Possibilities of Increasing of Ecological Conditions in Mining Environment by Reconstruction of the Present Engine DH30

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Solving the problems of increasing requirements on transport, while respecting actual environment criteria, new solutions are being looked for to make an optimum mutual equilibrium. One of the possibilities of increasing ecological conditions, which are decreased by means of transporting a mine, shows this contribution that suggests a reconstruction of the original diesel-hydraulic engine DH30 to two-system drive and hybrid drive. In the reconstruction, a DC and an asynchronous engine are suggested as traction engines. This reconstruction of the drive means not only increase of the ecological conditions in the mine but also an ability to use biofuel made from a crop that grew on contaminated soil. The aim of the reconstruction is to replace the combustion engine and hydraulic distribution with an electric drive while traction characteristics will remain at their values. A one-engine traction drive with an asynchronous engine with short circuit armature is regarded as one of the most prospective for an output range from several W up to MW. By using the asynchronous engine powered from semiconductive changer the problem of pulsing parts of torque is dealt with regulation. This reconstruction also means energy saving. This system also improves storing and manipulation with oil production in the mine.

Key words*: *mining environment, hybrid drive, distribution of traction output, transport

Introduction

Requirements demanded by production plants regarding minerals are currently rising, which results in the increasing traffic intensity of material flows in mining companies. Therefore, an alternative to this kind of transport must be searched (Turnbull D. A, 2013). The interplant transport of mineral raw materials plays an important role in the mining process carried out in mining companies (Andrejiová et al., 2015). Investments in new transportation systems are required only at the opening of new deposits or due to measures increasing the strictness of ecological limits. The investment environment connected with the mining industry is quite unique when compared to the environments of other typical production industries (Cehlár et al., 2009). On the other hand, however, this transportation mode must also be well dimensioned, so that the material flow is smooth, efficient, and cost-effective (Drottboom, 2013). Reducing the cost of resources in solid mineral extraction is an urgent task. For its solution is possible used logistic approach use to management of mining company all resources, including extraction processes, transport, mineral handling, and storage (Tyurin, 2017), (Andrejiová, 2016). The selection of the mode of transport for moving bulk materials is never a simple task as there are various concerns/considerations applied to the selection of the most practical and cost-effective mode of transport to be used to move bulk materials (Verkerk, 2005). Belt conveyor system technology is acquiring its specific place in the in-plant transportation system in every company and represents a stable mainstay of efficient in-plant transportation (Grujič, 2011). The development trends in the field of conveyor belt wear, in terms of disruption damage, are mostly focused on the innovation support systems of damping components of buffer beds with impact rubber bars (Gondek et al., 2014). Impact bars are an essential component of innovative buffer beds suitable for several types of belt conveyors (Marasová et al., 2017; Ambriško et al., 2017; Gondek et al., 2014). Maintenance cost reduction can be achieved by improvements in utility properties of conveyor belts (Ambriško et al., 2016), (Grinčová,2014).

The demand for the quality of the environment has recently increased. This fact evolved its impact on criteria of devices that change energy from oil products to traction energy. The present state-of-the-art transportation systems used in hard coal mines on main and divisional routes were discussed in comparison to the conditions from previous years. Current development trends in the aspect of more and more extended use of Diesel engines as well as resulting limitations were indicated in work (Pieczora, 2008). In the last item directions of R & D work, which is aimed at designing new Diesel and electric drives were specified. The aim of the work (Arsentiev et al., 2017) was to study the possibility of using induction motors with reduced voltage power supply for traction electric underground mining locomotives; to determine the conditions of conformity of mechanical characteristics of induction traction motor with reduced voltage regarding the characteristics of a standard voltage.

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Mine engine with combustion engines, which are a typical representative of a moving detrimental emission producer. Results of researches and monitoring of smoke particles in exhaust gases as well as the mechanism of their creation and their influence to human body mean an intricate problem that is necessary to solve (Kucera and Saly, 2000). In general, these solutions could be made in two ways:

- by increasing of the efficiency both ventilation and air conditioning of subterranean spaces,
- by decreasing of detrimental emission.

The first suggestion is highly economically demanding; therefore, the second suggestion should be taken into consideration. One of the ideas which could be applied to this problem is using of two-system traction drive powered from electron accumulator (Kucera, 1996).

One of the main goals of underground rail transport is to achieve marginal traction characteristics of variable frequency induction motors in conditions of the limited magnitude of the supply voltage of the contact network DC of underground transport for electrical safety reasons (Arsentiev, Baranov, Vilnin and Kladiev, 2017).

Also, electric motor, electronic converter, and electric battery were studied for mine locomotive (Matyuschenko, 2016), (Frivaldsky, M., Drgona, P., Spanik, P., 2013).

Development trends ecological conditions in the mining environment are primarily focused on the energy consumption reduction, structural component material savings, reduction of the negative environmental impact service life extension. Assessment of transportation systems for minerals may be carried out while applying several methods (SFRA, monitoring, thermovision and procedures, especially the simulation and mathematical modeling (Kodali, 2001; Lysenko, 2005; Werelius et al., 2008; Wang et al., 2009). Appropriate tools are available to identify the process of damage to electromotors, transformers during operation (Gutten, 2007; Huynen, 2004; Gutten et al., 2009). Electromagnetic compatibility and functional safety can no longer be treated as two separate disciplines when electrical or electronic systems are considered performing safety-related functions (M. Kucera and M. Sebok, 2012). Reliable operation of electronic equipment at various technological and operation conditions requires a safe operation on communication devices. Information transfer, automatic processing, and data recording are exposed to detrimental influences from various sources (Jurčík, J. et al., 2011). Disturbance effect of environments shows unwanted bonds, interference noise, resonance and transitional phenomena that may cause incorrect operation of electronic equipment, distortion and degradation of data transfer and its recording and in extreme cases also a destruction of the equipment (FEMV, 2002). A system that is perfectly reliable, but not electromagnetically compatible has no practical use (Vaculíková, P., Vaculík, 2003). This paper deals with a device for online, real-time analysis of recuperative current with the use of a microprocessor. This system is used in railway transport for measurement and analysis of recuperative-currents from converter in railway engine. Recuperative currents from converters in railway engines flow through rail back to the distribution point. Content of higher harmonics in these currents must not exceed limits specified in international standard UIC 550-3, so exact measurement and analysis of this harmonics are necessary. Proposed device uses a microprocessor for real-time measurement and analysis of recuperative currents (Gutten et al., 2017)

The paper presents the results of changing energy values of W-10 switches for various design solutions of their contacts (Kozak et al., 2012). The experiments have been performed on a computer-supported testing stand described in (Zukowski P., Kozak C., 2010). The testing cycle consisted in recording characteristics of current, voltage drop and temperature of a normally-closed fixed contact as well as the real-time arc energy values for each switching cycle at the direct voltage and for every 20th cycle at alternating voltage. The measurements have been performed at the voltage of 120 V in order to avoid incessant burning of the arc at direct voltage. In the process of performing measurements for direct voltage, an automatic change of polarity has been applied at the starting of each subsequent switching cycle. It follows from the obtained measurement results (Zukowski P., Kozak C., 2008) that at the positive polarity of the fixed contact the mean arc energy value has been higher than in the case of negative polarity. The paper presents theoretical and experimental analyses of a possible effect of the short-circuit forces on the transformer winding (Arumugam, 2014).

Analysis of the evaluated traction drive for Engine DH30 system

Considering a present economic status complete elimination of pollution in mining spaces caused by exhaust gases from the DH30 Engine (Fig. 1) could only be done by reconstruction of the Engine.

The aim of the reconstruction is to replace the combustion engine and hydraulic distribution with an electric drive while traction characteristics will remain at their values. Scheme of such reconstruction, where the source is energy from electric/accumulator batteries, is showed in Fig. 2.

The batteries are recharged while the engine operates on a cabled section of a route. Braking with the use of a recuperator decreases demand for energy and extends the life expires of traction wheels. An important parameter which essentially determinates the actual design of traction batteries is the time spent on the uncalled route and their energy requirement.

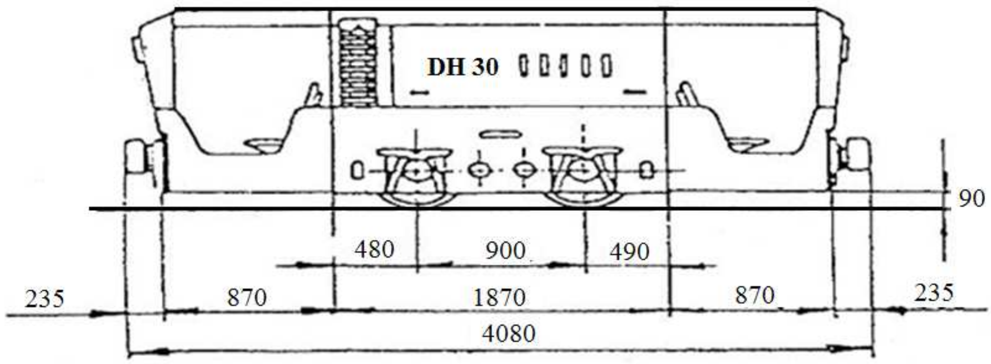

Fig. 1. Basic dimensions of DH30 Engine.

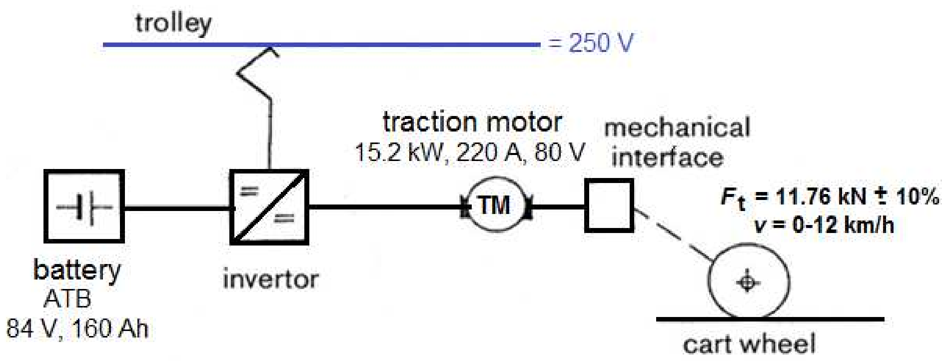

Fig. 2. Scheme of electric traction circuits of the reconstructed, two-system engine DH30.

Drive with DC Traction Engine

Exploiting of DC engine in traction application is well known. Using of power electronic it is possible to supply such drive that the energetical loading of electro accumulators will be at a minimum. High-quality power transistors/current loading 400A, voltage 120V, galvanically separated control element excitement in one integrated box together with power part/ and their ability to work at the frequency of 20 kHz, that is above a human hearing level, enable reliable and noiseless operation.

Fig. 3 shows a scheme of connection of the DC engine with the independent exciter. The excitement of the engine is powered from a 4-quadrant changer. The amount of voltage is controlled by a 2-quadrant changer. This scheme is used in applications, where quick changing from drive to the braking regime is necessary.

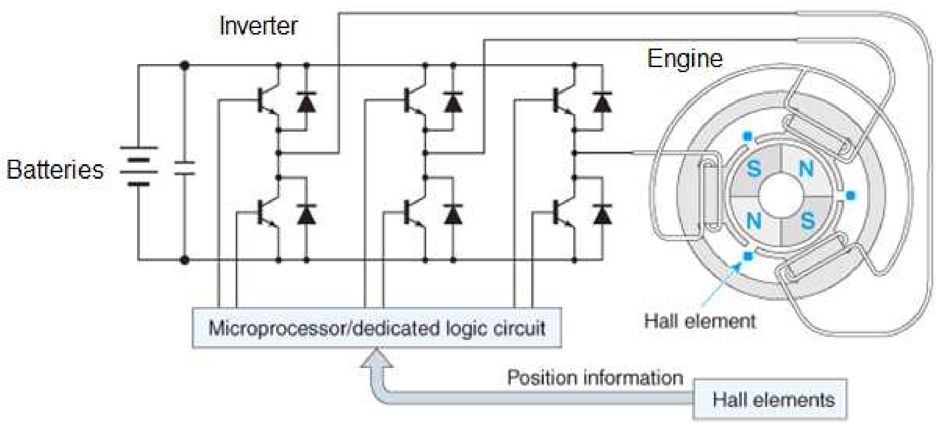

Fig. 3. Scheme of connection of the DC engine with independent exciter.

Drive with an Asynchronous Traction Engine

A one-engine traction drive with an asynchronous engine with short circuit armature is regarded as one of the most perspectives for an output range from several W up to MW. According to its output, regulation range, kind of loading, quadrant characteristics, dynamical requirements, etc., an array of solutions arise. (Glowacz A., 2019).

Each solution differs from one another with a kind of frequency changer, way of control, and technical devices. In the motoric regime, the changer changes input DC values to AC values of different rate, frequency, and the number of phases. In case of electric braking the engine changes to the generator. A scheme of connection and control of the asynchronous engine is in Fig. 4.

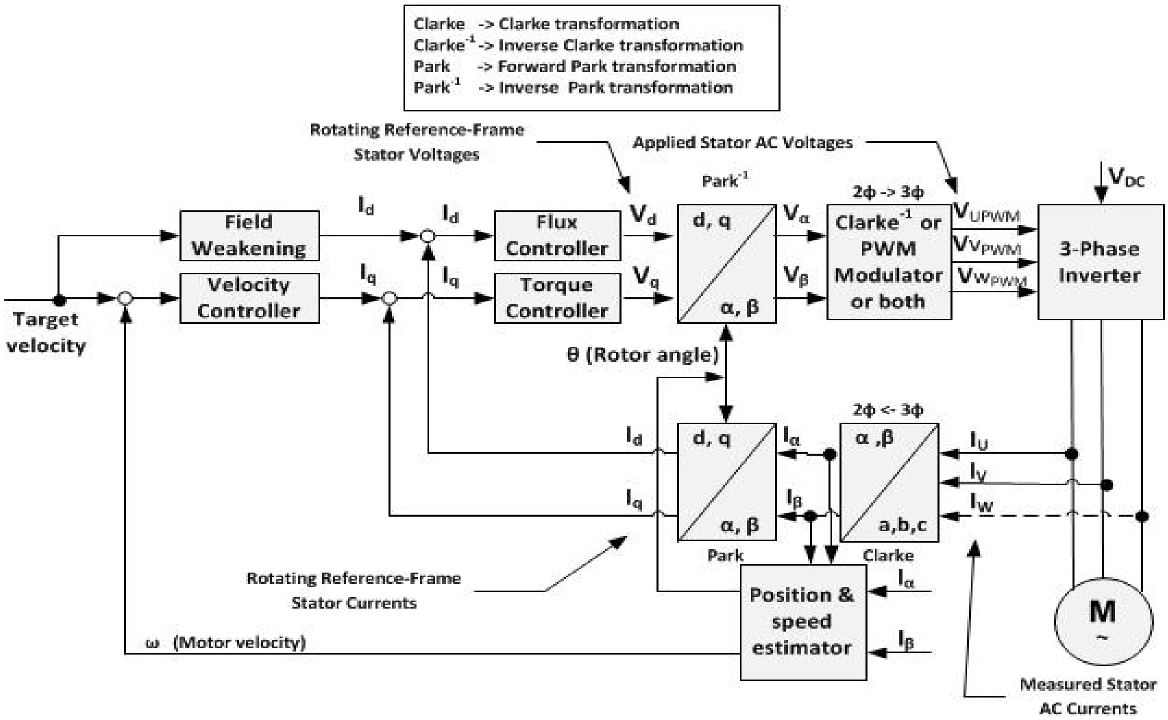

Fig. 4. Scheme of connection and control of the asynchronous engine.

Design of hybrid traction drive for DH30

Using electro-petrol and electro-diesel engines in mines have been used for more than 70 years. The first electro-petrol engine in Slovakia was introduced in The Mine Hodruša in 1928. The output of a 4-stroke petrol engine was 5.85 kW, and a clutched dynamo had an output of 6.2 kW that produced a voltage of 380 V. An Electro-diesel engine was used in Slovakia for the first time in the year of 1934. This system of traction drive has been used until the present time by the terms of transport requirements in the mine.

In a similar principle is based on the proposed reconstruction of the mining engine DH30 (Fig. 1). The essence of this reconstruction is replacing of the original diesel-hydraulic drive unit with the electro-diesel-accumulator unit where the asynchronous engine acts the traction engine. A block diagram of the electrical part of this reconstruction is in Fig. 5.

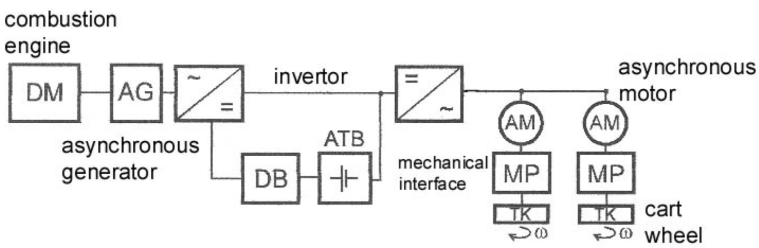

Fig. 5. Block diagram of the electrical part of this reconstruction.

Capacity ATB is less important with hybrid traction drive compared with electric drives since the engine also provides capacity. Therefore, the battery can be much smaller, saving weight. However, the battery may still be required to provide the same instantaneous power as the EV battery from time to time. This means that the smaller battery must deliver much higher currents when called upon.

Analyzing typical traction drive for mining train

In the Fig. 6, there is depicted one period of maximal power output demand, where particular partitions on tome axis mean:

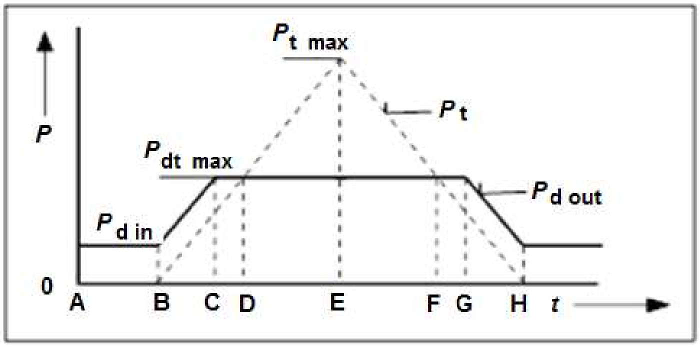

Fig. 6. One period of maximal power output.

A- Traction alternator charges ATB and combustible motor works with constant output $P_{dtNAB.}$

B-C: The demand for power output started to increase. In consequence of this demand, speed starts to rise, and the traction generator is excited. The generator was given an impulse to increase the asked value of current for the asynchronous motor.

C: Maximal output for the asynchronous motor is reached from the combustible motor.

C-D: On behalf to cover power output demand, the current for charging ATB have to be decreased.

D-E: Output is constant, and the taking current starts to rise.

E: At this moment, the combustible motor is able to supply maximal power output.

E-F: Power output decreases and together with its also the asked current from ATB.

F-G: Output of combustible motor is still maximal, but ATB starts to charge.

G-H: ATB is charged with asked current and output of combustible motor decreases together with power output.

For suggested operation cycle of simulated travel correspond the average output of the asynchronous motor.

$$P_{\text{average}} = \int_0^T P(t)dt = 8.53\text{kW} \qquad (1)$$

- ASM motor power 15 kW,
- nominal voltage /current 180V / 30 A,
- the maximum angular velocity 2073 speed/min,
- the maximum frequency of 70 Hz.

Draft traction output for the hybrid drive system

Distribution of traction output could be done partially according to a user or according to predefined software. Autonomous control of a microprocessor unit for the distribution of traction output is depicted in normal operation only ATB /NiCd battery capacity 250 Ah/ drive with insufficient accumulator capacity, drive with using of all energetical sources, and recuperation of traction output.

In a system of control, information from the operator is processed together with information about a state of input supply, impulse changer, invertor, and traction engine. The control must fulfill specific requirements derived from a traction engine and technology of transport. It means mainly the control of a magnetic flow in the engine and torque. Drives for general purposes are often dealt with a cheap solution without speed sensors and only with a small number of another sensor for electrical values. For drives with dynamic requirements, vector control has become common. This enables to control a magnetic flow and torque in the steady-state regime as well as in transition state. Mathematical simulation of controlled traction drive with an asynchronous engine reveals very good dynamical characteristics.

The scheme of direct torque controlled induction motor with a fuzzy controller is in Fig. 7. The fuzzy controller is designed to have three fuzzy state variables and one control variable for achieving constant torque and flux control. Each variable is divided into fuzzy segments.

The number of fuzzy segments in each variable is chosen to have maximum control with a minimum number of rules. (Spanik, P., Sedo, J., Drgona, P., Frivaldsky, M., 2013).

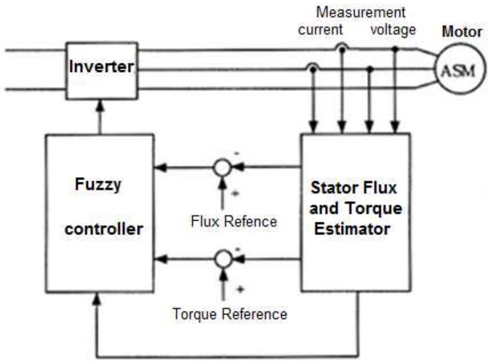

Fig. 7. Fast regulation of torsion moment.

The first is difference between the command stator flux ψS^* and estimated stator flux magnitude ψS (error in stator flux $E\psi$) given by:

$$E\psi = |\Psi^* S| - |\Psi S| \tag{2}$$

The actual stator flux can be calculated from the voltage and current information in the stator reference frame as

$$\Psi\alpha = \int (u\alpha - i\alpha \cdot RS)\,dt \tag{3}$$
$$\Psi\beta = \int (u\beta - i\beta \cdot RS)\,dt \tag{4}$$
$$|\Psi S| = \Psi 2\alpha + \Psi 2\beta \tag{5}$$

For suggested operation cycle of simulated travel correspond the average output of the asynchronous motor.

Optimal Torque Computation

This control strategy was developed by Ohio State University under a subcontract with NREL. Information for this help file was taken from the final technical report entitled "Development of Fuzzy Logic and Neural Network Control and Advanced Emissions Modelling for Parallel Hybrid Vehicle" which provides additional detail on the model and is available in the ADVISOR reading room.

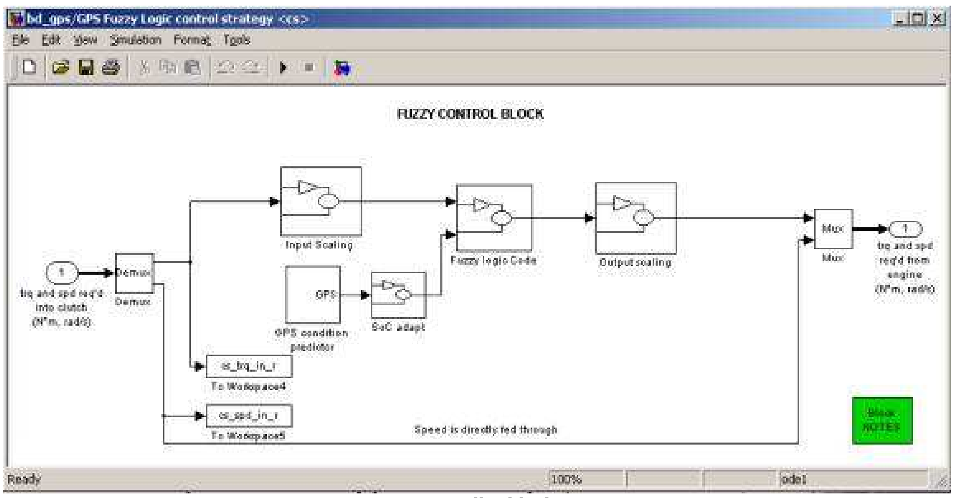

Fig. 8. Fuzzy Controller block components.

The controller programs are created using MATLAB script files and can be modified by the user. The following Fig. 8 indicates the position of the Fuzzy Logic Controller in the Simulink block in ADVISOR.

Finding an optimal IC Engine operating point

The data for an IC Engine in ADVISOR is in the form of a 2-dimensional map, indexed by torque and speed. Information regarding fuel economy [g/s] and emissions such as CO, HC, and NOX [g/s] is available for various speeds and torques (Fig. 9).

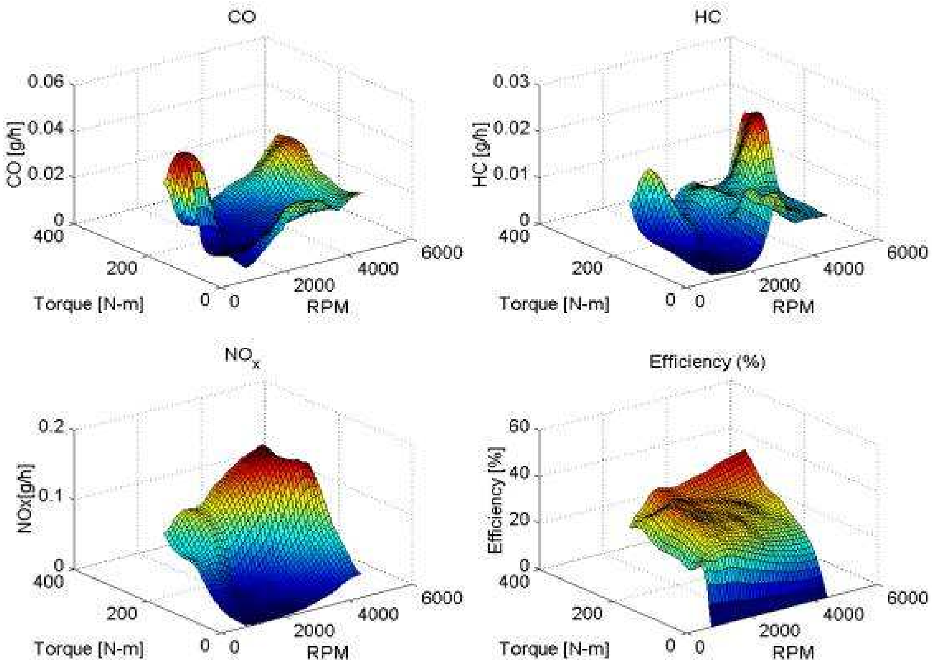

Fig. 9. IC Engine emissions – a general trend from MATLAB.

From the graph in Fig. 10, we can state that the proposed hybrid drive solution ensures sufficient traction by preserving the dimensions of the original locomotive and reducing the ecological load.

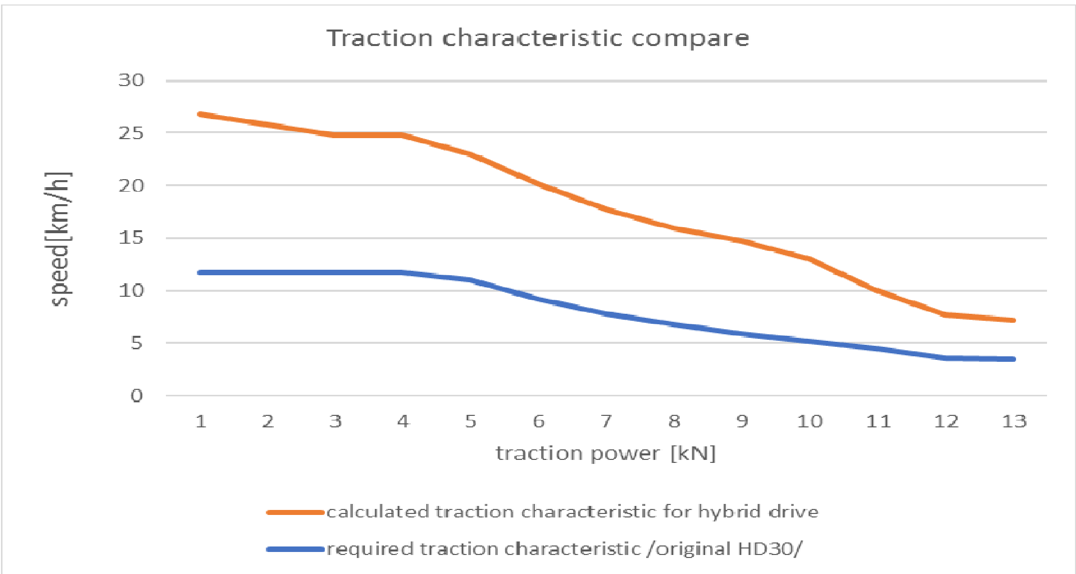

Fig. 10. Traction characteristic.

Results and conclusion

The actual operation of mine engines DH30 and DH100 involve high costs for the working environment. This article shows that using electrical energy for traction purposes highly eliminates (hybrid system) or almost completely reduces (two-system drive) detrimental influences on the working environment. Several options of reconstruction of the DH30 engine for two-system or hybrid electric traction enables to use of an asynchronous engine or DC engine as a traction engine. By using the asynchronous engine powered from semiconductive changer the problem of pulsing parts of torque is dealt with regulation. This reconstruction also means energy saving. This system also improves storing and manipulation with oil production in the mine. Another advantage apart from increasing the ecological conditions and energy saving is that, that the Elsbett engine uses a vegetable oil which can be produced on contaminated soil.

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