



DISTRIBUTION OF POWER OUTPUT IN THE HYBRID PASSENGER AUTOMOBILE

SISTEM NAPAJANJA KOD PUTNIČKIH VOZILA SA ALTERNATIVNIM IZVOROM ENERGIJE ("HIBRIDNI AUTOMOBIL")

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Abstract: Solving the problems of increasing demands of transport when respecting environment requirements there is more and more intensive searching for way of their mutual balance. Among the essential elements which are the condition for serious level of environment ranks, not only water, soil, light but also air must be taken into account. One of the possibilities of decreasing the ecological overload by means of transport presents this contribution. It deals with the hybrid passenger automobile. Passenger automobile is powered by asynchronous power motor with the energy feeding from secondary cell (accumulator), which is powered from common mains, from photovoltaic cells and from the alcohol motor, as well. Such proposed power system of an automobile presents not only decreasing of environment overload but also decreasing of the specific energetic weight and increasing of the distance of movement.

Key words: hybrid passenger automobile, power output, environment

Apsrakt: Brze komunikacije i saobraćaj, s jedne strane, i zdrava životna sredina, s druge, su imperativi modernog doba, koji su često suprotstavljeni, što zahteva iznalaženje rešenja kojima će se prevazići pomenuta suprotnost. Kvalitet vazduha, koji osim vode i zemlje, predstavlja jednu od osnovnih kategorija životne sredine, mora se sačuvati. Cilj ovog rada je da pruži svoj doprinos u smanjenju zagađenja vazduha kroz nova rešenja u oblasti saobraćaja. Naime, rad se bavi pitanjem hibridnog automobila, odnosno putničkog vozila koje se snabdeva alternativnim gorivom. Putničko vozilo pokreće se pomoću asinhronog motora koji se napaja iz akumulatora koji se napaja preko kablova, fotoelektrične ćelije, koja proizvodi električnu energiju kada je izložena svetlosti i takođe preko motora na alkohol. Ovakav sistem napajanja automobila ne samo da umnogome smanjuje nivo zagađenja životne sredine, već umanjuje i specifičnu energetsку težinu, a povećava se dužina kretanja.

ključne reči: hibridni putnički automobili, napajanje, životna sredina

1 INTRODUCTION

The idea of a hybrid electroautomobile (HEM), which enables to receive the electrical energy for secondary cell from more sources is not new. Phylosophy of HEM construction is derive from statistical data. Most people use their cars with low

1 UVOD

Ideja o hibridnom elektro automobilu (HEM), gde se električna energija za akumulatorske ćelije dovodi iz više izvora, nije nova. Osnovna koncepcija zasnovana je na statističkim činjenicama koje govore da većina ljudi koristi svoj automobil za

piston displacement for traveling to/from work. The average time of such path is 40 min. and the average distance is 25 km. On traveling from work is the mentioned path 5 km longer and the time is increased on the value 52 min (due to shopping, meetings, etc, ...). Utilization factor of weight is low – circa 40%. Another statistical data is that most of employees are at their place of work 7 – 9 hours. Such exploited automobile is liable for sun rays 8 hours daily in winter and 15 hours daily in summer. As it is not possible to exploit this time always for charging the secondary cell from common mains, there is a option in exploiting of sun energy as a additional source of energy. For the possibility of increasing the secondary cell capacity and the power output and for the cabin heating in winter is in this HEM suggested biofuel motor.

2 PRIMARY SOURCES

The main primary source of electrical energy for secondary cell is the common mains, mostly in night hours, when the price of this energy is the cheapest. Process of power supply is solved with one-phase system and voltage of 230V.

Another power supply represent photovoltaic cells (PhC). Monocrystalline silicon is most often used and also most tackled material for PhC technology. Efficiency of PhC on the basis of a-Si:H with P-I-N structure was 10,1% in the year 1982 . Five years later was used microcrystalline coat P a-SiC:H with efficiency of 12%. In the year 1994 ECD/Sovonics company presented PhC with efficiency of 13%. Limited factor which impacts the efficiency of PhC is the glistening surface. It reverberates up to 36% of light, which lowers the sun energy. Respecting the parameters of today made PhC suitable for surface of our HEM (cca 1m²), we may await the output of 80W.

Most of hybrid vehicles are able to divide on the ground of configuration of combustible motor and electric motor

In the serial connection combustible motor drives generator, which charges batteries and those drives electric power motor (EPM). In the parallel connection combustible motor together with EPM are used for traction. This vehicle do not need generator.

In simulated HEMs suggested Elsbett motor which presents output of 15 –20% of power output (efficiencies of particular combustible motors are in Table 1)

odlazak na posao i povratak sa posla, pri čemu ne dolazi do značajnog pomeranja klipova motora. U proseku putovanje do posla traje oko 40 minuta, dok prosečna razdaljina iznosi oko 25 km. Povratak s posla obično nešto duže traje, oko 52 minuta a pređeni put je 5 km duži (zbog kupovine, sastanaka i raznih aktivnosti). Faktor iskorišćenja je veoma nizak, oko 40%. Još jedan statistički podatak nam govori da većina zaposlenih provodi na svom radnom mestu od 7 do 9 časova. Automobil je tako izložen sunčevim zracima 8 sati dnevno u toku zime, a 15 časova dnevno u toku leta. S obzirom na to da nije moguće iskoristiti ovo vreme u potpunosti za punjenje elektrolitičke ćelije preko kablova, postoji mogućnost da se za to iskoristi sunčeva svetlost kao dodatni izvor energije. Radi povećanja kapaciteta elektrolitičke ćelije i obezbeđivanje energije za grejanje kola u zimskim uslovima HEM predviđa upotrebu motora na biološko gorivo.

2 PRIMARNO NAPAJANJE

Primarno napajanje akumulatora vrši se preko kablova i to prvenstveno u noćnim satima kada je cena energije najniža. Za napajanje koristi se monofazni napon od 230 V.

Drugi izvor energije su fotoelektrične ćelije, koje proizvode struju kada su izložene svetlosti (PhC). Najčešće korišćeni materijal u PhC tehnologiji je monokristalni silicijum. Efikasnost PhC na bazi Si:H sa P-I-N strukturom je bila 10,1% 1982. god. Pet godina kasnije počinje da se koristi mikrokristalna obloga od P a-SiC:H, čija efikasnost je iznosila 12%. Firma ECD/Sovonics je 1994 god. predstavila PhC koja je imala efikasnost of 13%. Faktor koji je ograničavao efikasnost PhC je svetlucava površina koja odbija svetlost do 36%, što umanjuje sunčevu energiju. Parametri PhC-a koja se danas proizvodi odgovaraju HEM metodama, (cca 1m²), i može se očekivati kapacitet od 80W.

Konfiguracija većine hibridnih vozila je takva da se može jednostavno razdvojiti motor sa unutrašnjim sagorevanjem i električni motor.

U serijskoj vezi motori sa unutrašnjim sagorevanjem pokreće generator, koji puni akumulator koji, zatim, pokreće elektro motor (EM).

U paralelnoj vezi motor sa unutrašnjim sagorevanjem u kombinaciji sa elektro motorom koristi se za vuču. Ovakvom vozilu nije potreban generator. Za simulirani hibridni automobil predložen je Elsbett motor, čiji je kapacitet od 15 do 20% od ukupnog napajanja. U tabeli 1 prikazana je efikasnost pojedinih motora sa unutrašnjim sagorevanjem.

Table 1 Efficiencies of particular combustible motors

tabela 1 Efikasnost pojedinih motora sa unutrašnjim sagorevanjem

	Power density [Wh/kg]	Power [Wh/kg]	Lifetime of cycle	Drive time [km]	Duration of charge [hour]	Efficiency [%]	Recycle material [%]
Contemporary Pb	33	130	400	90	8 - 17	65	97
Future Pb	42	240	800	150	-	-	100
Nickel-cadmium	57	200	2000	180	8	65	99
Nickel- iron	55	100	2000	170	4 - 8	60	99
Nikel-hydrid	70	250	600	380	-	90	90
Lithium-ionic	100	300	1200	300	-	-	50

Fuel elements may change our future. This new technology, which make use of chemical energy of hydrogen and oxygen for production of electric energy, were first time used as a fuel resource in space means of transport. This perspective is a great motivity of todays research. Governments put into it considerable financial resources.(USA: 70 millions USD, Japan: 65 millions USD, Germany: 12 millions USD) In our presented automobile we did not take into consideration the using of fuel elements.

3 SECONDARY RESOURCES

Secondary cells in electric automobile resemble those which are used for starting of common car. However there are some differencec. Normal leaden batteries are not suitable for often charging and for total discharge therefore are used Pb accumulator traction battery (ATB) with deep period of discharging. ATB suitable for HEM endure about 600 charging periods (normal Pb barely 30). From the point of view of it is more prefable to use 6V batteries, whih have higher specific density of energy, but from the point of view of output demands 12V bateries are prefered. The efficiency of Pb batery is influenced by surround temperature. This present Table 2.

Table 2

MOTOR	Fuel	Efficiency
Elsbett	vegetable oil	40 %
Diesel	naphtha	28 %
Diesel	MERO	28 %
Spirit	metanol	31 %
Spirit	etanol	30 %
Gas	gas	27 %
Gas	hydrogen	23 %

This deficiency is solved with Elsbett motor (in winter). Characteristics of todays batteries are in fig.1. The effort for developing efficient and cheap battery is enormous. On examlpe in USA was founded the Advanced Batteries Consortium focused on above mentioned problems.

Gorivi elementi mogu promeniti našu budućnost. Ova nova tehnologija, koja koristi hemijsku energiju vodonika i kiseonika za proizvodnju električne energije, prvi put je upotrebljena kao energetsko gorivo za letove u svemir, što predstavlja veliku motivaciju za dalja istraživanja. Vlade raznih zemalja uložile su značajna finansijska sredstva u pomenuta istraživanja (SAD 70 miliona USD, Japan 65 miliona USD, Nemačka 12 miliona USD). Automobil koji je ovde prikazan ne uzima u obzir upotrebu pomenute tehnologije.

3 AKUMULATORSKO ILI SEKUNDARNO NAPAJANJE

Akumulatorske ćelije elektromotora slične su elektrolitičkim ćelijama akumulatora koji se koriste za pokretanje običnog automobila. Međutim, postoje i određene razlike. Naire, ćelije standardnog olovnog akumulatora nisu pogodne za često punjenje i na njih veoma nepovoljno utiče potpuno pražnjenje, pa se prema tome koriste Pb akumulatorske vučne baterije (AVB) koje imaju produženi period pražnjenja. AVB su pogodne za hibridni automobil jer podnose oko 600 punjenja (standardni Pb akumulator podnosi jedva 30). Sa ove tačke gledišta pogodnije je koristiti akumulatore od 6V, jer imaju veću specifičnu gustinu, ali sa akpekta snage bolje je koristiti akumulatore od 12V. Efikasnost Pb akumulatora zavisi od spoljašnje temperature, što je prikazano u tabeli 2.

tabela 2

MOTOR	Gorivol	Efikasnost
Elsbett	biljno ulje	40 %
Diesel	nafta	28 %
Diesel	MERO	28 %
Spirit	metanol	31 %
Spirit	etanol	30 %
Gas	gas	27 %
Gas	vodonik	23 %

Ovaj nedostatak može se prevazići pomoću Elsbetovog motora (u zimskom periodu). Karakteristike savremenih akumulatora date su na slici 1. Treba istaći da se ulažu veliki napor i sredstva u razvoj efikasnog i jeftinog akumulatora. Na primer, SAD su osnovale organizaciju pod nazivom Konzorcijum za razvoj akumulatora, koji se bavi pomenutom problematikom.

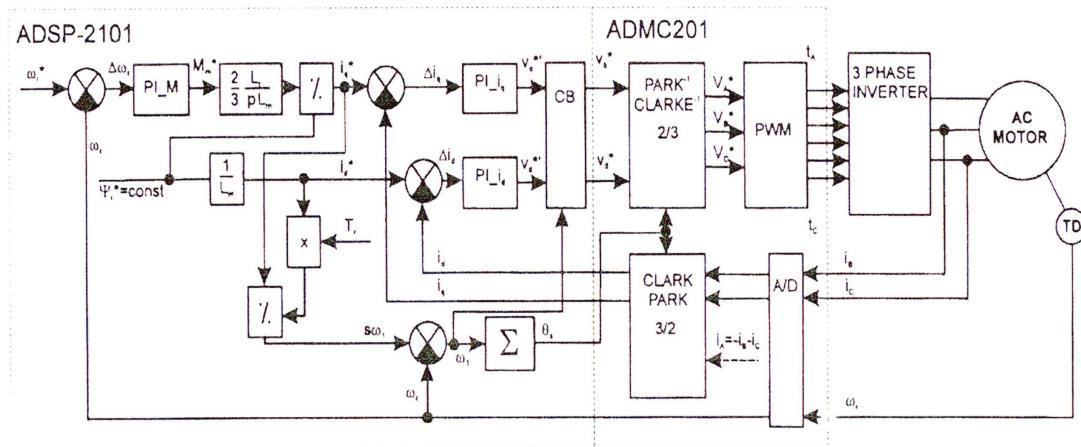


Figure 1 A scheme of connection and of control of the asynchronous engine
 slika 1 Šema priključaka i sistema regulacije kod asinhronog motora

4 TRACTION DRIVE

In calculation of HEM characteristics the way conditions and technology of transport were fully respected. The exploiting of DC serial motor characteristics are in traditional application well known. Thanks to semiconductor technics most of producers use three phase asynchronous motor. One of possibilities of the ideal regulation is the indirect current-voltage control of asynchronous motor (fig.2).

4 VUČNI POGON

Za procenu karakteristika hibridnog automobila uzeti su u obzir uslovi i tehnologija transporta. Karakteristike linearne motora jednosmerne struje su dobro poznate. Zahvaljujući poluprovodnicima većina proizvođača danas koristi trofazne asinhronne motore. Osim toga, asinhroni motori pružaju mogućnost regulacije struje i napona (slika 2).

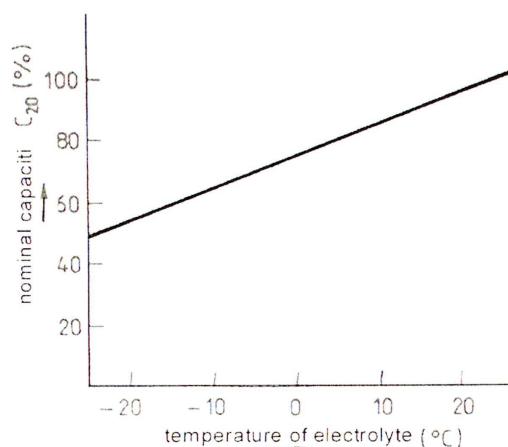


Figure 2 Direct current-voltage control of asynchronous motor
 slika 2 Regulacija struje i napona kod asinhronog motora

From the fig.2 is visible the division of tasks into coprocessor and processor. The fully controlled asynchronous motor is able to do distribution of power output of HEM.

Sa slike 2 lako se može uočiti podela operacija na koprosesor i procesor. Asinhroni motor sa potpunom regulacijom je u stanju da obavi razvod napajanja kod hibridnog automobila.

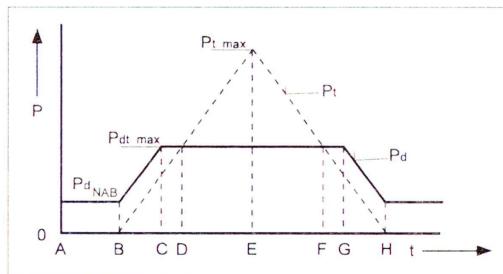


Figure 3 Period of maximal power output demand of HEM
slika 3 Period maksimalnog napajanja kod hibridnog automobila

In the fig.3 there is depicted one period of maximal power output demand of HEM, where particular partitions on time axis means:

- A-B: Traction alternator charges ATB and combustible motor works with constant output P_{dtNAB}
- B-C: The demand of power output started to increase. In consequence of this demand, speed starts to rise and the traction generator is excited. Generator was given a impulse for increase the asked value of current for asynchronous motor.
- C: Maximal output for asynchronous motor is reached from 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: In this moment 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 asynchronous motor.

Flow diagram of HEM is depicted in Figure 4

Slika 3 prikazuje period maksimalnog napajanja kod hibridnog automobila, gde pojedine oznake imaju sledeće značenje:

- A-B: Alternator snabdeva AVB, a napajanje motora sa unutrašnjim sagorevanjem je konstantno, P_{dtNAB} .
- B-C: Potreba za povećanim napajanjem raste, što dovodi do povećanja brzine i pobuđuje generator. Generatoru je dat impuls radi obezbeđivanja tražene električne energije za rad asinhronog motora.
- C: Maksimalno napajanje potrebno asinhronom motoru obezbeđuje motor sa unutrašnjim sagorevanjem.
- C-D: Da bi se zadovoljila potreba za napajanjem, jačina struje za punjenje AVB mora se smanjiti. Napajanje je konstantno, a jačina struje se povećava.
- E: U ovom momentu motor sa unutrašnjim sagorevanjem je u stanju da obezbedi maksimalno napajanje.
- E-F: Napajanje opada, a s tim i potražnja struje iz AVB.
- F-G: Rad motora sa unutrašnjim sagorevanjem je još uvek na maksimumu, ali AVB počinje sa punjenjem.
- G-H: Punjenje AVB je obavljeno, pa motor sa unutrašnjim sagorevanjem počinje da radi manjim intenzitetom, a ujedno opada i napajanje.

Za predloženi simulirani radni ciklus potreban je prosečan rad asinhronog motora.

Tehnološka šema rada hibridnog automobila prikazana je na slici 4.

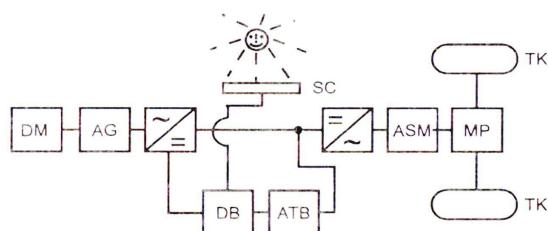


Figure 4 Flow diagram of HEM
slika 4 Šema rada hibridnog automobila

where the abbreviations mean:

- DM: combustible motor
- AG: electric generator
- DB: ATB charge controller
- ASM: asynchronous power motor
- MP: mechanical transfer
- ATB: accumulator traction battery
- SC: solar collector

gde je:

- DM: motor sa unutrašnjim sagorevanjem,
- AG: generator električne energije,
- DB: regulator napajanja AVB,
- ASM: asinhroni motor,
- MP: mehanički prenos,
- AVB: akumulatorska vučna baterija i
- SC: solarni kolektor.

5 FASTTORQUE OF THE HEM

The basic scheme of direct torque controlled induction motor with fuzzy controller is Fig. 5. 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 minimum number of rules. The first is difference between the command stator flux ψ_S^* and estimated stator flux magnitude ψ_S (error in stator flux E_ψ) given by:

5 BRZA REGULACIJA OBRTNOG MOMENTA KOD HIBRIDNOG AUTOMOBILA (HEM)

Na slici 5 prikazana je osnovna šema upravljanja indupcionim motorom pomoću direktnog obrtnog momenta sa "fazi" upravljačem. "Fazi" upravljač je koncipiran tako da ima dve "fazi" promenljive i jednu kontrolnu promenljivu, kako bi se obezbedila konstantha kontrola obrtnog momenta i fluksa. Svaka promenljiva izvedena je u "fazi" segmente. Broj "fazi" segmenata u svakoj promenljivoj je određen tako da se postigne maksimalna kontrola sa minimalnim brojem pravila. Prvi segment je razlika između kontrolnog fluksa statora ψ_S^* i obračunate vrednosti fluksa statora ψ_S (E_ψ - greška u fluksu statora), kao što je dato u:

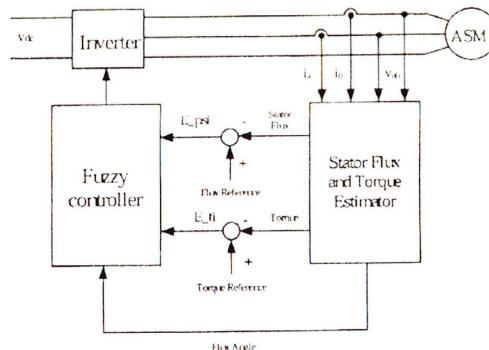


Figure 5 Fast regulation of torsion moment
slika 5 Brza regulacija obrtnog momenta

$$E_\psi = |\Psi_S^*| - |\Psi_S| \quad (1)$$

$$E_\psi = |\Psi_S^*| - |\Psi_S| \quad (1)$$

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

$$\Psi_\alpha = \int (u_\alpha - i_\alpha \cdot R_S) dt \quad (2)$$

$$\Psi_\beta = \int (u_\beta - i_\beta \cdot R_S) dt \quad (3)$$

$$|\Psi_S| = \sqrt{\Psi_\alpha^2 + \Psi_\beta^2} \quad (4)$$

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

Stvarni fluks statora može biti izračunat iz podataka o naponu i struji koji se nalaze na statoru.

$$\Psi_\alpha = \int (u_\alpha - i_\alpha \cdot R_S) dt \quad (2)$$

$$\Psi_\beta = \int (u_\beta - i_\beta \cdot R_S) dt \quad (3)$$

$$|\Psi_S| = \sqrt{\Psi_\alpha^2 + \Psi_\beta^2} \quad (4)$$

Za predloženi radni ciklus simuliranog puta odgovara prosečna snaga asinhronog motora.

6 DISTRIBUTION OF TRACTION OUTPUT

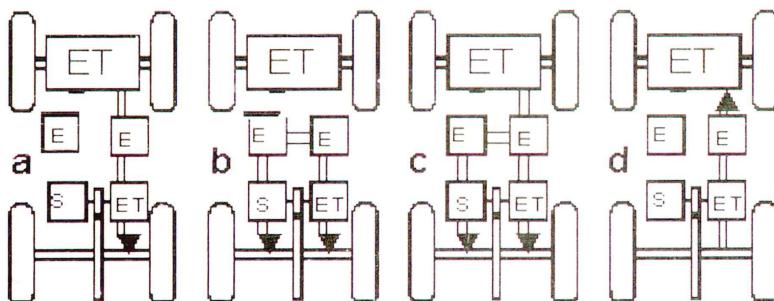
Distribution of traction output could be done partially according to a user or according to a predefined software. An autonomous control of a microprocessor unit for the distribution of traction output is depicted in Fig.6.

In system of control information from operator is prosesed 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 from 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 small number of other sensor for electrical values. For drives with dynamic requirements a vector control has become common. This enables to control a magnetic flow and torque in steady-state regime as well as in transition state. Mathematical simulation of controlled traction drive with an asynchronous engine reveals very good dynamical characteristics.

6 RAZVOD VUČNE SNAGE

Razvod vučne snage ne može se izvesti parcijalno prema zahtevu pojedinačnog korisnika ili prema unapred definisanom softveru. Na slici 6 prikazana je kontrola razvoda vučne snage putem nazavisne mikroprocesorske jedinice.

U sistemu kontrole, informacija striže od operatera i obrađuje se sa informacijama o ulaznom napajaju, impulsnom izmenjivaču, izmenjivačkom uređaju i vučnom uređaju. Kontrola mora da zadovolji određene zahteve koje nameće vučni uređaj i tehnologija transporta. Drugim rečima, ovo se odnosi, uglavnom, na kontrolu magnetnog protoka u motoru i obrtni momenat. Vozači su često u situaciji da koriste jeftina rešenja bez senzora brzine i samo nekoliko drugih senzora za električne ventile. Za dinamične vozače vektorska kontrola je postala uobičajena. Omogućena je kontrola magnetnog toka i obrtnog momenta u stanju mirovanja kao i u pokretu. Matematička simulacija kontrolisanog vučnog pogona sa asinhronim motorom ukazuje na odlične dinamičke karakteristike



ETB - Electric Traction Battery
 EG - Electric Traction Generator
 EM - Electric Convertor
 SM - Gas Engine
 ETM - Electric Traction Engine

Figure 6 a - normal operation, b – drive with insufficient accumulator capacity,

c – drive with using of all energy sources, d – recuperation of traction output

slika 6 a – normalno funkcionisanje, vožnja sa nedovoljnim kapacitetom akumulatora,

c – vožnja sa korišćenjem svih izvora energije, d – jačanje vučne sile

7 SUMMARY

Recently hybrid automobiles occurs more often in combination of combustible and electric engine. From the point of view of the ecological overload by car transport this contribution suggest not only one of possible way of application the HEM, but also it suggests a way of gaining the energy necessary for realisation specific transport technology. Suggested HEM gains primary energy for secondary cells not only from common mains, from solar energy, but also using the Elbstet combustible motor for bio fuel. It possible to gain the bio fuel from contaminated soil, which is momentary so much as it is able to produce 40% of annual consumption of common fuel for automobiles.

7 REZIME

U poslednje vreme hibridni automobili se sve češće prave u kombinaciji motora na sagorevanje i električnih motora. Sa aspekta ekološkog preopterećenja automobilskim saobraćajem, predloženo rešenje daje svoj doprinos ne samo kao jedno od rešenja za hibridno vozilo, već, takođe, sugerise način da se obezbedi energija koja je neophodna da se realizuju ove specifične transportne tehnologije. Predloženi hibridni automobil obezbeđuje primarnu energiju iz akumulatora, ne samo preko kablova i solarne energije, nego i upotrebom Elbstet motora koji sagoreva biološko gorivo. Biološko gorivo se može dobiti iz zagađenog zemljišta, koga trenutno ima toliko da može pokriti 40% godišnje potrošnje goriva za automobile.

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