Power Export Platform Based on the All-Terrain Vehicle

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Abstract **– In this paper the power export platform based on the all-terrain vehicle "BV 206" is presented. Proposed platform is possible solution for the mobile power source delivering in the combat zone. For the platform the hybrid-electric drive is chosen. This type of drives has a lot of important in combat zone advantages, as fuel economy and exported energy production. The drive system has two electric motors, generator and energy storage system; the parameters of these elements are calculated.**

Keywords **– Drives, engines, gears, generators, supercapacitors**

I. Introduction

In addition to traditional items of supply like rations and ammunition, the modern battlefield requires electric power. Electric power, provided primarily by mobile generators in the combat zone, is the lifeblood of the armed forces. It is necessary for the networked systems that modern soldiers rely on to communicate critical information across the battlefield. For without it, all the technical wizardry of modern warfare (the Weapons' Systems, the Command, Control, Communications and Intelligence (C3I) Systems, and Logistics Support Systems) is useless [1].

It is necessary to deliver tactical generators [2, 3] in a zone of military operations that can be difficult appear in the conditions of an improper landscape.

The aim of this research is to propose a mobile power source with the facilitated delivery in the battlefield [4].

The proposed solution is the power export platform [5], based on the all-terrain vehicle "BV 206", which is designed to meet tough military requirements for high mobility in all weather conditions. The research objective can be reached by installation of the hybrid electric drive on the "BV 206" platform.

II. Tracked All-Terrain Vehicle as Basis of the Power Export Platform

As basis for mobile power export platform the all-terrain carrier "BV 206" is chosen [5, 6]. The vehicle consists of two sections, with all four tracks powered at all times. The front section is coupled with rear section by the ingenious steering device. This device provides steering between the two sections, and allows necessary freedom of the two sections individually follow uneven terrain. The vehicle can be air-dropped and transported by a variety of aircraft and helicopters. The vehicle is designed to meet tough military requirements for high mobility in all weather conditions, high reliability and low operating costs [6, 7].

On the mentioned vehicle 100 kW internal combustion engine is installed, and the fuel consumption can be 60-80 liters of 98 octane leaded petrol per 100 km, which no longer meets contemporary requirements [5].

For creation of the power export platform based on the all - terrain vehicle "BV 206" the hybrid electric drive system was chosen. It consists of two power sources, the engine generator and the energy storage system (ESS). Usually ESS includes high energy density batteries to supply vehicles systems and support the autonomous traction mode and supercapacitor for autonomous auxiliary traction, power maximum alignment and braking energy recuperation [6].

For military applications the most tangible benefits of the hybrid-electric drive are fuel economy, available power onboard, silent watch and silent mobility, exported energy production, flexible structure [5, 8].

The series hybrid (Fig. 1.) as it is easier for integrating into available vehicle has been chosen to realize power export platform [6].

Some options of the electrical motors installing on the platform BV-206 are in [5] described. Taking into account the features of a running gear of the vehicle, one motor is enough to set in motion the caterpillar of both sections, however such decision imposes some restrictions both on re-equipment and further operation of the vehicle as well [5].

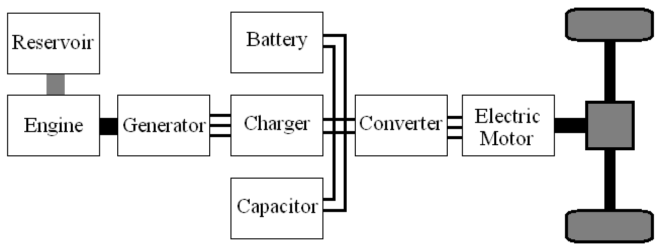

Fig. 1. Structure of the series-hybrid vehicle.

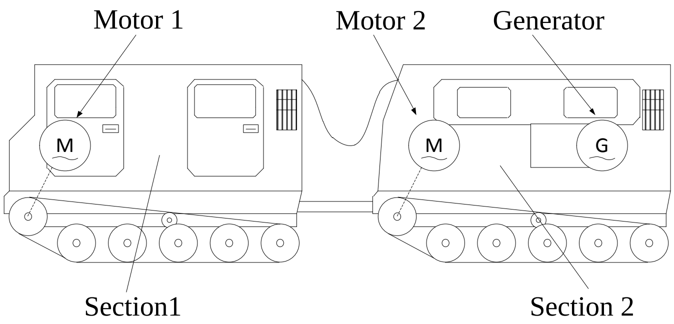

Fig. 2. Topology of the power export platform drive.

It was accepted, that motors would be placed in both sections of the "BV 206" (Fig. 2.). In this case having a failure of one motor the vehicle is able to continue movement at a half power [5].

III. Calculation of the Hybrid-Electrical Drive Elements

A. Electrical Motors

The maximum power of the "BV 206" engine "2658 Ford E" is Pmax = 100 kW. Maximum torque [9, 10] at engine speed n = 3000 rpm is Tmax = 216 Nm (Fig. 3.).

Torque T_1 at maximum power value and speed 5200 rpm can be calculated as in (1):

$$T_1 = \frac{P_{\max} \cdot 60}{2\pi \cdot n}, \quad (1)$$

and is equal to 183.6 Nm.

The gear ratio is calculated as product of the vehicle separate mechanisms gear ratios (Fig. 4.).

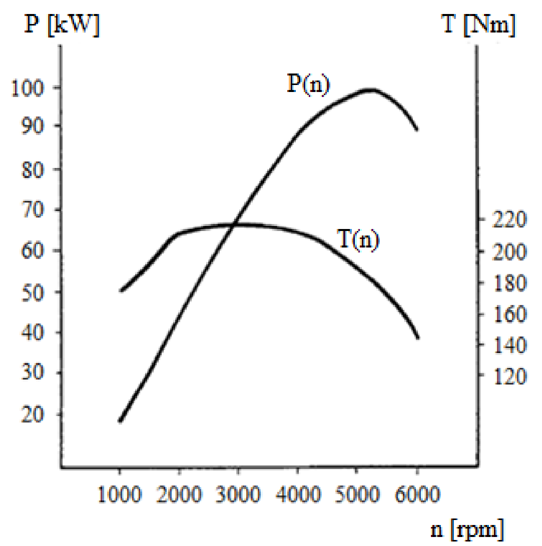

Fig. 3. The "2658 Ford E" engine power and torque dependence on the speed of rotation.

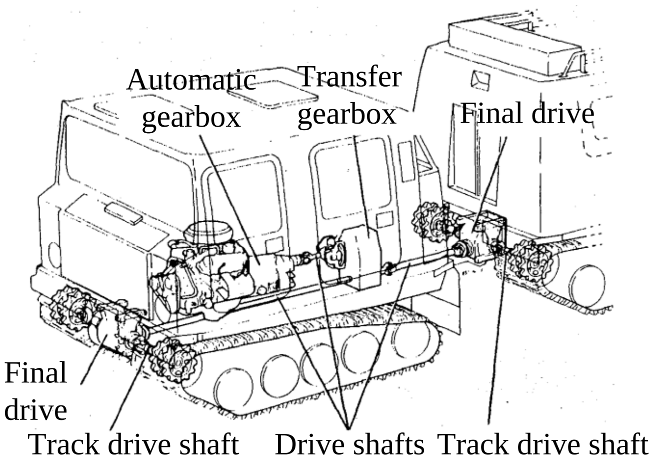

Fig. 4. The transmission of "BV 206".

The minimum gear ratio i_{min} is calculated as in (2):

$$i_{\min} = i_{agb,\min} \cdot i_{dgb,\min} \cdot i_{fd,\min}, \quad (2)$$

where: $i_{agb,min}$ = 1 – minimum gear ratio of the automatic gearbox;
$i_{dgb,min}$ = 1.28 – minimum gear ratio of the transfer gearbox;
$i_{fd,min}$= 4.75 – minimum gear ratio of the final drive.

Thus, i_{min} = 6.08.

Losses in the bearings and gearboxes are characterized by efficiency η, which is calculated as product of the separate vehicle mechanisms efficiencies:

$$\eta = \eta_{gb} \cdot \eta_{mg} \cdot \eta_{fd} \cdot \eta_{pg}, \quad (3)$$

where η_{gb} – gearbox efficiency;
η_{mg} – main gearbox efficiency;
η_{fg} – final drive efficiency;
η_{pg} – planetary gearbox efficiency.

The calculation of the overall efficiency of the separate transmission elements depends on cogwheel pair number, through which the torque is transferred [10, 11]. The values of the mechanical gear elements efficiency are given in Table 1.

TABLE I
The Values of the Mechanical Gear Elements Efficiency

Transmission element	Efficiency
Closed cylindrical cogwheel	0,96 ... 0,97
Closed conic cogwheel	0,95 ... 0,96
Open chain drive	0,90 ... 0,93
Closed chain drive	0,95 ... 0,97
Flat belt drive	0,96 ... 0,98
V belt drive	0,95 ... 0,97
Pair of bearings	0,99 ... 0,99
Coupling	0,98

The final value of efficiency is η = 0.8.

Torque on the cogwheel is calculated as in (4):

$$T_c = T_1 \cdot i_{\min} \cdot \eta, \quad (4)$$

and is equal to 893 Nm.

Maximum rotation speed n_c of the cogwheel is calculated as in (5):

$$n_c = \frac{v}{c \cdot p}, \quad (5)$$

where v = 55 km/h – maximum speed at higher gear;
c = 12 – number of teeth;
p = 98.8 mm – teeth step.

Maximum rotation speed of the cogwheel is equal to 773 rpm.

Maximum angular speed is equal to:

$$\omega_c = \frac{2 \cdot \pi \cdot n_c}{60} = 80.9 \text{ (rad/s)}. \quad (6)$$

Maximum power the cogwheel needs can be calculated as in (7):

$$P_{c,\max} = T_c \cdot \omega_c , \quad (7)$$

and it is equal to 72.244 kW.

Electrical motor rotation speed is calculated as in (8):

$$n_M = n_c \cdot i_{fd} , \quad (8)$$

where i_{fd} = 4.75 – gear ratio of the final drive.

Electrical motor maximum power is calculated as in (9):

$$P_{M,\max} = \frac{P_{c,\max}}{\eta_1} , \quad (9)$$

where η_1 – overall efficiency.

Overall efficiency η_1 is equal to multiplication of the separate mechanisms efficiencies:

$$\eta_1 = \eta_b \cdot \eta_c \cdot \eta_{coup} , \quad (10)$$

where n_b – bearings overall efficiency;
n_c – cogwheel overall efficiency;
n_{coup} – coupling efficiency.

Because of final gearbox has 3 pairs of bearings and 2 pairs of cogwheels, overall efficiency is calculated as in (11):

$$\eta_1 = \eta_b^{\ 3} \cdot \eta_c^{\ 2} \cdot \eta_{coup} = 0.913. \quad (11)$$

Considering (9) and (11), $P_{M,max}$ = 79.128 kW. The motor Heng Tian BS22-3200 [12] can be used in mentioned drive system, the parameters are given in Table 2.

TABLE II

PARAMETERS OF THE ELECTRICAL MOTOR HENG TIAN BS22-3200

Parameter	Value
Rated voltage	320 VDC
Rated rotation speed	3200 rpm
Maximum rotation speed	4000 rpm
Rated torque	65.7 Nm
Maximum torque	131 Nm
Rated power	22 kW
Maximum power	44 kW
Efficiency	96.8 %

B. Generator

The necessary generator power is:

$$P_G = P_{M,r} + P_{el.d.} + P_{pump} , \quad (12)$$

where $P_{M,r}$ – rated power of the motors;
$P_{el.d.}$ = 3.747 kW – power of the electronics devices of the BV 206;
P_{pump} – hydraulic pump power.

Considering, that it is planned to use two pumps with rated power 22 kW, the overall rated power is $P_{M,r}$ = 44 kW. The power of the hydraulic pump can be expressed as in (13):

$$P_{pump} = \frac{p_{valve} \cdot Q}{\eta_{pump}} , \quad (13)$$

where: p_{valve} = 12 MPa – pressure of the safety valve;
$Q = 0.426 \cdot 10^{-3}$ m^3/s – pump's volume feeding;
η = 0.85 – pump's efficiency.

According to (13), pump's power P_{pump} = 6,014 kW. Thus, the necessary generator power equals to 53.761 kW. The main parameters of the chosen generator [13] are given in Table 3.

TABLE III

PARAMETERS OF THE DIESEL GENERATOR DEUTZ E65DM

Parameter	Value
Rated voltage	400/230 VDC
Rated rotation speed	1500 rpm
Frequency	50 Hz
Rated power	52 kW
Fuel consumption	15.5 l/h
Fuel tank volume	150 l

C. Energy Storage System

Considering, that operating modes of the vehicle can change, for calculations the general time is accepted equal 1 h. It is accepted, that 20% of general time the vehicle consumes the maximum motor power, but the remained time (48 min. or 80%) it consumes the rated power of the generator. Full energy balance can be estimated as in (14):

$$E_{full} = P_G \cdot t_{PG} + P_{M,\max} \cdot t_{P\max} , \quad (14)$$

where: t_{PG} – time, during which the vehicle consumes the maximum power, h;
t_{Pmax} – time, during which the vehicle consumes the rated generator power, h.

The necessary power of the ESS P_{ESS} is equal to:

$$P_{ESS} = P_{M,\max} - P_G = 27.128 \text{ kW}. \quad (15)$$

The necessary energy density of the ESS in kWh is:

$$E_{ESS} = P_{ESS} \cdot t_{P\max} = 5.4 \text{ kWh}. \quad (16)$$

If the voltage of the ESS is V_{ESS} = 24 V, the necessary energy density of the ESS in Ah is:

$$C_{ESS,Ah} = \frac{E_{ESS}}{V_{ESS}} = \frac{5.4 \cdot 1000}{24} = 225 \text{ Ah}. \quad (17)$$

The necessary energy density of the ESS in F is:

$$C_{ESS} = \frac{C_{ESS,Ah} \cdot 3600}{V_{ESS}} = 33750 \text{ F}. \quad (18)$$

Supercapacitors have high specific power, therefore they can be used for power maximum alignment. On the other hand, batteries have more specific energy and can support the autonomous traction mode. Therefore, the necessary energy density can be divided between both of the storage devices.

IV. Conclusions

The power export platform based on the all-terrain vehicle "BV 206" is proposed. The hybrid electric drive system was chosen with purpose to reach some advantages required in military field.

The series hybrid as it is easier for integrating into available vehicle has been chosen. The parameters of the motors and generator were calculated, the relevant elements were chosen.

The necessary energy density of the energy storage system was calculated at its voltage equal to 24 V. The question about operating voltage of the storage system is still discussed. After that, most likely, recalculation of the energy density will be necessary. The next step will be the choice of the relevant storage devices and the dividing required energy density between them.

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