MULTI-TRANSDUCER SYSTEM FOR OPTIMAL CORELATION BETWEEN THE WORKING REGIME AND THE ENERGY CONSUMPTION OF THE EXCAVATATING UNITS IN OPEN PITS

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Abstract:

This paper presents a multi-transducer system for optimal corelation between the working regime and the energy consumption of the excavators in open pits; it is intended to have an approximate constant flow of excavated material at the level of reference performances of the outfit at a specific optimum energy consumption.

The system carries out the measurements with intelligent transducers and uses technical equipment for acquisition and control. This is integrated into a distributed information system and makes possible the calculation of the required excavator parameters and the energy consumption. By tuning the parameters, the excavator can be driven optimally, in automatic condition, with reduced energy consumption. The system is used in Romania at EMC Rosia.

In a cooperation with the IAT Gelsenkirchen the functionality of the distributed system will be extended with techniques for a fuzzy-based estimation of environmental impacts of excavation processes and of the effectivity of the multitransducer system.

Keywords: Real time data acquisition & control, energy consumption, intelligent transducers, centralised monitoring and control.

1.INTRODUCTION

The problem of knowing the excavated coal amount is very important in mining. When excavating a volume estimation is aimed in order to follow the production of each outfit; furthermore the estimation of costs of product unit and training of each belt profitableness under different time sections are intended. The permanent display of the instantaneous amount into the excavatorist cabin allows to trace belt charging, removing unproductive times and managing the information for profitability determination. Anather important requirement is the loop of the equipment and the excavator driving

system for an uniform load of the coal on a belt, such carrying out the automatic control of belt charging. The equipment such achieved by function convering becomes important in the information system for dispatching in the open pits.

The achieving principle is base on the possibility of the designed equipment to maintain a pre-set value of the excavated flow under the circumstances of excavating parameter variation cutting, run rotation and conveying), reflected by different energy consumption of the drives between limits economically optimal and acceptable from the point of view of overall surety of the driven mechanisms.

By the way of selecting the variation ranges for the monitored energy parameters, there is the possibility to get some information on the behaviour manner of the receptive mechanisms (e.g. the wear of cutting component, wears and additional mechanic resistances to run and rotation) and even on some stresses in the strength metal structure, which at an exceeding of some thresholds considered as critical, can generate an intervention on aimed at technical damage avoidance.

By means of the excavated mass determination equipment - based on intelligent transducers in fuzzy logic technology- information on the excavated and conveyed flow is got, which represent at the same time the feed-back parameter of system.

By a system of multiple intelligent transducers, information concerning the energy consumptions from cutting, run, rotation and conveying processes, angular speed, relative position, forces and moments will be taken over, all being discharged and processed according to a mathematical model established in this equipment.

An equipment for the determination of excavated coal volume and amount - EDCV - is at the bases of the developed system acting on the excavator run and rotation aiming at the working condition improvement and energy consumption decrease. The ECDV equipment is based on the following principles: coal volume measurement by means of an ultrasonic intelligent (fuzzy logic) transducer assembly, coal amount measurement by an indirect measure of the energy consumed by the motor and a data acquisition, control and processing equipment.

The equipment is intended mainly to trace the production and to improve the power operating duty of the outfits working in lignite pits: rotor excavators, rubber conveyor belts and waste conveying installation. The measuring equipment is a complex unit, which provides the determination, display, record, control and remote transmission of the following parameters:

-instant flowrate (m^3/ h);
-material amount metering (t);
-intensive use indices;
-extensive use indices;
-power indices.

The proposed system has the task to carry out the following functions:

- automatic acquisition of the parameters by means of some transducers generating unified signals or impulses at the output;
- primary processing of the on local equipment (scaling, averaging complying with the limits, alarming, monitoring, etc.);
- indirect calculation of coal amount in relation with the input current of the engine;
- calculation of the excavated coal volume by time integration of the determined instant sections;
- storing, archiving and presentation of the quatities taken over and processed for a pre-set time period, operative and statical reports providing support for communication withen the company's INTERNET for leadership structures.

- providing decision decentralization and a high tolerance to failures
- data transmission in a pyramid system to a level hierarchically higher
- tracing of the production and the excavated coal amount energy consumption and its correlation with the operational or stationary data of the outfits, for failure categories.

The local equipment for indirect measurement of the conveyal coal volume is integrated into the dispaching system of the open pit. The system determine:

- optimal power duty for excavation, depending on the excavated material nature: lignite, marl, clay, etc.
- economic useful life of dipper tceth for rotor excavators;
- optimal power duty for rubber conveyor belts;
- removing of installation deterioration;
- removing of un - productive times and energy losses by limiting the idling;
- monitoring of the excavated coal amount and contact thr consumed power ;
- removing of installation deterioration by detecting the breakage of conveyor belt or runway.

The economic effect of using this system is firstly the electric energy consumption decrease during lignit excavation from pits.

2.CONSTRUCTIVE SOLUTION CONCEPTION

Starting from the model and characteristics of the excavators and conveying belts working in surface pits the parameters, which indirectly, can to the estimation and administration of coal amounts and energy consumption were identified.

The identified parameters led to the solution definition. From here it results the constructive solution of the device. The device contains the following constructive units: current and voltage unit, belt speed measuring unit, ultrasonics emission-reception unit, coal amount, volume calculation and estimation unit, driving unit for excavator run and rotation, data communication unit.

3.FUNCTIONAL UNIT ANALYSIS. VOLUME DETERMINATION

It has been started from the consideration that, by means of ultrasonic units, the estimation of conveyed coal shape (section) could be achived. The instantaneous section is determined by points, by means of some ultrasonic transducers whose number has been calculated by fuzzy algorithms. The excavated and conveyed volume determination is done by interpolating and time integration.

4.AMOUNT DETERMINATION AND CONTROL

Surveillance and control is performed by measuring the active power consumed by the engine. Considering that the consumed power is a measure of the torque, the following elements could be taken into account.

Power should be measured by using the formula: $P= UI\cos\phi$

The measurement should be accurate, especially the repeatability should be high. The shortest possible reaction time is a half of the measured voltage period (10 ms at 50Hz). The measurement should be valid even for non-sinusoidal currents. The

equipment should have functions such as: starting time, automatic zero, detector of peaks for loading mass (min, possibility of voltage compensation). In order to fulfil these requirements, a real time data acquisition system is used by means of which the following functions are implemented:

- phase current and voltage acquisition
- active/ reactive power and power factor calculation
- calculation of excavated coal amount
- power, voltage, current, power factor and possibly consumed power displaying, by request
- operation of the relays provided for installation control, depending on the pre-set limits
- control of the invertor assembly for run and rotation drive, by means of an analogic output

The measuring principle refers to the definition relations of the involved quantities

(1) $Xeff = 1/T \int x^2(t)dt$

(2) $P=1/T \int u(t)*i(t)dt$

X(t) = u(t) or I(t) , periodical quantities in the period T: x(t) = x(t+4) and reffering alternating quantities x+(t) = x-(t).

The respective relations can be implemented in discrete by using the sampled and quantified values of the respective quantities, uniformly distributed for a period.

(3) $Xeff= 1/N \sum x^2(k*To)$

(4) $P=1/N \sum u(k*To)*i(k*To)$

where To is the sampling period. The synchronized acquisition of the samples supposes the fullfiling of the condition:

N*To = T(5), such provid removing of additional errors. In particular, it is required that N, representing the number of samples in a period, is an exponent of 2, by easy considerations for the previous processing.

5.PROGRAM PACKAGES; CALCULATION ALGORITHMS

Program packages and calculation algorithms have been analysed having the following necessities:

- acquisition of signals from current, voltage, belt speed, level on ultrasonic band transducers;
- signal filtering;
- equipment and belt calibration;
- ultrasonic processing by fuzzy algorithms and section shape determination;
- determination of excavated and conveyed volume by interpolating and time integration;
- instantaneous amount estimation, relating to the current through the driving engine;
- correction of coal amount estimation;
- control of inverter assembly for run and rotation drive, for the purpose of an uniform loading and an optimal power operation duty;
- data transmission to the level hierarchically higher and to the excavator operator;
- determination of energy use indices and consumtion improvement;
- determination of optimal operation duty, which becomes the prescribed quantity for local equipment.

CALIBRATION CONSIDERATIONS.

The method of consumed active energy and the volume determination by means of ultrasonic transducers had been no more implemeted in Romania util now and it results from calculations that it is a rather efficient method for estimating the amount and volume of coal conveyed on a belt. If there is only one three- phase engine for driving, the restricted algorithm is the following:

- The active energy consumed at idling in the time interval (which can be 5-10 minutes) is calculated, and it will be called apparatus calibration routine. The value of active energy consumed at idling is represented as a sum of kinetic and potential energies;
- Kinetic energies so that the belt can be conveyed under a certain angle between the starting and arrival point;
- Potential energies, which can be the friction energies between belt and ground on the entire length of belt path, friction energies between the rolling pulleys and belt, losses in reducer and other energies dissipated in any real mechanical system.

Assuming that the value of the active energy consumed by motor at idling in the time unit allocated (5-10 minutes, depending on the mesurements performed in real situations) is energy consumed by engine at idling is already know (empty belt), simultaneosly with the putting into operation of the on-load engine, then belt, a timemetter and a kilowattmetter inside the equipment, which will operator as long as the belt is working, are started. At the end of the calculation period the timemetter and kilowattmeter are stopped. By the energy difference correlated with material mass according to a linear or exponential law (depending on the on-site measurements) the material amount conveyed by the belt during operation can be estimated.

The central unit is connected to a PC by means of a serial line RS 485 through which, at the end of the operation period, the on -load operation time and the active energy consumed is communicated. PC carries out a daily report on the coal amount conveyed by belt, then following the elaboration of some hourly weekly, monthty, quarterly reports or other operative reports. The presented algorithm contains, also the calculation of some efficiency indices, which are depending on the belt, roller wear and of every factor determing energy loss in system.

Calibration routine (idling for a time period for calculating the active energy of belt conveying and overcoming the resistance forces) has to be performed as often as possible, in order to determine accuratcly the material amount conveying through the belt. We consider that a central unit calibration once in a month is enough, if we take into account the accurancy class of the apparatus. Immediately after a calibration routine, which is performed on a central unit (implicitly on the belt corresponding to that unit), the configuration file of the measuring station from PC is up-dated in order to take into account the changes related to the time wear of different subansamblies.

Further more the calculation algorithm is the following:

- belt travelling speed vt (m/s) measured at idling before the calibration
- electric energy consumed at idling during the calibration period: Ee (kWh)
- idling time: Tc (hours)
- active electric energy consumption at the beginning of the mesuring interval, with a view to starting the instant flow rate E1(kWh)
- active elctric energy consumption at the end of the mesuring interval, with a view to starting the instant flow rate E2(kWh)

- duration of momentary flow rate Tm (hours) the momentary flow rate is calculated with a sampling rate with an order of magnitude of seconds
- maximum operating power during the measuring interval: Pmax (kW).

The technical characteristics of the conveyer, taken from its technical book are:

- qb-weight of the conveying belt on a length of 1 meter (kg /m) - possibly the weighted average of weight for the belts made of many rollers of different types
- qrs -weight of moving parts of upper rollers (kg / m)
- Vt- traveling speed (the practical one, and not the theoretical one, taken from the conveyer technical book)
- H - level difference between the receiving point and delivering point of the material (m)
- conveying path slope against the horizontal line, at the level of the upper branch (degrees)
- overall efficiency of the motor reducer driving set

The following formula are used:

- average flow rate conveyed on the upper branch Qb=3.6*qb*vt (t/hour)
- average power at idling P0=Ee/Te (kW)
- specific energy consumption for upper belt conveying

e0=[P0+K(qrs-qri)2Ke]/2*Qb (kWh/t)
K=P0/[2qb*cos()+qrs+qri]
Ke=[qb*vt*H]/102*

- average instant flow rate Qm=[E2-E1-(P0*Tm)]/e0*Tm (t/hour)

6.CONCLUSIONS

The described system is implemented in Romania EMC Rosia open pits and is proposed for others mines.

This paper presents a system intended to optimise the energy consumption and to improve the working conditions of the excavators operating in lignite pits based on direct measurements, intelligent transducer and acquisition & control equipment.

The equipment is based on the following principles: coal volume measurement by means of an ultrasonic intelligent (fuzzy logic) transducer assembly, coal amount measurement by an indirect measurement the energy consumed by the engine and a data acquisition, control and processing equipment.

Starting from the model and the characteristics of the excavators and conveying belts operating in open pits the, parameters which indirectly can allow to the estimation and administration of coal amounts and energy consumption were identified.