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Improving of the energetical performances for electric bus used in urban and interurban transport

Contract number 2SOFT/3.1/54

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Romania-Republic of Moldova
ENI-CROSS BORDER COOPERATION

A project implemented by
„Gheorghe Asachi" Technical University of Iasi, Romania and Technical University of Moldova, Chisinau, Republic of Moldova

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Project information

Project reference number: 2SOFT/3.1/54

Grant contract Joint Operational Programme Romania–Republic of Moldova - financed by European Neighbourhood Instrument (ENI), Cross Border Cooperation (CBC)

Start date and end date of the implementation period:
01.04.2020, 02.06.2020 – 30.03.2022.

Project identification

Project acronym: ELBUS
Project title: *Improving the cross-border public transportation using electric buses supplied with renewable energy*
Name of the lead beneficiary organisation: „Gheorghe Asachi" Technical University of Iasi, Romania
Thematic objective: 7. Improvement of accessibility to the regions, development of transport and communication networks and system
Programme priority: 3.1 Development of cross border transport infrastructure and ICT Infrastructure
Priority expected results to which the project is expected to contribute: 3.1.2 Improved integrated ICT networks and facilities to support the cross–border connections
Type of action: soft
Type of project: integrated

Project results

Description of the project results

Description result 1. Improved automation system for auxiliary loads of the electric bus.

Achieving of this result is closely related to the research carried out in activities A.3.1., respectively the researches started within activity A.3.2.

The researches highlighted the power circuits of the electric bus, energy consumptions, which can be optimized by an automated model controlled with PLC, having as final result a reduction of consumption, by saving electricity to auxiliary consumers. The energy management of the HVAC (Heat, Ventilation and cooling) were analysed resulting the possibilities to reduce the energy consumption for the auxiliary loads and to optimise the electric energy on the electric buses by developing new strategies and solutions for the control system.

Using the Programmable Logic Controller - PLC an automation system for auxiliary loads was developed in order to optimise the control of the heating/cooling devices on the electric bus. Experimental tests, with electric currents, supply voltages variations, temperature and energy consumption measurements realized on the laboratory of TUIASI, demonstrates that using the automation system implementation and control optimization, a decrease of the energy consumption was estimated up to about 4% to 7%, according to different starting values of some parameters, such as the temperature of the environment and the initial temperatures of the components. This demonstrates an improvement of the automation and control system of the auxiliary loads from the electric bus.

Description result 2. Advanced thermal model related to the climatic environment within the electric bus.

Achieving of this result is closely related to the research carried out in activities A.3.3., and the Activity A.3.4.

By these researches it was developed an advanced thermal model for the indoor bus environment using a dedicated CFD software package based on finite element method. For this thermal model conduction, convection and radiation heat transfer were considered and specific mathematical relations were established.

A geometry model of the electric bus was designed at TUIASI to be used for the thermal model, considering: geometry description of the real electric bus (with real materials and component place on the vehicle), geometry model method used on Computer Aided Design, and the geometry of the real electric bus.

Having the thermal model and the model of the inside geometry of the electric bus, various simulations were realised in order to obtain a thermal map of the inside of the bus. This thermal map was compared with the temperature measurements provided through an infrared camera by the UTM partner.

A comparative analysis between the temperature measurements inside the bus and the simulations results (TUIASI) was realised. The errors between the measured temperature and the simulated data are between 0.3% and 9.3 % inside the drivers' cabin and of 3.1% inside the passengers' cabin. The simulated maximum temperatures inside the drivers' cabin are between 25.2 °C and 27.9 °C, which are very close to the measured temperature, of 27.8°C. As for the heaters inside the passengers' cabin, the simulated temperature is of 40°C which is close to the measured one of 41.3°C.

Considering these data compared between the simulated and measured ones, it is to conclude that the thermal model of the electric bus can be validated as been correct and it can be used further for a wide types of simulations in order to estimate the optimal solutions to improve the indoor climatic environment for the electric bus.

Having the bus geometry and the thermal model already determined, a thermal map can be estimated also for the air conditioning system of the electric bus consideirng: 11 air conditioning grids on the left side of the passengers' cabin and 13 on the right side; the air conditioning grid inside the passengers' cabin are of the dimensions of 0.16x0.06m. On the driver's cabin there are 6 circular air conditioning grids of a diameter of 0.065m. The temperature of the cold air given by the air conditioning system is considered of 18°C. Initial temperature is considered as 30°C, a medium value in the summer.

The results of the study show that the temperatures decreases inside the electric bus from 30°C to about 25°C (maximum temperature is 25.8°C) in the back side of the bus, next to the third door. At a high of 1.2 m (on the seats high) the medium temperature is between 22..24°C, which represent a quite comfortable temperature for the passengers.

Considering these data compared between the simulated and measured ones, it is to conclude that the thermal model of the electric bus can be validated as been correct and it can be used further for a wide types of simulations in order to estimate the optimal solutions to improve the indoor climatic environment for the electric bus.

Based on the first simulations and data, the thermal model of the electric bus indoor was improved, various specific thermal loads being considered: heat loss by the windows of the bus, heat loss by the laminate walls of the bus, heat loss by the floor, heat loss by the roof, heat loss by the open doors (in stations). Using the heat transfer theory and the thermal transmittance calculation, heavy loss were determined as about 3000 W through the windows, about 1800 W through the walls, about 5000 W through the floor and almost 1000 W through the roof.

The total heat loss by conduction through the windows, walls, floor, and roof area is estimated at almost 11000 W to keep the cabin of the vehicle at 18 °C for an exterior temperature of 0 °C. For a cold day in winter, considering a difference between the cabin temperature 18 °C and an exterior temperature of -10 °C, and with the same above materials, the heat loss by conduction is estimated at almost 17000 W. These values are not absolutely, and they can vary with about 5% to 10% or even more, depending on the bus route, number of passengers and the number of bus stops. Traffic agglomeration and the open doors time during the bus stops

are also variables into a thermal model of the electric bus which can have a large variation.

In order to increas the overall energy efficiency of the electric bus by reducing the impact of the energy consumption over the environment, it proposes an eco-friendly solution of using the renewable energy for recharging the bus batteries that is using photovoltaic panels to supply the recharging stations.

In order to develop photovoltaic panels (PV) as renewable power source for the electric bus supply systems, were studied fundamentals on the photovoltaic panels, numerical modelling and simulations of a real photovoltaic module, and were considered experimental data for a PV module. Practical aspects were studied considering the series resistance and the parallel resistance of the PV cells, developing then a mathematical model and simulation for the PV structure. Using the parameters of a PV module and the parameters at nominal operating conditions, simulations were realized, considering: maximum power of 239W, voltage at maximum power 29.6V, current at maximum power of 7.9 A, number of cells as 60. Various characteristics for the photovoltaic structure were simulated, such as I-V, P-V and respectively P-I characteristics, for different solar irradiance (from 200 to 1000 W/m^2).

A hybrid charging system design for electric buses with authonomus power source was studied and designed for trolleybuses with autonomous running (UTM). The distance travelled by trolleybus in autonomous regime is 11.25 km. The charging time of the trolleybus with autonomous running is 20 [min], during this time 20 [%] is charged. Approximately 10 [kWh] are consumed on a charge. The charging station for trolleybuses with autonomous running mode is installed at the terminus station in Sângera town (Republic of Moldova).

According to the analysis of the annual electricity consumption of the charging station currently located in the town, a park with an installed capacity of 90[kW] was estimated. The designed park provides both the charging station with electricity, and the surplus is injected into the network.For energy injection into the network and for the charging station operation in autonomous mode, 3 Hybrid inverters of 30 [kW] were selected. To ensure the off-Grid mode of the charging station it was necessary to add buffer batteries. The battery pack that stores the energy generated by the photovoltaic panels has a total capacity of 150 [Ah].

To analyze the characteristics of the e-bus batteries operating the during charging, a model was developed in MatLab SimPowerSystem. This model consist from a photovoltaic park, the DC/DC converter with MPPT algorithm, the inverter that injects the surplus energy into the network, the buffer batteries, the power rectifier with transformer and electric bus batteries. The variation of the energy flow on the main components of the charging station in different operating regimes was considered.

Thus, by developing an advanced thermal model of the electric bus and implementing a hybrid charging system based on a photovoltaic system, the climatic impact over the environment of the electric bus is reduced, with low energy consumption and assuring the passengers' confort.

Programme outputs according to the description in the project proposal

Programme output 1. Description: 3.1.4 Number of environmentally friendly (carbon-proofed) cross-border transport initiatives developed. Value: 4.

Description the initiatives developed:

Description the initiative 1. Optimization of electric energy consumption.

The research undertaken by the two teams (LB and B1) in activity A.3.1 identified a number of issues which highlights that optimizing the energy consumption of the electric bus will increase energy efficiency by integrating them into an automated system controlled by Programmable Logic Controllers (PLC). In this context, an experimental bench (electric power

circuits) was built in order to estimate the electricity consume for various types of electricity consumers. Power and current consumption were determined on the test bench. Various characteristics of the bus motors was studied for different loads, such as: Unloaded characteristic of the DC generator, External characteristic of the DC generator, Control characteristic of the DC generator, Torque speed characteristics of the three-phased AC motor.

Description the initiative 2. Increasing of power efficiency.

Power efficiency has impact over the power consumption on the electric bus by increasing the performances of the components at the same energy consumption or by decreasing the energy consumption without affecting the performances of the vehicle. For this the auxiliary loads on the electric bus (such as heating, ventilation, cooling systems, and even lighting) were studied in order to identify the possibilities to increase the power efficiency. Using the test bench developed at TUIASI, based on Programmable Logic Controller-PLC, different control algorithms were developed and tested to increase the power efficiency for the auxiliary loads on the electric bus. Experimental tests were conducted on the laboratory of TUIASI, measuring parameters such as: energy consumptions, electric currents, supply voltages variations. Due to the automation system implementation and control, a decrease of the energy consumption was determined up to about 4% to 7%, corresponding to various entry values of some parameters, such as the temperature of the environment and the initial temperatures of the vehicle's elements.

Description the initiative 3. Decreasing of the thermal losses.

Based on the auxiliary loads test bench developed (TUIASI) on the Activity A.3.2., considering the energy consumption reduction estimated, the thermal loses inside the environment of the electric bus can be estimated. For this it was developed (TUIASI, Activity A.3.3) a thermal model for the indoor climatic system using a software based on Finite element method.

Thermal measurements were achieved by UTM partner resulting a