantaneous torque value changes.

In some cases the usage of additional functions, usually implemented in factory’s software of frequency converters is necessary e.g. in range of lower motor’s shaft speed and high load changes the voltage compensation of shaft or in higher shaft’s speed region and high load changes the slip’s frequency compensation can be used.
The velocities of individual caterpillars are determined theoretically. In spite of precise determination of individual caterpillar’s speed in the time of the movement during the turn the possibility of correction of the caterpillar’s speed should be foreseen when the permanent load or significant under load of one of the motors occurs. Because of the reason that practically the rotational speed of the squirrel cage motor’s shaft is linearly depended on frequency of voltage supply, the correction of motor’s speed can be realized by means of experimentally determined constant coefficient values of calculated caterpillars’ turn radii.

The overcome of moment of inertia $J \text{[Nms}^2\text{]}$ in the time of excavator’s acceleration don’t force the usage of significant over-dimensioned motors and frequency converters because of the reason that the acceleration time is equal to about 15 s in order to achieve the velocity of 6 m/min. The dynamical component of motor’s load torque is in this case marginal.

The utilization of isolated IT mains in brown coal mining force the usage of frequency converters adjusted do work with IT mains. Such frequency converters should in particular have such features as:

1. EMC filters (Electro Magnetic Capability) of intermediate circuit of frequency converter should be adjusted to interception of high frequency leakage currents from the motor and shielded motor’s cable (Yoshihiro et al., 1992; Szymański, 2007),
2. the protection of frequency converters against excessive voltage increments in the intermediate circuit of the converter in the time of supply voltage’s grounding occurrence.

5. Summary

Proposed solution of digitally controlled excavator and spreader caterpillar’s drive used in brown coal mining is a novel and energy saving solution. Good synchronization of drive’s motors of individual caterpillar is achieved. For control of caterpillar’s drives the advanced program function of frequency converters were used.

The usage of scalar controlled frequency converters which control the motors without speed measurement makes the mechanical construction of the machine simpler and increases its reliability. This solution is commonly used in industry. Multi-motor drives based on the frequency converter displace other solutions of mining machines’ caterpillar drives. The excavators and spreaders has different mechanical construction of caterpillar’s drive – Fig. 10. This fact, however, don’t change the caterpillars’ drives construction rules based on described control methods.

References


Fig. 10. Different geometrical sets of brown coal excavator’s caterpillars – SchRs-4600 type with non-turnable caterpillars’ set and turnable caterpillars’ set:
a) Double-caterpillar excavator type – K41 with single turnable caterpillars’ set and single non-turnable caterpillars’ set – “Belchatow” brown coal mine, b) six-caterpillar excavator K42 with double turnable caterpillars set – “Belchatow” brown coal mine


Received: 15 April 2008