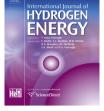


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Numerical simulation model for the preliminary design of hybrid electric city bus power train with polymer electrolyte fuel cell



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ABSTRACT

A hybrid power train, consisting of a Polymer Electrolyte Fuel Cell (PEFC) system and batteries, which feeds an electric motor for city bus propulsion, can be dimensioned ad hoc respect to the performed route, avoiding his oversizing in the greater energy rationalization optic.

In this article a calculation tool is developed and implemented in Matlab[®] and Simulink[®] environments in such a way that it can be used both for verifying the electric motor proper operation in the route and for dimensioning the hybrid system (PEFC system and batteries), after that city bus characteristics and route have been defined.

It considers the electric energy recoverable by city bus both downhill and in the deceleration phase (regenerative braking), can simulate various traffic conditions and can be used to obtain a good estimate of both the hydrogen amount on city bus board and the batteries state of charge along the route.

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Introduction

The transport system requires 30–35% of the industrialized countries primary energy needs and a large part of this request is related to road transport [1].

In the optic of greater energy rationalization and of air quality improvement, the road transport system is the sector, where research and development activities are more concentrated, with the objectives of reducing its energy consumption end its emissions of pollutants and of greenhouse gases, as carbon dioxide.

In urban areas a policy of improving people mobility as city buses would not only reduce its pollutants and greenhouse gases emissions, but would encourage its increased use by citizens at the expense of private transport. In a short time this phenomenon would produce a substantial reduction in the number of private vehicles circulating on the road with a consequent reduction of the road network congestion and a

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Nomenclatures		bridge	bridge
		net	net
Symbols		system	system
Р	power, kW	PEFC	Polymer Electrolyte Fuel Cell
η	efficiency, -	aux	auxiliaries
MTT	vehicle mass excluding the PEFC system,	auxiliar	y auxiliary
	hydrogen cylinders and batteries masses, kg	H ₂	hydrogen
1	length, mm	cylinder	r hydrogen cylinder
w	width, mm	oc	open circuit
h	height, mm	rated	rated
n	number, -	ор	operative
fa	friction factor, -	DC	continuous electric current
d	diameter, mm	max	maximum
m	mass, kg	hyp	hypothesized
с	coefficient, -	st	stop
I	inertia moment, kg m ²	i	i-th
С	capacity, Ah	CS	change of slope
V	voltage, V	charge	
Т	temperature, °C	-	ge discharge
е	specific energy, Wh kg ⁻¹	rot	rotor
М	torque, N m	stat	stator
i	electric current, A	rms	rms current value
Ν	revolutions per minute, rpm	AC	alternating current
t	time, h	poles	TAM magnetic poles
x	distance, km	start	in the starting phase
Δt	interval of time, h	1	chosen value
SOC	state of charge percentage, %	Gross	Gross value excluding the electric power
f	frequency, Hz		consumed by auxiliary system
R	electric resistance, Ω	Heat	heating
L	auto inductance, H	bidir	Bidirectional
Lm	mutual inductance, H	DC-DC	conv DC–DC converter
S	slip, -	Inverter	inverter
φ	magnetic flux, Wb	serv	daily service
ω	Angular velocity, rad/s	charge-	-discharge line Batteries charge–discharge line
F	Combined rotor and load viscous friction	act	active
	coefficient, J s	react	reactive
н	Combined rotor and load inertia constant, J s ²	арр	apparent
		sim	simulated
Subscrip		com	commercial
seats	seats	stroke	bus stroke
-	s bearings	pt	Power train
conv	conventional	batt	batteries
	wheels	AB	At A and B nodes
brakes	brakes	Q	q axis quantity
axles	axles	D	d axis quantity
r	resistance	е	electromagnetic
t	transmission		5
tot	total	Superscr	-
TAM	Three phases Asynchronous electric Motor	Ť,	tentative value
m	mechanical	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	operative condition of TAM as electric generator
gb	mechanical gearbox	"	referred to relative reference system

further reduction in fuel consumption and in polluting and greenhouse gases emissions.

Today the traditional power trains for city buses are based on internal combustion engines (ICE) coupled to a transmission system, but already the main vehicles manufacturers are developing new solutions which make use of electric power trains through prototypes designed for short-term applications and in some cases already placed on the market. Three different solutions are now available:

• Batteries Electric Vehicles (BEV), where the batteries store the electric energy supplied by the electric network during

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