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REALIZACIJA RADA SISTEMA TRAČNIH TRANSPORTERA SA DALJINSKIM UPRAVLJANJEM

REALIZATION OF SYSTEM OF BELT CONVEYORS OPERATION WITH REMOTE CONTROL

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Ključne reči
- kontrolni centar
- SCADA
- nadzor
- upravljanje
- tračni transporter

Keywords
- control centre
- SCADA
- supervision
- control
- belt conveyor

Izvod

Potreba za neprekidnim radom sistema tračnih transportera sa maksimalnim vremenskim i kapacitivnim iskorišćenjem, uzrokovala je uvođenje sistema daljinskog nadzora i upravljanja u toku projektovanja novog V BTO sistema na površinskom kopu „Drmno“. Sistem upravljanja i nadzora, koji je ovde predstavljen, je modularnog tipa. Poboljšana dijagnostika svih modula, dostupna u kontrolnom centru omogućuje kratko trajanje zastoja prouzrokovano otkazima opreme, a servis se na licu mesta obavlja jednostavnom i brzom zamenom modula. U radu je prikazano jedno rešenje daljinskog upravljanja sistemom tračnih transportera, primenjeno u praksi na površinskom kopu. Ovo rešenje predstavlja pionirski poduhvat na površinskim kopovima u našoj zemlji.

Abstract

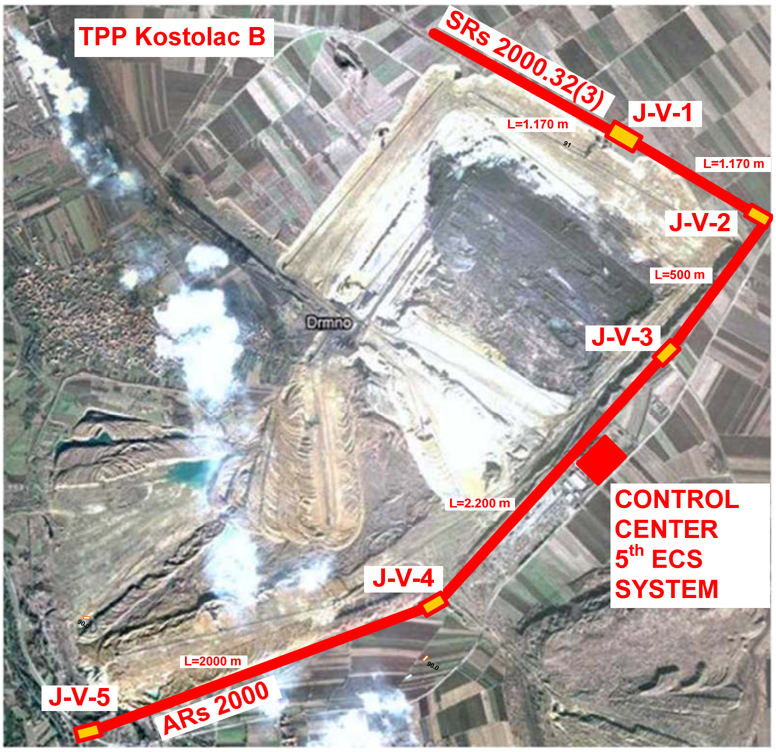
Due to existing demand for continuous operation of the belt conveyor system with maximal time and capacitive utilization, it was decided during the design phase of the new 5th ECS system on OPM “Drmno”, to implement the remote supervision and control system. The presented control and supervision system is modular, as a necessity for this kind of technological system. Improved diagnostics of all modules, accessible from the control centre, enable short stoppages caused by equipment malfunctions, and service performed on-site, with simple and fast module replacement. One solution of remote control and supervision for the belt conveyors system implemented on open pit mine is presented. The application represents the pioneering achievement on open pit mines in Serbia.

UVOD

Transport materijala, jalovine ili uglja, u zavisnosti od toga da li se radi o BTO sistemu (Bager Traka Odlagač), BTD sistemu (Bager Traka Drobilana) ili BTU sistemu (Bager Traka Utovarno mesto), vrši se sistemom tračnih transportera, koji ove količine materijala prenose na razdaljine i po nekoliko kilometara. Zajednička karakteristika svih pomenutih sistema je potreba za neprekidnim radom, 24 časa dnevno, 365 dana godišnje. Na površinskom kopu „Drmno“ Javnog preduzeća „Elektroprivreda Srbije“ realizovan je novi V BTO sistem, koji se sastoji od bagera SRs2000, odlagača ARs2000 i sistema od pet tračnih transportera maksimalne ukupne dužine od 8 km, sa regulisanim pogonima, /1/, snage 4×1,2 MW na svakom transporteru, a u čije su projektovanje, nadzor i puštanje u rad, kako elektro, tako i upravljačkog dela, bili uključeni autori ovog rada. Dispozicija BTO sistema sa označenim dužinama tračnih transportera nakon puštanja sistema u rad, septembra 2009. godine, prikazana je na sl. 1.

INTRODUCTION

Transport of material, overburden or coal, depending on the type of system – ECS (Excavator-Conveyors-Spreader), ECC (Excavator-Conveyors-Crushing plant) or ECL (excavator-conveyor-loading point) is performed with the system of belt conveyors over distances several kilometres long. The common characteristic of all mentioned systems is the existing requirement for continuous operation, 24 hours per day, 365 days per year. A new ECS system has been realized on the open pit mine “Drmno” of the Public enterprise „Electric power industries of Serbia”, comprised of excavator SRs2000, spreader ARs2000, and the system of five belt conveyors with maximum total length of 8 km with installed power controlled electrical drives of 4×1.2 MW, /1/. Authors of the paper were deeply involved in the design and commissioning of the electrical and control systems of both, the system of belt conveyors and Spreader. Disposition of the ECS system with designated lengths of belt conveyors after commissioning in September 2009, is presented in Fig. 1.



Slika 1. Dispozicija V BTO sistema na površinskom kopu „Drmno“, nakon puštanja sistema u rad 2009. godine
Figure 1. Disposition of 5th ECS system on the open pit mine “Drmno” after commissioning.

OPIS UPRAVLJAČKOG SISTEMA

Zbog potreba za neprekidnim radom sistema, sa maksimalnim vremenskim i kapacitivnim iskorišćenjem, u toku projektovanja V BTO sistema odlučeno je da se koristi sistem daljinskog nadzora i upravljanja. Prema svetskim iskustvima u radu takvih sistema, /2/, daljinski nadzor i upravljanje povećavaju kapacitivno i vremensko iskorišćenje sistema. Oprema koja je korišćena i rešenja koja su primenjena, izabrani su sa ciljem da se smanje vremena polaska sistema i trajanja zastoja, kao i da se smanji njihova učestanost.

CONTROL SYSTEM DESCRIPTION

Due to existing demand for continuous operation of the system, with maximal time and capacity utilization, it was decided during the design phase of the new system of belt conveyors, to implement the system for remote supervision and control, as in accordance with experience in the operation of similar systems world-wide, /2/. The equipment used and the solutions applied were chosen with the aim to reduce duration of system start and to reduce the frequency and duration of unplanned stoppages.

Monitoring rada sistema tračnih transportera, kao i upravljanje, vrši se daljinski, iz kontrolnog centra, u kome su sve relevantne informacije za rad sistema trenutno dostupne kvalifikovanom osoblju. Na ovaj način se postiže brže dijagnosticiranje i otklanjanje kvarova, kao i za angažovanje manjeg broja zaposlenih, jer je moguć pristup svim procesnim veličinama od interesa, kao i stanju svih hardverskih komponenata u sistemu.

Kontrolni centar je smešten u upravnoj zgradi kopa i povezan je optičkim kablom sa njemu najbližim transporterom. Tračni transporteri su na međusobnoj udaljenosti od 1500 do 2200 m i njihove trase su iskorišćene za postavljanje optičkih kablova, koji zajedno sa optičkim kablom iz centra i modularnim industrijskim svičevima čine Eternet mrežu.

Sistem za upravljanje i sistem za daljinski (video) nadzor su funkcionalno odvojeni. U okviru sistema daljinskog nadzora ugrađene su i mrežne (IP) video kamere predviđene za snimanje svih tehnološki kritičnih mesta, koje je potrebno neprekidno nadgledati iz kontrolnog centra.

Sistem za upravljanje je konfigurisan u tri nivoa. Najviši nivo je kontrolni centar. Tu je smešten PLC (programski logički kontroler) koji obavlja funkcije zajedničke za sve tračne transportere u sistemu. Optičkim kablovima se prosleđuju referentne brzine ka svim PLC, smeštenim na svakom tračnom transporteru. Osim funkcije kontrole brzine sistema, PLC u kontrolnom centru šalje i uslove za rad sistema, sekvencijalno uključenje potrošača na tračnim transporterima, i takođe izvršava algoritam za optimizaciju popunjenosti traka. U kontrolnom centru nalazi se i operatorska stanica, koja se sastoji od PC računara sa dva monitora visoke rezolucije i SCADA aplikacijom, koja omogućava nadzor i upravljanje sistemom. Grafički interfejs omogućava operatoru uvid u sve tehnološke parametre od interesa za pouzdan i bezbedan rad sistema.

Sledeći nivo u hijerarhijskoj strukturi upravljačkog sistema je procesni nivo, raspodeljen i prisutan na svim tračnim transporterima. Na ovom nivou, na svakom transporteru se kontrolišu uslovi rada, zaštita svih pogona i podsklopova, prikupljanje informacija sa senzora na transporteru, njihova obrada i prenos na viši nivo upravljanja i odlučivanja. Upravljanje brzinom i raspodelom opterećenja u višemotornom pogonu tračnog transportera obezbeđeno je na ovom nivou, sa adekvatnom preciznošću i brzinom izvršavanja.

Treći nivo u hijerarhijskoj strukturi upravljačkog sistema čine frekventni pretvarači i ulazno-izlazne jedinice za obradu diskretnih (digitalnih) i kontinualnih (analognih) signala koji postoje na jednom tračnom transporteru. U diskretne signale ubrajamo pomoćne veze za pokretanje, prekidače i osigurače, tastere i sigurnosne elemente, granične prekidače. Analogne signale čine, pre svega, sila zatezanja trake, koja se mora održavati u određenom opsegu, temperature ulja i ležajeva svih reduktora glavnih pogona, kao i temperature namotaja i ležajeva motora. Pored ovih veličina, sistem omogućuje praćenje 10 veličina iz svakog pogona (izdvajamo moment opterećenja, struja i napon motora, napon jednosmernog kola i temperatura hladnjaka frekventnog pretvarača), i veličine vezane za potrošnju svakog pojedinačnog transformatora (struja i napon primarnog kola, faktor snage i temperatura namotaja). Senzor popunjenosti

Supervision, control and operation of belt conveyors is performed remotely from the control centre. All relevant information for system operation are gathered and available to qualified employees in the control centre. This enables better diagnostics and faster fault clearance, resulting in the reduced number of maintenance employees, due to availability of all process values, and values concerning the status of all hardware components in the system.

The control centre is located in the head office of the open pit mine and is connected by the optical cable to the nearest belt conveyor. Belt conveyors are 1500 to 2200 m away from each other, and their paths are used for placing optical cables, which together with the optical cable from the control centre and modular industrial switches establish the Ethernet network.

The control system and the video supervision system are functionally separated. Ethernet video cameras, integrated in the system for remote video supervision are provided for continuous monitoring and evaluation of all technology-critical points by an operator in the control centre.

The control system is configured in three levels. The control centre is the highest level where the master PLC (programmable logic controller) is located. The master PLC performs functions common for all belt conveyors in the system. It uses optical cables to pass the speed reference to all PLCs located on each belt conveyor. Beside the function of system's speed control, the PLC passes conditions for system operation, sequential switch on and off of belt conveyor consumers and also performs the algorithm for optimal belt loading. The operator station is also located in the control centre and consists of a PC with two high resolution monitors and the implemented SCADA software, that enables supervision and control of the system. Through the graphical interface of the monitor, the operator can visualize all technological parameters which are significant for reliable and safe operation of the system.

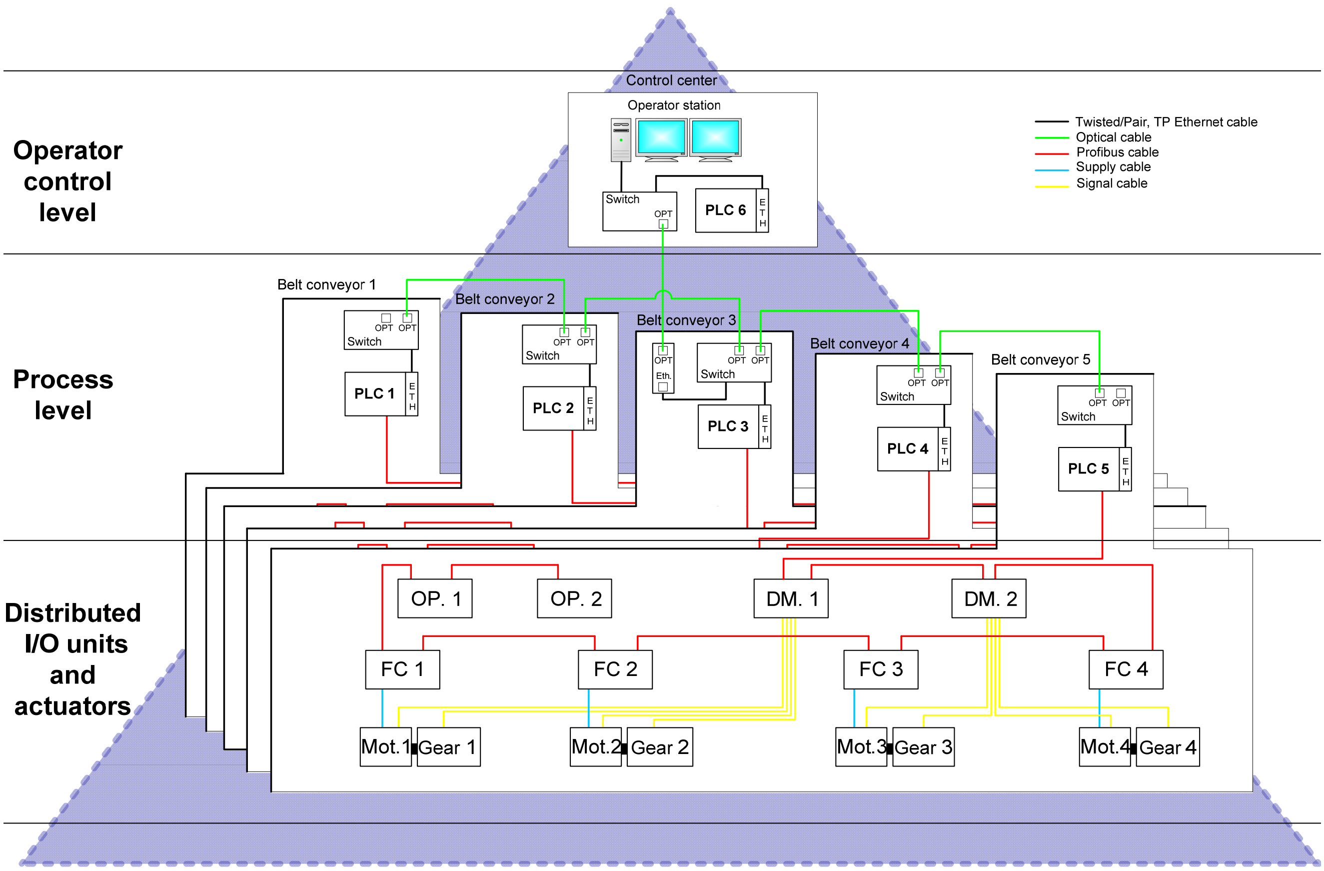
The next level in the control system hierarchy is the process level, distributed and located on each belt conveyor. At this level, the control of operating conditions, protection of all drives and subassemblies, information gathering from sensors on belt conveyors, their processing and passing to the higher control level is performed on each belt conveyor. Speed control and equal load distribution in the multi motor drive of belt conveyor is also performed at this level, with proper precision and speed of operation.

The third level in the hierarchy of the control system consists of frequency converters and input-output units for processing digital and analogue signals from each belt conveyor. Digital signals are: auxiliary activation contacts, switches, fuses, tasters and safety devices – limiters. Analogue signals are, first of all, belt tension which has to be kept in the proper range, temperatures of oil and bearings in main drives, as well as temperatures of motor windings and bearings. Besides these, the system enables the monitoring of 10 variables from each drive (such as load torque, motor current and voltage, DC voltage and temperature of the frequency converter cooler) and values connected with the consumed energy of each transformer (primary current and voltage, power factor and winding temperature). Device for trake nalazi se na kraju drugog etažnog transportera u nizu. Analogni signal sa ovog senzora ima važnu ulogu u algoritmu za upravljanje brzinom sistema tračnih transportera, /3/.

Na sl. 2 je prikazana struktura upravljačkog sistema sa prikazom sva tri nivoa upravljanja. Povezivanje nivoa upravljanja ostvareno je korišćenjem različitih komunikacionih protokola i načina povezivanja. Povezivanje operatorske stanice u kontrolnom centru, kao najvišeg nivoa i PLC tračnih transportera kao srednjeg nivoa, ostvareno je korišćenjem Eternet TCP/IP protokola, preko optičkih kablova za prenos signala između lokacija na relativno velikoj udaljenosti (do 2,5 km). PLC na tračnom transporteru je sa sledećim nivoom upravljačkog sistema, ulazno-izlaznim modulima, operatorskim panelima i frekventnim pretvaračima povezan PROFIBUS komunikacionim protokolom, realizovanim pomoću bakarnih komunikacionih kablova, jer su dužine kablova između pojedinih elemenata sistema na ovom nivou relativno kratke (do 100 m). Na sl. 2 se vide elementi distribuirane strukture upravljačkog sistema, kao i lokacije i raspored navedenih komunikacionih mreža.

measuring the bulk material cross section is located at the end of the second bench conveyor. The analogue signal from this device is significant for the algorithm of the energy efficient transportation of bulk material [3].

The structure of the control system with all three control levels, as well as the location and disposition of different types of communication networks, are presented in Fig. 2. Connection of operator station in the control centre, as the highest level, and PLCs of each belt conveyor, as the middle level, is performed using Ethernet TCP/IP protocol through optical cables for passing signals over long distances (up to 2.5 km). A PLC is placed on each of the belt conveyors, connected with frequency converters and distributed modules through PROFIBUS communication protocol, realized with cooper communication cables, due to relatively short distances between system elements on this level (up to 100 m). Elements of distributed structure of the control system can be seen in Fig. 2, as well as disposition of the indicated networks.



Slika 2. Kontrolna piramida upravljačkog sistema V BTO sistema
Figure 2. Control system represented as a pyramid.

DALJINSKO UPRAVLJANJE SISTEMOM TRAČNIH TRANPSORTERA

Sistem tračnih transportera realizovan na površinskom kopu „Drmno", je još u fazi projektovanja koncipiran tako da se ostvari rad sa daljinskim upravljanjem. Upravljanje svim elementima sistema je ostvareno pomoću odgovarajućih izlaza na distribuiranim modulima PLC, ili se kao u

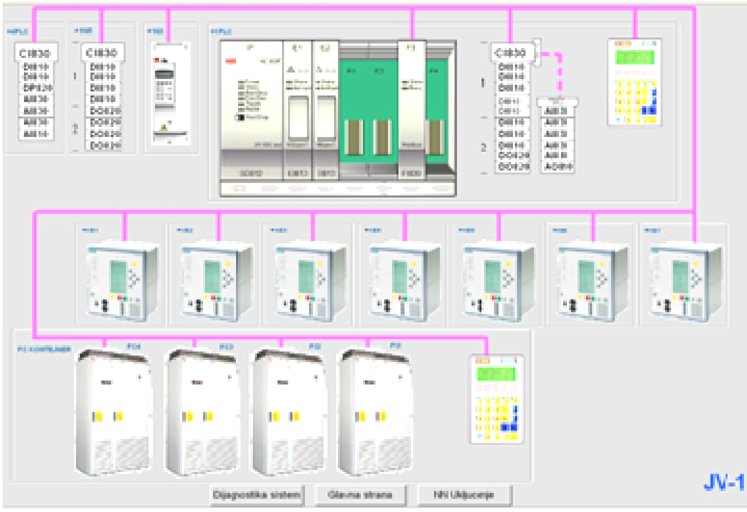
CONCEPT OF REMOTE CONTROL AND SUPERVISION OF BELT CONVEYOR SYSTEM

The new system of belt conveyors, realized on the open pit mine "Drmno", was considered during the design phase to operate with remote supervision and control. The control of all system elements is realized with adequate outputs on distributed modules of the PLC, or frequency converters are slučaju pogona transporta materijala i zatezanja trake koriste frekventni pretvarači kao aktuatori. Dijagnostika stanja svih zaštitnih elemenata u sistemu je obezbeđena pomoću zasebnih digitalnih ulaza, tako da se informacija o aktiviranju svakog zaštitnog elementa jednoznačno očitava u sistemu i praktično trenutno je dostupna na operatorskoj stanici.

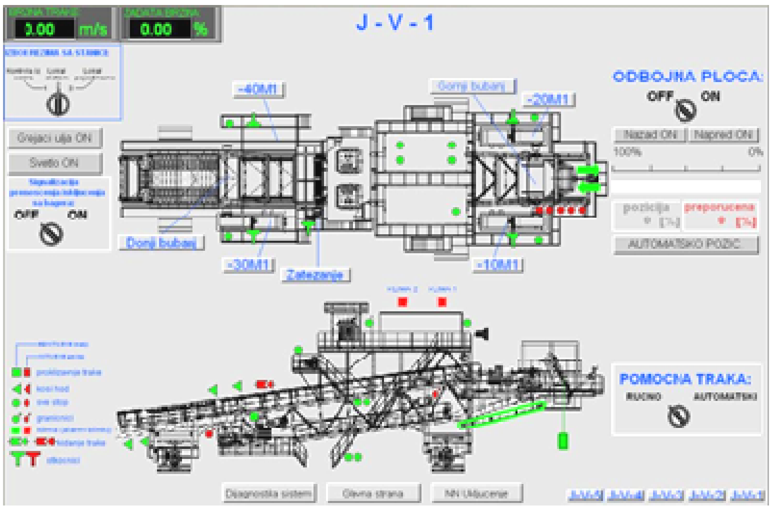
PLC moduli korišćeni za realizaciju ovog sistema imaju integrisanu dijagnostiku, kako pojedinačnih kanala, ulazno-izlaznih modula u celini, do komunikacionog (PRFOIBUS) modema zajedničkog za grupu modula. Otkazivanje svake od navedenih komponenti signalizira se operatoru u vidu alarmne poruke. Ekran operatorske stanice sa prikazom dijagnostike svih elemenata upravljačkog sistema jednog tračnog transportera povezanih PROFIBUS mrežom, prikazan je na sl. 3. Na ekranu dijagnostike, element na kojem se javio problem bilo koje vrste trepće crveno, a operator može da dobije više informacija aktiviranjem tastera miša (kliktanjem) na slici elementa.

used as actuators as in the case of drive for material transportation and tension drive. State diagnostics for all protection elements in the system is provided through separated digital inputs, in order to have the exact information about activation of each protective element in the system, and its practically instantaneous availability on the operator station.

PLC modules used for the realization of this system have integrated diagnostics of separate channels, I/O modules and a common communication (PRFOIBUS) modem for the group of modules. Failure of any of the foregoing components is signalized to the operator as an alarm message. The operator station screen with displayed diagnostics of all elements of belt conveyor control system connected through PROFIBUS network is presented in Fig. 3. On the diagnostics screen, the element having the problem is blinking red and the operator can get more information with the mouse taster activation (by clicking) on the image of that element.



Slika 3. Dijagnostika svih elemenata upravljačkog sistema jednog tračnog transportera
Figure 3. Diagnostics of all control system elements of the one belt conveyor.



Slika 4. Sveobuhvatni pregled pogona i senzora na jednom tračnom transporteru
Figure 4. Complete preview of the drive and sensors on one belt conveyor.

Na svakom od pet tračnih transportera nalazi se više-motorni pogon transporta materijala, /4/, sačinjen od četiri regulisana pogona sa kaveznim asinhronim motorima napajanim iz frekventnih pretvarača industrijskog tipa, /5/. Posebna pažnja je posvećena ravnomernoj raspodeli opterećenja između pojedinačnih pogona na tračnom transporteru, /6/. U PLC je smešten regulator brzine koji dobija vrednost brzine pogona iz pretvarača, dok pretvarači rade sa direktnom kontrolom momenta. Zbog teških uslova rada i ostvarenja povećane pouzdanosti rada pogona, regulacija je izvedena bez upotrebe senzora brzine na vratilu motora.

Za rad regulisanog pogona tračnog transportera – pokretanje gumene trake i prenos materijala, potrebna je kontrola brojnih uslova. Pored sigurnosnih pečurki raspoređenih na samom tračnom transporteru, korišćeni su i tasteri za zaustavljanje trake na tračnom transporteru, ali i duž čitave dužine trase transportera. Graničnici iskošenja trake na povratnom bubnju i na tračnom transporteru, signali sa otkočnika glavnih pogona, kontrola temperature ulja u reduktorima, kontrola pregrevanja ležajeva, ispravno funkcionisanje rashladnog sistema za kontejner u kojem su smešteni frekventni pretvarači, i drugi, pored zadovoljenja uslova rada iz samog elektro postrojenja (zaštite svih strujnih krugova, prisustvo napajanja na frekventnim pretvaračima i dr.) kontrolišu se u upravljačkom sistemu na tračnom transporteru. Gubitak nekih od uslova izaziva različitu reakciju upravljačkog sistema – u određenim slučajevima potrebno je trenutno isključenje pogona tračnog transportera, i svih transportera pre njega, kao i bagera, koji je na samom početku tehnološkog lanca otkopavanja i transporta materijala. Sa druge strane, postoje i uslovi kod kojih je moguće dozvoliti rad tračnog transportera još određeno vreme, tako da se uz pravilnu signalizaciju neki od uslova mogu ponovo obezbediti (intervencijom službe održavanja) u toku tog dozvoljenog vremena. Jedan od ekrana sa grafičkim prikazom uslova za rad tračnog transportera prikazan je na sl. 4.

Operatorski paneli su postavljeni na svakom tračnom transporteru da bi se omogućilo upravljanje i praćenje sistema u lokalu. Takođe, preko njih se dobija uvid u stanje svih pogona, funkcija i zaštita upravljačkog sistema. Na ovaj način je dijagnostika kvarova moguća i na samom tračnom transporteru.

Uključenje transformatorskih ćelija za tro-namotajne transformatore za napajanje frekventnih pretvarača, ispravljača frekventnih pretvarača i ostalih niskonaponskih potrošača neophodnih za sam rad transportera, odnosno, transport materijala može se vršiti lokalno i daljinski. Izbor mesta upravljanja vrši se ključ prekidačem na samom transporteru. U slučaju servisnih intervencija službe održavanja, obezbeđenje od neželjenog daljinskog uključenja postiže se okretanjem ključa u položaj „lokalno upravljanje“. U tom slučaju, upravljanje svim funkcijama transportera se vrši sa lokalnog mesta upravljanja, postavljenog u elektro sali. Svi pogoni se mogu uključivati i isključivati ravnopravno i sa lokalnog i sa daljinskog mesta upravljanja, u zavisnosti od položaja ključ prekidača. Vraćanjem ključ prekidača na položaj „daljinsko upravljanje“, mesto upravljanja se premešta na operatorsku stanicu u kontrolnom centru.

Multi motor drive, /4/, placed on each of five belt conveyors consists of four cage induction motors supplied from frequency converters (FC) of industrial type, /5/. Special attention is given to uniform load distribution, /6/, among individual drives on a conveyor. The speed controller, that reads estimated speed of the belt from the frequency converter, is implemented in the PLC. Drives are torque controlled. Owing to heavy duty working conditions and requirement for increased drive robustness, the control of the drive is realized without the speed sensor on the motor shaft.

For the operation of controlled drive of belt conveyor - starting of the rubber belt and transport of the bulk material, a supervision of numerous settings must be performed. Besides emergency stop switches distributed along the belt conveyor itself, tasters to stop the belt are also used on the belt conveyor and along the whole route, too. In the belt conveyor control system, the following equipment and signals are monitored and controlled: limit switches for belt misalignment on the return pulley and on belt conveyor, signals from brake thrusters of main drives, oil temperature monitoring in gearboxes, monitoring of bearings overheating, proper function of cooling system of electrical container where frequency converters are placed, etc. Additionally, fulfilment of the conditions for operation from the electrical plant (all current circuits protection, existence of electrical supply on frequency converters), is also controlled. Loss of any condition for operation causes reaction of the control system – in some cases it is necessary to stop the belt conveyor drive instantly, and all other conveyors considered before in the queue, as well as the excavator at the very beginning in the technological line of excavation and transport of bulk material. Beyond this, there are some operating conditions that allow operation of the belt conveyor for additional time, so with the proper signalization, some operating conditions can be again provided (with the action of the maintenance) within tolerable time. A display screen with belt conveyor operating conditions is shown in Fig. 4.

Operator panels (OP) are installed on each of the belt conveyors in order to enable local control and monitoring of the system. Additionally, they enable visualization of all drives operating conditions, functions and protections of the control system. This way, the diagnostics of failures is possible on the belt conveyor, too.

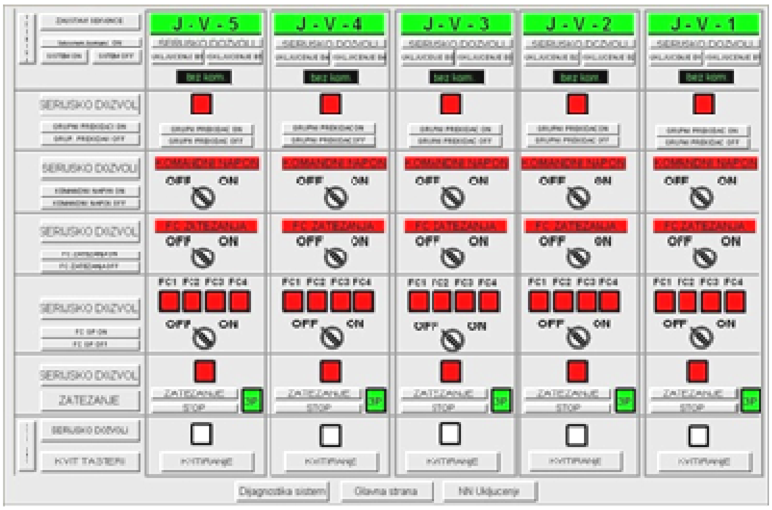
Switching on transformer cubicles for three-winding transformers which supply frequency converters, rectifiers of frequency converters and other low voltage consumers, necessary for the operation of belt conveyor, i.e. bulk material transportation, can be performed locally or remotely. The choice between these two control places is performed with the key switch. To provide system from undesirable switching on of remote control while the maintenance service is intervening, key switch is turned into the position “local”. In this case, control of belt conveyor functions is performed from the local control place, located in the electrical room. Depending on the position of the key switch, all drives can be started and stopped equally from both control places. Placing the key switch into the position “remote control”, the control functions are transferred to the operator station in the control centre.

Za startovanje sistema posle pauze u radu, potrebno je uključiti ispravljače svih frekventnih pretvarača na svim tračnim transporterima u sistemu, komandne napone na svim transporterima, kao i niskonaponski prekidač pomoćnih pogona (sopstvene potrošnje) transportera, pretvarač pogona zatezanja trake, a zatim, pre polaska i dotegnuti traku na svakom transporteru u sistemu. Ovaj skup operacija zahtevao bi izvesno vreme da se sprovede ručno, uz veliku mogućnost pojave greške operatora koji vrši toliki broj sekvencijalnih radnji. Mogućnost automatizacije ovog postupka nametnula se kao rešenje, ne samo zbog potrebe da se rukovaocima sistema olakša posao, već i zbog toga što se na taj način može ostvariti značajno skraćenje vremena potrebnog za postizanje pogonske spremnosti transportera. Na osnovu iskustava autora sa površinskih kopova u Srbiji, ali i u svetu, na ovaj način se može postići povećanje vremenskog iskorišćenja sistema tračnih transportera od 2–5%.

Izgled ekrana operatorske stanice na kojem su prikazane komande za automatsko sekvencijalno uključenje frekventnih pretvarača i niskonaponskih potrošača potrebnih za dovođenje sistema tračnih transportera u stanje spremno za rad je prikazan na sl. 5.

To start the system after the discontinuity in operation, it is necessary to start rectifiers of all frequency converters on all belt conveyors in the system, command voltages also, as well as low voltage switches for auxiliary drives (self consumption) of belt conveyor, frequency converter for belt tension drive and, before system start, it is necessary to additionally tense the rubber belt of each conveyor. This set of operations will require some time to perform locally, with the great possibility of operator made mistakes while performing numerous sequential actions. The possibility to perform these actions automatically is imposed as a solution, not only to make easier manipulations for operators, but also to achieve significant reduction of time required for attaining the drives ability to start the belt conveyor. Based on author’s experience from open pit mines in Serbia and in the world, time utilization of the system of belt conveyors thus can be increased from 2 to 5%.

The operator station screen layout with commands for automatic sequential start of frequency converters and low voltage consumers required to prepare belt conveyor system for operating condition is shown in Fig. 5.



Slika 5. Daljinska kontrola uključenja frekventnih pretvarača i nisko-naponskih potrošača – zajednička strana za sve transportere u sistemu
Figure 5. Remote control for switching on frequency converters and low voltage consumers – common display for all transporters in the system.

Primena regulisanih pogona na tračnim transporterima omogućila je regulisanje brzine pogona transporta materijala po kriterijumu optimalne popunjenosti trake, čime se povećava energetska efikasnost postrojenja. Kako je moment tračnih transportera približno konstantan, (mala promena u funkciji brzine) rad sa smanjenom brzinom trake dovodi do smanjenja trenutne aktivne snage pogona. U PLC koji se nalazi u kontrolnom centru, implementiran je i nadređeni regulator brzine sistema, koji prosleđuje odgovarajuću referentnu brzinu svakom PLC na tračnim transporterima u sistemu.

OSTVARENI REZULTATI

Projekat izgradnje V BTO sistema na površinskom kopu „Drmno“ je ušao u završnu fazu realizacije tokom 2009. godine. Nakon realizacije svih pet transportera sa regulisanim pogonom 4×1,2 MW, stekli su se uslovi za puštanje u rad sistema za daljinski nadzor i upravljanje. Postavljeni su

The application of controlled electrical drives enables speed control of the belt according to the criterion of optimum belt loading, thus contributing increased efficiency of the process. If the load torque is considered constant (minor variations in the function of speed), operation with the reduced belt speed will lead to the reduction of instantaneous active power of the drive. The controller of optimum belt loading acting on the speed reference is implemented in the master PLC located in the control centre.

ACHIEVED RESULTS

Commissioning of the 5th ECS system on the open pit mine “Drmno” has come to the end of realization during the 2009 year. After the realization of all five belt conveyors with controlled drives 4×1.2 MW, conditions to start the system for remote control and supervision are achieved. Optical cables are placed, the developed software for remote optički kablovi, razvijeni softver za daljinski nadzor i upravljanje je pušten u rad i detaljno testiran. Izgled jednog tračnog transportera nakon puštanja BTO sistema u rad prikazan je na sl. 6.

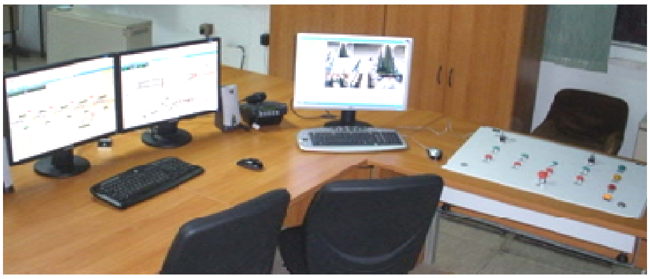
Slika 6. Izgled jednog realizovanog tračnog transportera sa regulisanim pogonom 4×1,2 MW u sklopu V BTO sistema
Figure 6. The exterior of one realized belt conveyor with controlled 4×1.2 MW as a part of the 5th BSC system.

Na sl. 7 prikazan je izgled operatorske stanice smeštene u kontrolnom centru. Na levoj strani slike mogu se videti dva monitora visoke rezolucije koji prikazuju pregledni ekran celog sistema (na krajnje levom monitoru) i pregled senzora jednog tračnog transportera (monitor u sredini). Na trećem monitoru (desnom) prati se rad sistema putem mrežnih (IP) video kamera, postavljenih na svakom transporteru. Krajnje desno na sl. 7 može se uočiti pult upravljanja sistema tračnih transportera, na kojem se pored tastera i signalnih lampi nalaze i sigurnosna pečurka (sve-stop) i ključ prekidač za zaključavanje komandi na pultu. Računar na kojem se izvršava upravljačko nadzorni softver je standardni PC računar sa grafičkom karticom sposobnom za prikaz na dva monitora u isto vreme.

Pored upravljačkih funkcija koje su realizovane, sistem za daljinski nadzor i upravljanje ima mogućnost snimanja podataka o radu i stanju tračnih transportera u dugom vremenskom periodu. Kao ilustracija ove funkcije može poslužiti snimak prelaznog procesa etažnog tračnog transportera pri promeni brzine sa 950 min^{-1} na 700 min^{-1} i nazad, prikazan na sl. 8 i rad transportera sa konstantnom brzinom od 900 min^{-1}, pri promenljivom opterećenju, prikazan na sl. 9. Obe slike pokazuju da je raspodela momenata između pogona praktično idealna, jer su trenutni momenti oba motora (M_{e1} i M_{e4}) jednaki i u toku prelaznog procesa i u ustaljenom stanju, bez obzira na opterećenje. Malo odstupanje trenutne brzine od referentne brzine (n^*) koja se menja po S rampi je dozvoljeno kod primene na tračnim transporterima jer dovodi do manjeg naprezanja trake. Dužina S rampe referentne brzine od nule do nominalne vrednosti (1000 min^{-1}) iznosi 25 s. Sila zatezanja u gumenoj traci se meri senzorom sile i data je u tonama. Obe slike pokazuju relativno malo odstupanje u odnosu na početnu vrednost, kao i odsustvo trenutnih promena ili pikova. Trenutna zapremina jalovine na traci, merena laserskim meračem prikazana je na donjem dijagramu sl. 9, a izražena je u m^3/10 s.

Primenjeni upravljački sistem pruža mogućnost promene brzine trake u toku rada po unapred definisanoj rampi. Promene brzine se dešavaju bez udara po momentu i sili zatezanja tako da primenjeno rešenje pokazuje očekivana optimizaciona svojstva. U višemotornom pogonu kakav je

control and supervision is put into operation and carefully tested. The exterior of one belt conveyor after ECS system commissioning is presented in Fig. 6.

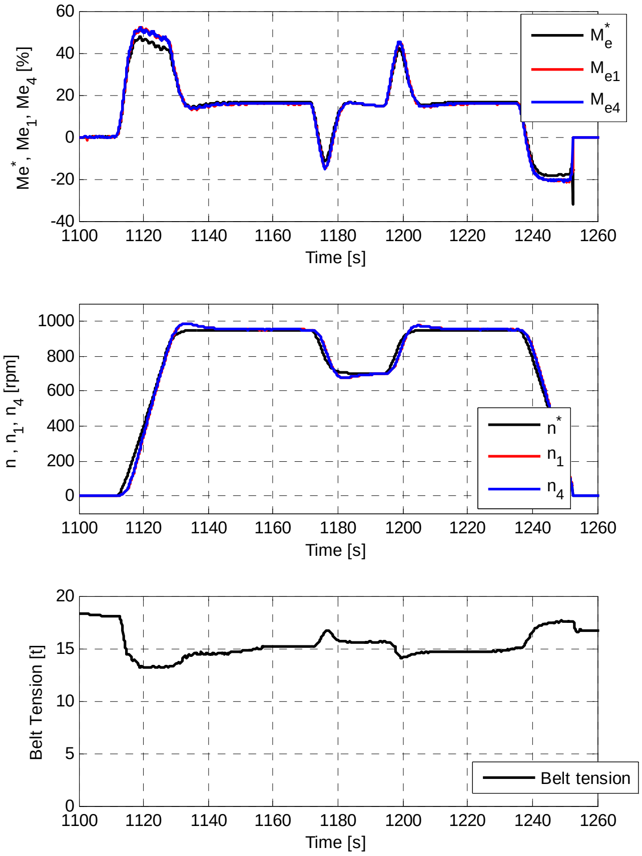


Slika 7. Izgled operatorske stanice u kontrolnom centru
Figure 7. The photo of operational station in the control centre

The appearance of the operator station located in the control centre is presented in Fig. 7. On the left side in the figure, two monitors with high resolution present the screen of the whole system (first on the left) and the screen displaying all sensors on one belt conveyor (monitor in the centre). On the third monitor to the right, system operation is monitored with the use of network (IP) video cameras, located on each of the belt conveyors. On the far right in Fig. 7 the operator stand for the belt conveyor system is also shown. Tasters, signal lamps, emergency stop switches and key switch to lock commands are located on the stand. The computer that executes software for control and supervision is a standard PC with a graphical card that is able to present two monitors at the same time.

Besides control functions that are realized, the system for remote control and supervision has the ability to record data on the operation and state of belt conveyors in the long time period. To illustrate this function, recorded characteristic values during the transition period of the speed change from 950 min^{-1} to 700 min^{-1} and back, on the bench conveyor, are presented in Fig. 8, as well as the conveyor operation at constant speed of 900 min^{-1}, under variable belt loading, presented in Fig. 9. Both figures show that the torque distribution among the drives is practically ideal, as the actual torques of the two motors (M_{e1} and M_{e4}) are equal both in transient and steady state operation, regardless of the load. Small deviation of the actual speed from the S-shaped reference speed (n^*) is tolerable for the application on belt conveyors, and results in lower stress of the belt. The S-shaped ramp of the reference speed to the nominal set speed equal to 1000 min^{-1} lasts 25 s. The tension force in the rubber belt is measured by the tension measurement device and given in tonnes. Both figures show relatively small deviation from initial tension, without sudden changes or peaks. The instantaneous volume of overburden on the belt under the laser based measurement device is shown on the bottom graph in Fig. 9, expressed in m^3/10 s.

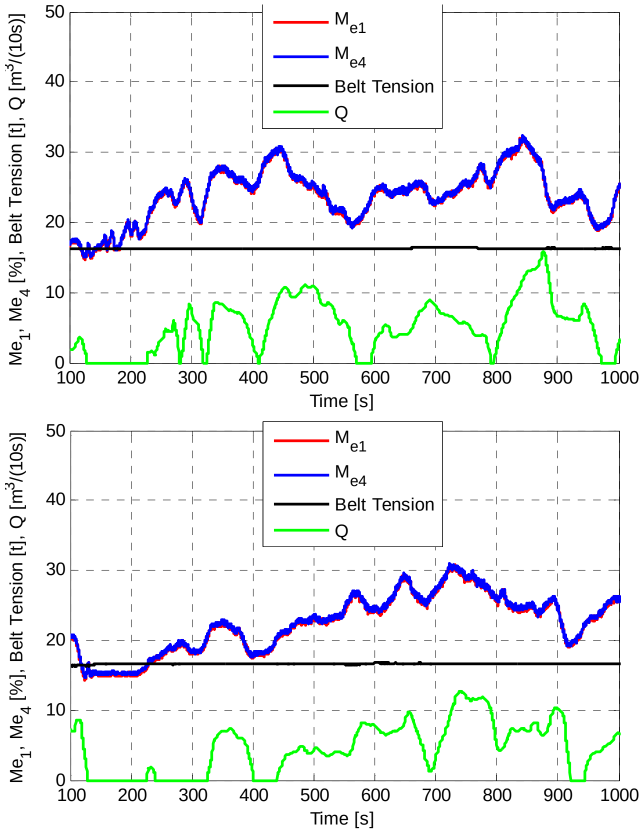
The applied control system offers the possibility of belt speed change in operation, with a defined ramp. The speed change is accomplished with smooth change of motor torque, giving no sudden changes in the measured belt tension, so the applied solution verifies expected optimal characteris pogon tračnog transportera, pravilna raspodela momenata opterećenja između pojedinih pogona u svim uslovima je osnovni preduslov ispravnog i energetski efikasnog rada.



Slika 8. Karakteristične veličine pri promeni brzine sa 950 $\min^{-1}$ na 700 $\min^{-1}$ i nazad

Figure 8. Characteristic values during speed change from 950 $\min^{-1}$ to 700 $\min^{-1}$ and back.

tics. In the multi motor drive such as the belt conveyor drive, uniform load distribution among individual drives in all conditions is the major requirement for safe and energy efficient operation.



Slika 9. Rad transportera sa konstantnom brzinom od 900 $\min^{-1}$, pri promenljivom opterećenju

Figure 9. Operation of conveyor at constant speed 900 $\min^{-1}$, under variable belt loading.

ZAKLJUČAK

Sistem upravljanja i nadzora, koji je predstavljen u radu, modularnog je tipa. Mogućnost dijagnostike svih modula i elemenata sistema iz kontrolnog centra omogućava kratko trajanje zastoja prouzrokovano otkazima opreme, a servis se na licu mesta obavlja jednostavnom i brzom zamenom modula. Unifikacijom opreme postiže se da je potrebno skladištiti relativno mali broj rezervnih delova u magacinu, što je sve češći zahtev u savremenom načinu poslovanja.

Automatizovano i centralizovano puštanje sistema u rad obezbeđuje da vreme pripreme sistema za rad nakon zastoja traje kraće nego u slučaju sistema sa rukovaocima na tračnim transporterima. Mogućnost praćenja i snimanja velikog broja signala iz sistema tračnih transportera na operatorskoj stanici u kontrolnom centru, i analiza tih signala omogućuju preventivno otkrivanje mogućih problema iz domena mašinskog održavanja. Prikazano rešenje daljinskog nadzora i upravljanja sistemom tračnih transportera, primenjeno je u praksi na površinskom kopu „Drmno“. Ovo rešenje predstavlja pionirski poduhvat na površinskim kopovima u našoj zemlji, i pruža mogućnosti koje nadmašuju malobrojna slična rešenja primenjena u svetu.

CONCLUSION

The system for control and supervision presented in the paper is of modular type. Improved diagnostics of all modules and system elements, accessible in the control centre, enables short stoppages caused by equipment malfunctions, and service performed on site, with simple and fast module replacement. The unification of equipment causes relatively small number of spare parts to stock. This is common requirement in modern business environment today.

Automatic and centralized putting system into operation, provides that the time required for the system to operate after discontinuity is shorter than in the case with the operators on belt conveyors. The ability of monitoring and recording of numerous signals from the system of belt conveyors on the operator station in the control centre and the analysis of those signals, enables prevention of possible problems in the domain of mechanical maintenance. The paper presents one solution of remote control and supervision for the system of belt conveyors, implemented on open pit mine “Drmno”. The application represents a pioneering achievement on open pit mines in Serbia and offers possibilities that exceed a few similar solutions applied in the world.

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